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Solar Decathlon Africa: Building Envelope Design

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Solar Decathlon Africa: Building Envelope Design

A Major Qualifying Project submitted to the faculty of
WORCESTER POLYTECHNIC INSTITUTE
in partial fulfillment of the requirements for the Degree of Bachelor of Science

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Submitted To:
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Abstract

The goal of this project was to create an innovative net zero energy building envelope design and construction health and safety plan for Team OCULUS of the Solar Decathlon Africa 2019 Competition. The design consisted of developing an envelope assembly that blended practical and innovative materials and attachment configurations. In addition, a construction site safety plan was generated to protect all personnel who enter the site during the construction phase. The building envelope group of Team OCULUS has provided an original design that incorporates local construction materials, Moroccan architecture, and makes energy conservation a priority. The result was an adaptable and sustainable envelope design and construction drawings for the Solar Decathlon Competition and that would be used and implemented in communities around the world for ecotourism purposes.
Acknowledgements

Sincere thanks to our advisors, Professor El-Korchi and Professor Van Dessel for providing insight and guidance throughout the design process. Thank you to Kenza El-Korchi and Anass Harmal for your work in furthering this project.
Executive Summary

In September of 2019, the International Solar Decathlon will take place in Ben Guerir, Morocco, marking the first time the competition will be hosted on the African continent. The Solar Decathlon is an International collegiate competition where university teams design and build innovative, net-zero homes powered by renewable energy. The student’s final designs are constructed and judged on architectural and engineering excellence with innovation, market potential, building efficiency, and smart energy production.

WPI has partnered with three other universities to form Team OCULUS to compete in the Solar Decathlon Africa 2019. Within team Oculus, students were divided into sub teams with assigned disciplines. The Building Envelope sub team has worked to provide a competitive and innovative building envelope assembly for the OCULUS home. The OCULUS building envelope team has completed the following four objectives, (1) Designing an innovative and affordable building envelop and wall system to integrate unique local and regional characteristics (2) Designing envelope penetrations that provide sustainable and comfortable living situation (3) Modeling the supporting foundation to fit the unique shape of building design (4) Preparing the health and safety construction plan in accordance with OSHA guidelines.

The majority of the scope of work was focused on designing the building envelope. The envelope assembly consists of the walls, doors, windows, roof, and foundation of a building. The purpose of a building envelope is to ensure that the interior environment can be maintained at a consistent temperature without any air or water leaks due to variable weather conditions outside the building. The envelope functions to maintain consistent indoor conditions during variable weather events occurring outside the building. A thermally efficient envelope is comprised of layers of compatible materials that provide thermal performance adequate for the climate of the house location. The materials chosen will encompass the entire building with minimal gaps in insulation, subsequently preventing thermal bridging phenomena. When designing and constructing net-zero buildings, it is especially important to have a robust wall assembly to minimize thermal gain and loss. Additionally, an efficient envelope can reduce the load carried by the building HVAC systems therefore reducing the amount of energy consumed.

The following considerations were used when designing the envelope: cost, constructability, thermal efficiency of materials, compatibility of materials, and minimizing leakage area. An iterative design approach was used when designing the building envelope.

The proposed envelope design is shown in Figure A, and consists of five layers. The bottom layer, which will serve as an interior finish and is directly attached to the structural members, is ½ inch of marine grade plywood sheathing. This layer provides a sturdy base for the successive layers
to be added, and also create an aesthetically pleasing interior finish. On top of the plywood sheathing, a self-adhered roofing underlayment is added to provide a waterproof barrier to the interior. To provide a thermal barrier, multiple layers of Rockwool Cavity Rock insulation are mechanically attached to the plywood sheathing. This insulation type is semi rigid, is made of recycled materials, and is fire and moisture resistant. In the proposed assembly, 9 inches of this insulation are utilized to achieve an R value of 38.7 hr.ft$^2$.F/Btu at 75 degrees Fahrenheit. Finally, a wicker facade is mechanically attached to an exoskeleton constructed of steel rods. A wicker facade accomplishes the goal of utilizing local Moroccan craftsmanship in the architectural design, while also protecting the envelope layers underneath from degradation due to sunlight exposure.

A detailed health and safety plan was assessed to ensure the safety of all personnel on site during construction. The health and safety plan also provided insight to the constructability and feasibility of the materials chosen, solidifying the design schemes.

![Figure A: Building Envelope Layers](image-url)
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Chapter 1: Introduction

Sustainable design and the implementation of net-zero buildings is at the forefront of building technology practices. In an effort to educate and inform students and the public about renewable energy and sustainability principles, the U.S. Department of Energy initiated the Solar Decathlon competition in 2002. The Solar Decathlon is a collegiate competition where students are challenged with designing and constructing a net zero solar powered house that is at the forefront of innovation. The technologies and innovative solutions presented by students in Solar Decathlon competition homes have influenced and changed the building industry in the United States and other countries (Lockheed Martin Energy Services, 2012). The constructed design is judged on 10 contests:

1. Architecture Contest
2. Market Potential Contest
3. Engineering Contest
4. Communications Contest
5. Innovation Contest
6. Water Contest
7. Health and Comfort Contest
8. Appliances Contest
9. Home Life Contest
10. Energy Contest

To perform well in the competition, each team must receive high marks for each contest, blending architectural form and function with innovative solutions for energy use. (CITE) Since the competition was founded, the Solar Decathlon has expanded to host projects in countries all over the world. In September 2019, the first Solar Decathlon Africa Competition will be held in Ben Guerir, Morocco. Twenty teams will be designing and constructing homes for the competition. WPI’s team OCULUS consists of a collaboration of students, faculty and staff from WPI, L’École nationale supérieure d’informatique et d’analyse des systèmes (ENSIAS)(Rabat, Morocco), École nationale supérieure d’arts et métiers (ENSAM) (Meknes, Morocco) and African Institute of Science and Technology (AUST) (Abuja, Nigeria).

MQP, IQP, Graduate and HUA Students from WPI collaborated and contributed to the several aspects of the Team OCULUS house. Specifically, nine MQP students concentrated on three different components of the project: structural design, mechanical design, and building envelope and foundation design. The following report includes an overview of the Building Envelope MQP team’s contribution to Team OCULUS in order to complete the MQP capstone design project.
Chapter 2: Background

2.1 Scope of Work

The building envelope design team had four primary objectives: (1) designing an innovative and affordable building envelop and wall system to integrate unique local and regional characteristics (2) designing penetrations to provide sustainable and comfortable living situation (3) modeling the supporting foundation to fit the unique shape of building design (4) presenting the health and safety construction plan and finish OSHA training.

The designs produced by the building envelope team had to coincide with the overall objectives of the OCULUS home, and the limitations presented by the site. These goals and limitations are discussed in subsequent paragraphs of this chapter.

2.2 Ecotourism

In addition to creating a net-zero solar powered home, team oculus has set out to design a home with a purpose further than the standard competition judgement criteria. Our team considers the longevity and the useful life after the competition to be as important as the demands of the 10 day competition. Therefore, team oculus decided to dedicate our house to serve educational purposes for Moroccan and global communities through the concept of ecotourism.

Ecotourism is one design aspect of the OCULUS house that separates it from the missions and goals of the other houses in the competition. The “tourism” part of ecotourism means that it is expected that this house will be rented by travelers passing through Morocco or the region of placement. The “eco” aspect is in regards to how any traveler who uses this house will experience living in a net-zero home that generates and replaces the resources it uses while also learning about sustainable buildings. Travelers will be able to journey to different parts of the world and leave as if they had never been there, provided they stay in a home like ours. The initiative of the Solar Decathlon competition is to promote sustainable building and living practices around the world. The OCULUS dome takes this goal one step further to provide environmentally conscious travelers the opportunity to stay in a net zero home.

2.3 Prefabricated Homes

The OCULUS home is designed to be prefabricated with flexible interior layout options. This makes the home multifunctional for a variety of users in different locations. Key aspects of the home include a dynamic floor plan, easy prefabricated construction assembly, and flexibility in design which
can adapt to different occupant preferences. The design principles of prefabrication and flexible use were a cornerstone of creating a sustainable building envelope.

Team OCULUS delivers a house that is designed not only for the competition but to be executed across the world for ecotourism purposes in the future. To accomplish this goal, detailed construction drawings were developed that can be easily read and understood by the students and laborers from all over the world who will be constructing the OCULUS dome. The OCULUS home was designed not only with ease of construction during the competition period, but also with ease of deconstruction and transportation to its future location in mind.

2.4 Competition Location

Morocco is a country located at the north-western corner of Africa with ocean coasts on its western and northern edge, it shares land borders with 3 countries: Algeria, Spain, Western Sahara. Morocco covers about 446,000 square kilometers (17220 square miles) of land and 250 square kilometers (100 square miles) of water. The world’s third largest desert, the Sahara desert, located in the southeastern region of Morocco, covers over 3,600,000 square. (Worldatlas. 2017, April 07). Flanked by deserts and plains, Morocco also has a central spine of mountains. In the north, the Rif mountain range runs parallel to the Mediterranean. A series of tree Atlas Mountain ranges around the South of Rif range. Near the interior mountainous region, there are many valleys interspersed between Morocco’s mountainous areas, the highest point in Morocco is Jebel Toubkal which rises to about 13,000 feet, white its lowest point is Sebka Tah. Additionally, Morocco has about 1,835 kilometers of coastline along the Northern Atlantic Ocean and Mediterranean Sea. Morocco also has the most extensive river system in North Africa, which one river called Moulouya that flows into the Mediterranean Sea and one river called Sebou that flows into the Atlantic Ocean. (Franack.com., n.d.)

The climate of Morocco varies with location, but overall the country has a tropical climate with temperature as high as 95 Fahrenheit and as low as 40 Fahrenheit. In the far south. Most of Morocco north of the Western Sahara, the coastal region is tempered by breezed off the Atlantic Ocean and Mediterranean, winter can be fairly cold, and summers could be extreme hot and dry. On the Atlantic Coast, the mean temperature is 16.4° C to 23° C. The rainy season generally extends from October to April, which occasionally produce devastating floods. (Details - Morocco - Seasons & Climate, n.d.) By contrast, the climate is more extreme in the interior, where it has wide seasonal variation with temperature ranging from 10° C to 27° C. Going inland to the northern plateau reason, it as a continental climate with more extreme temperature. In the summer the temperature can get over 38° C, but generally it ranges within the 29° C to 35° C. However, the winter can be rather cold with daily temperature around 20° C and nights dropping to 5°C to 7°C. Heading to the south into the interior lowlands, the region has an average winter temperature of 18° C and summer temperature of 36° C. The hottest months of the year are July, August and September since there is still some humidity so the
summers are bearable. Around the Sahara area, it is always sunny all year around, with mild winters that can bring heavy downpours of rain and the temperature at night can be as low as 5º C. Going in the Mountain areas, the temperature can drop below zero Celsius in the winter and mountain peaks are covered with snow throughout most of the year. (Pike, J., n.d.)

The first African Solar Decathlon will be held in September 2019 in the green city Mohamed VI of Benguerir, Morocco. Benguerir is the capital of Rehamma Province in central Morocco, in the Marrakesh-Sadi Region. This relatively rural city is located approximately one hour north of Marrakech, a bustling city of 928,850 people. This region has the Ourika River flowing north towards Marrakech, and lies about 20 miles from the foot of the Atlas Mountains. Benguerir features a semi-arid climate, mild wet winters and hot dry summers. Average temperature range from 12º C in the winter to 28-29º C in the summer. The climate is similar to Mediterranean climates, but this region receives less rain than is typically found in a Mediterranean climate. (Pike, J., n.d.) During the months of March, April, May, October and November, the city most likely to have good weather with pleasant average temperatures. During our creative process of building design, a great deal of consideration is given based on our climate analysis to ensure our building to function properly during the competition period or even permanently. During the competition period, we should expect hot and dry weather condition with little chances of thunderstorms. (World Weather and Climate Information, n.d.)

![Figure 1: Average Min and Max Temperatures in Marrakech, Morocco](https://www.weather-and-climate.com)

2.5 Coordination between Students and Universities

For the purpose of this project, it was necessary for team Oculus to split into sub teams by discipline in order to be more efficient in design skill and accomplish more work over the time we were allotted. WPI Major Qualifying Project (MQP) students were broken into sub teams according to discipline including Mechanical, Building Envelope, and Structural design. These teams relied heavily on coordination and communication to create a cohesive, functional house. Each team had separate design goals but also relied on and interacted with other teams to produce a cohesive final product. For example, the sizing of mechanical units relies on the thermal performance of the envelope, more
specifically the R value of the insulation chosen for design. Structural plans and calculations provided by the structural team were built upon in the design of the envelope facade. The dead load and the various live loads the facade will face when erected are to be tied into the main structure, resulting in required coordination between the envelope and structural teams. Overall, the way the students were able to coordinate with each other all under one roof simulates the climate of a design firm with various in house specializations that work with one another. This experience working with other specialties towards a common goal is one of the major lessons and takeaways for the students collaborating on team OCULUS and other Solar Decathlon Teams.

In addition to working alongside other disciplines, the students on team OCULUS had the opportunity to meet and work with students and professors of different cultural backgrounds and nationalities. Team OCULUS is comprised of people who have lived very different lives, speak multiple languages, and subsequently have various perspectives. The diversity of team OCULUS is an asset to the team, and provided connections and opportunities to all of its members. In particular, the typical codes, materials and methods used in American versus Moroccan and European design and construction standards are not always the same. By working on a team comprised of students and professors from North America, Europe and Africa, multiple ideas are offered for the complex design problems that arise. By having Moroccan students on team Oculus to consult on building materials for the envelope design, the envelope team was able to make better informed decisions on the materials that would be available and functional to build with for the purpose of this competition.

2.6 Context of Design

The envelope assembly consists of the walls, doors, windows, roof, and foundation of a building. The purpose of a building envelope is to ensure that the interior environment can be maintained at a consistent temperature without any air or water leaks due to variable weather conditions outside the building. A thermally efficient envelope is comprised of layers of compatible materials that provide thermal performance adequate for the climate of the house location. The materials chosen will encompass the entire building with minimal gaps in insulation, subsequently preventing thermal bridging phenomena. When designing and constructing net-zero buildings, it is especially important to have a robust wall assembly to minimize thermal gain and loss. Additionally, an efficient envelope can reduce the load carried by the house HVAC systems therefore reducing the amount of energy consumed.

In order for the envelope to perform according to the needs of the building, the components of the envelope must be connected, sealed and comprised of materials for the specific application. Selecting the right the most efficient materials for envelope assembly the most efficient performance is one of the main challenges of a Building Envelope designer. Efficiency of the materials depends on thermal performance and compatibility. Materials not only need to offer the right thermal
performance, but need to be compatible with each other, as there are multiple layers of the envelope that will interact with each other, therefore it is imperative to choose materials that will be compatible in application. Altogether, the Building Envelope is one of the most intricate design areas of a building and its design or mis-design can drastically affect the thermal comfort of the occupant.

The OCULUS home the shape of a geodesic dome, further complicating the geometry of the envelope design. Team OCULUS welcomes this challenge and seeks to provide innovative ways to recommend an Envelope design for a geodesic dome style structure. In the OCULUS dome, the building envelope must have the strength to withstand live loads from wind and precipitation and transfer these loads to the primary structure. For our house, use of the internal structure frame was imperative to carry the dead and live loads of the envelope as well as provide surface area for components of the envelope system to be securely installed.

Taking into consideration the basic design needs of the envelope as well as implementing strategic innovative ways to enhance the performance of the envelope assembly, team OCULUS is tasked with designing a complex system for the house. The following chapter goes into specific details about the makeup and configuration of the envelope for the OCULUS house. The following considerations were used when designing the envelope: cost, constructability, and thermal efficiency of materials, compatibility of materials, and minimizing thermal and moisture leakage area. An iterative design approach was used when designing the building envelope.
Chapter 3: Design and Construction of Building Envelope and Foundation

3.1 Initial Building Envelope Design

3.1.1 Design Iterations

As part of the design process, the building envelope team developed multiple iterations of an envelope design before focusing our efforts on the final design discussed in Section 3.1.2 of this paper. Details and challenges of earlier envelope iterations are discussed below.

Initially, it was proposed that a semi-translucent, insulated membrane be used as the primary material for the envelope. Using a semi-translucent membrane would allow the interior spaces to be illuminated with natural light while eliminating the need for traditional windows. The opacity of the membrane does not sacrifice privacy of the occupants. A wicker facade would be attached to the exterior to the exterior of the building, and could be woven in such a way as to provide intermittent shading in key areas of the home. Birdair’s PTFE Insulated Tension Membrane would provide the desired atmosphere while still achieving adequate thermal performance. Figure 2 shows a detailed view of the layers of the membrane.

Because this membrane is flexible, it would be attached to specific locations of the structure and held in tension and pulled tightly at the connection point. Figure 3 depicts this membrane installed in a gymnasium. Ultimately, this option was determined to be too expensive. Additionally, since it is a specialty material from a manufacturer in the United States, it did not align with team OCULUS’ goal of using materials that are locally available in Morocco and in other regions of sub-Saharan Africa.
In the first iteration, the most appealing aspect was the ease of construction that a flexible membrane provided. The second iteration was based off of ideas modified from the first iteration. In the second iteration, nicknamed the “pillow” system, essentially large pillowcases stuffed with insulation would be created. A fire retardant fabric, such as GLT’s Silicone Coated Fiberglass Cloth, would be used as the casing, and then filled with fiberglass batt insulation. The fabric would then create a textured interior finish for the home. Fiberglass Batt insulation was chosen due to its excellent thermal performance, light weight, and availability in Morocco. Prototypes of this system were created at WPI’s laboratories in Kaven Hall. In these prototypes, the insulation pillows were pressurized with air prevent sagging. The footprint of the OCULUS dome is a dodecagon, therefore, twelve rolls of these insulation pillows would be manufactured, with one securely encasing each side of the footprint. These pillows would be attached to a structural ring at the top of the dome, then rolled down over the structure and attached at the edge of the concrete foundation.

![Building Envelope Section](image)

**Figure 4: Building Envelope (2nd Iteration) Section**

There would be a layer of rigid foam insulation underneath the precast concrete slab, ensuring no thermal bridge would occur due to a gap in the insulation. The horizontal seams between each of the rolls would overlap, then attached together with Velcro. On top of the insulation pillow a vapor barrier would be added to ensure no water would leak through the seams. Finally, a wicker exterior facade would be added as an exterior finish. A section view of this envelope assembly is depicted in Figure 4. The wicker would be woven around horizontal and vertical steel dowels, in sections that mimicked the shape and size of the rolls of pillow insulation. The top-most horizontal dowel would be attached to the top structural ring using and eye-hook and spring. At the bottom of the structure, the
wicker would be attached via a similar eye hook and spring directly to the plywood footings used in earlier iterations of the foundation design. Details of these connections are shown in Figure 5. Ultimately, the largest limiting factor to this design was the cost of materials.

Figure 5: Building Envelope (2nd Iteration) Connection Details

3.1.2 Design Challenges

Both of the initial iterations were largely limited due to cost. For the second design iteration, the fire retardant fabric chosen did not meet the interior finish requirements specified by the International Building Code, as it was not a traditional building material. The fire retardant fabric we chose was primarily used for welding protection purposes. In order to determine if this fabric would be adequate to use as an interior finish, we would have needed to classify it for use as an interior finish in accordance with ASTM E 84 or NFPA 286 (International Code Council, 2015). For the amount needed to completely cover the dome, the cost of this fire retardant material would have surpassed our allotted budget. With the added expense of a full scale fire test, it was determined that this option would be too costly to pursue.
3.2 Final Building Envelope Design

3.2.1 Buildup Overview

The proposed envelope design is shown in Figure 6, and consists of five layers. First, a layer of $\frac{1}{2}$”, custom-cut marine grade plywood sheathing is attached directly to the wooden structure. This layer of plywood will provide a smooth, aesthetically pleasing interior finish, and create a sturdy platform for subsequent layers to attach on top of it. The plywood sheathing will be custom cut because the geometry of dome is complex with many triangular faces. For the plywood sheathing to cover these triangular faces perfectly, it will need to be custom cut.

On top of the plywood sheathing, a self-adhered roofing underlayment is added to provide a waterproof barrier to the interior. The waterproofing barrier that was chosen is the Grace Ice and Water Shield HT. The specification sheet for this product is provided in Appendix C, Table C-1 of this document. The Grace Ice and Water Shield provides a waterproof barrier to the interior using UV resistant polymeric film backed with a rubberized asphalt adhesive. The membrane is also advertised to seal around any penetrations, such as nails or screws, avoiding the need for additional flashing to prevent water leakage. This membrane is specifically used in high temperature applications, meaning it will not deteriorate or crack under high heat or UV exposure. This weather resistance makes it a great candidate for use in the Moroccan summer. Because the membrane is self-adhering, students will be able to quickly install this layer during the short construction period without any special training or special tools (GCP Applied Technologies, n.d.).
To provide a thermal barrier, multiple layers of Rockwool Cavity Rock insulation are mechanically attached to the plywood sheathing. The specification sheet for this material can be viewed in Appendix C, Table C-2. The Rockwool Cavity Rock insulation boards are made of mineral wool. This thermal insulation is manufactured by melting Calcium-silicate minerals at very high temperatures, producing air blown fibers and then forming them in panels (BYUCKSAN, 2013). This material is naturally fire resistant and bacteria resistant, as it does not absorb moisture. This Rockwool Cavity Rock boards are semi rigid, and is traditionally used in exterior cavity walls. The boards come in various sizes and thicknesses that can be cut to fit the challenging geometry of the dome exterior. In the proposed assembly, two, 4 inch layers of this insulation are utilized to achieve an R value of 34.4 hr.ft².F/Btu at 75 degrees. Fahrenheit (Rockwool, 2004).

Finally, a wicker facade is mechanically attached to an exoskeleton constructed of 1” steel rods. The external wicker support structure was designed similarly to a typical steel beam and girder structural system. The diameter of the steel rods was designed by assessing the loads acting on the wicker facade provided to the envelope team by the structural team. The loads to be carried by the wicker and distributed to the main structural framing are wind, precipitation, dead and live loads. Dead loads include the weight of the wicker and live loads include the weight of variable items or
people applying pressure on the facade during the construction phase. The use of the external structure to hold the wicker facade is necessary because the insulation layer below should not be in direct contact with the interior facade to allow proper drying and avoid tearing or abrasion. The calculations were assessed with extreme load conditions. The calculated steel rod diameter size is 2.5”; however, the diameter chosen for design has been downsized to 1” and approved by the advisors and design professionals overseeing this project. As per the Solar Decathlon Competition Guidelines, all structural designs need to be reviewed and approved by a licensed professional. (Solar Decathlon AFRICA, 2019, p. 12) The original diameter was calculated as if the wicker support system did not transfer the loads to the internal structure. Because of the careful placement of the steel rods, and use of intermediate supports, the external structure will distribute loads to the internal main structure and therefore 1” steel rods will suffice. The calculations for sizing the steel pipe can be viewed in Appendix D of this document. Twenty four sections of vertical pipe will be used as a connection point for the wicker facade panels, spaced evenly. Each vertical span is comprised of two lengths of steel rods, connected the second level of horizontal members in the primary structure. This connection point is not fixed, so adjustments can be made during construction. The Grainger Adjustable Elbow/Tee aluminum structural fitting will be used to connect the two lengths of pipe at this point, shown in Figure 8. This joint will also be tied into the primary structure at the second level of horizontal structural members. Twelve of the twenty four joints will be connected directly to the steel plate that acts connects members of the primary structure. The other twelve joints will need to be connected to a horizontal span of the wooden members. Shape of the dome creates a complex geometry that will need to be accounted for by bending the vertical spans of the exoskeleton at very specific curves that follows the shape of the dome. The vertical members of the wicker exoskeleton will be connected to the top structural ring of the dome and concrete foundation by using the Grainger Adjustable Base Flange Aluminum Structural Fitting, shown in Figure 9. This connection piece will be drilled into the precast concrete slab at the bottom connection, and bolted to the top structural ring. These details are shown in Figure 19, Drawing B for the top connection, and Figure 19, Drawing A for the bottom connection.
An exterior wicker facade accomplishes the goal of utilizing local Moroccan craftsmanship in the architectural design. The Building Envelope team coordinated with IQP students in Rabat, Morocco. The Morocco IQP team met with Moroccan craftsmen to obtain information about the materials that could be used for the facade exterior. What they found is that bamboo and laurel brush branch, not wicker, were the two most common materials used for weaving. They found that bamboo was the more rigid of the two options, but single bamboo strips tied with wire could be rolled into large sheets and easily transported. See Figure 10 for an example of the rolled bamboo. The branches from the laurel bush and similar native vegetation were much more flexible, and is more often used to make rocking and lounge chairs due to its flexibility. Bamboo is more traditionally used for shelves, furniture, chicken coups and fences. Figures 11 to 13 demonstrate the curvature capacity of laurel bush branches.

More intricate patterns can be woven out of the flexible laurel bush branches, but comes at the expense of more time to weave. An example of a more intricate woven pattern is Figure 14. They also found that the weight of the materials varied greatly; green bamboo branches were the heaviest, dried bamboo was an intermediate weight that was only slightly heavier than the laurel bush branches. The limiting factor for the size of panels that can be produced is the length of the branches form the plants used. The IQP team recommended that woven laurel bush branches be used due to their light weight and flexibility. (Le, Sichler, Payette & Brownlow, 2019)
building envelope recommends that large, curved rectangular panels of woven laurel bush branches, be purchased and mechanically fastened to the wicker exoskeleton. The lightweight panels can be easily adjusted on the facade during construction, so we are able to achieve the final look we desire. A rendering of a bird’s eye view of the dome showing design details is provided in Figure 15.

![Building Envelope and Structure Rendering](image)

**Figure 15: Building Envelope and Structure Rendering**

### 3.2.2 Envelope Penetrations

One of our design challenges is to propose a proper penetration to fit the unique design of the structure. Since we have a skylight dome on the top of our structure and we wanted to limited our window to window to wall ratio, our team decided to put two glass doors across from each other on each side of the building. Furthermore, this specific doorway design also fulfilled our egress recommendation to improve the accessibility. The doors will serve as the main penetrations of the building.

Two spaces were created to construct two doors from the dome structure by removing several structural members in order to create two base door openings of 1.2 meters. Loads are diverted around the doorframe with structural members that are anchored into the foundation. Additionally, our envelope consists of multiple layers and the structure is extended out on the first level. All of stated factors challenge the door frame to be unique and precise. The proposed door frame design is shown in Figure 17 (out of scale 1:40) consisted of eight adjustable custom cut wooden panels attached to each other with door hinges. The adjustable wooden panels provide flexibility to the door frame and the specific length ensures the frame will lay right under the structure with no or a little gap in between. The entrance details are shown in Figure 16 (out of scale 1:40).
The door frame is a sandwich panel composed of 2x2 wooden members faced with ½” plywood on each side, some insulation will be placed in between. A gutter is placed right about the door frame to collect rain water as it falls and move the water away from the door frame. There is a ramp placed in the front to permit wheelchair users to more easily access the building. The building envelope will lay on the top of the plywood.

There will be wooden framework in between the glass door and the door frame to keep the door in place in case, the detail is shown in Figure 18. Specific anchors and door handle are designed for the door and detailed are shown in Figure 18 (Scale 1:40).
3.2.3 Construction

The building envelope team created detailed shop drawings to be used during the construction process. Drawing A of Figure 19 shows how the components of the building envelope will connect to the cast in place concrete foundation. The base steel connections for the primary structural members will be anchored directly into the concrete foundation slab. Subsequent layers of the envelope are attached to the primary structural members. Wood blocks will be placed between the Rockwool Insulation boards and the concrete slab to create a finish cohesive in appearance, as well as a platform to extend
the Grace Ice and Vapor Shield to the foundation.

Figure 19: Building Envelope Connection Details

The wicker exoskeleton will be attached to the concrete foundation and a structural ring at the top of the dome by using Adjustable Base Flange Aluminum Structural Fittings, shown in Figure 9. This adjustable fitting will allow adjustments to be made to the angle of the wicker structure during construction. The floor will be finished with Moroccan tiles, donated by the Arabesque Moresco Design and Decoration in Fes, Morocco. Drawing B of Figure 19 shows how the envelope will connect to the wooden structural ring at the top of the dome. All members of the primary structure and wicker exoskeleton meet at this ring, which also supports a dome shaped skylight.

3.2.4 Innovation

Due to cost and time constraints, the final envelope design is more functional in its assembly and material choice. The most innovative aspect of our design is its practicality in locally sourcing materials and showcasing local craftsmanship. This includes coordinating with the Moroccan IQP team and working with craftsmen in Morocco to design a visually appealing wicker facade. Additionally, Team OCULUS is innovative in its consideration for the post competition use of the house. By creating a narrative and setting goals for the future use of the house, we provide an innovative outlook on the life of the house for ecotourism purposes. Lastly, team OCULUS has designed this house to be mass
produced and implemented in many regions through its customizable floor plan and modular design. The house’s ability to adapt to multiple climates or regions around the world is innovative because it allows the house to be changed with time and functional to multiple cultures or settings. Overall, the story and design intent of the house fulfills the innovative requirements for the competition through multiple facets more than the envelope design. Yet, the envelope has been designed to fit many narratives and be applicable in any setting with slight variation.

3.2.5 Challenges

The geometry of the structure created one of the largest challenges for creating a continuous, sealed envelope. The geometric footprint of the dome has twelve straight sides, and five levels of horizontal structural members. The connection point protrudes past the other structural joints. This creates problems for securely attaching layers of the envelope, and for ensuring the secondary structure supporting the wicker does not intersect with this protruding node. This protrusion is visible in Figure 6.

Additionally, the problems created by the complex geometry further exacerbated issues with unit conversions from Metric to English, and levels of tolerance during construction. The unit’s problem presents itself when ordering materials and hardware in the United States and Morocco. A primary goal for the OCULUS team was using materials locally sourced from Morocco when possible. Unfortunately, not every component of our design could be ordered from Moroccan manufacturers. This creates an issue when some hardware components from the United States and are designed and manufactured using imperial units, and need to be connected to components designed and manufactured in the international system of units.

An additional challenge that will occur during the construction process will be attaching 8” of the Rockwool Insulation boards to the structure. To have an envelope that performs efficiently in the climate of Benguier, we need to have a completely sealed system that has an R value of 35 or greater. The selected insulation design achieves an R value of 34.4 with two, 4” layers of the Rockwool Insulation boards. The challenge with having two layers of this material will be securely fastening the second layer of insulation to the plywood sheathing. At the time of this report, 6” screws have been ordered to connect the 8” of insulation to the plywood sheathing. One method proposed for overcoming this issue is to fasten the second layer of insulation fasteners to the disc securing the first layer of insulation. However, the area that each insulation fastener will need to be screwed in to is only 2 to 3 inches in diameter, making it very challenging to secure during construction.
3.3 Foundation Design

3.3.1 Initial Foundation Design

An iterative design approach was also taken in the design of the foundation system. In previous Solar Decathlon competitions that WPI competed in, teams were responsible for building their own foundations systems, as no slab would be provided during the competition. Based on this knowledge, the building envelope designed a pre-cast concrete foundation that would be assembled on site. The primary goals for the design of the foundation are listed below:

- Foundation must be able to be shipped to the competition.
- Foundation must be able to be made level to account for a difference in grade at the competition site, as per the Solar Decathlon competition rules.
- Structure must be able to be connected to the foundation.
- There must be penetrations in the slab to allow mechanical, electrical and plumbing systems to be piped into the home.
- Thermal losses through the foundation should be minimized.

From this criteria, the building envelope team designed a foundation that is comprised of twelve equally sized pre-cast concrete slabs. Each portion of the slab is approximately 4.2 m x 1.8m, to ensure they can be transported to the competition site. The slabs would be laid out in a circular array the size of the floor area of the home. A plan view of this layout is shown in Figure 20.
The concrete would be cast into a form with L5x3x1/2x1/2 steel angles on each of the four sides. The calculation procedure for sizing the steel angles is provided in Appendix E. The steel angles spanning from the center of the floor to the exterior edge of the home will protrude from the edge of the concrete slab by 13 cm. This protruding steel angles will provide a surface to horizontally connect the twelve slabs. Details of this connection are in Figure 21. Each slab will have an adjustable footing, located at the protruding steel angle, to account for level differences in the terrain. The adjustable footing will consist of an eye bolt threaded through the bottom span of the steel angle, a simplified version of this is shown in Figure 21.
The steel bolt will transfer gravity loads to a series of small plywood footings to spread loads evenly and within soil bearing capacity. As shown in Figure 22, each bolt will rest head down on a level plywood base which our team will place on the site. This wooden base may be stacked if necessary to keep a level plane for the house to rest on. Once placed, each bolt is able to be adjusted in order to set the house level. This design will minimize the need for any anchoring the foundation to the ground. With the weight of the precast concrete platform and the weight from the dome structure, sufficient weight will be available to counteract the forces of wind uplift or lateral movement. Since this is a temporary structure, long term settlement and consolidation of soil are of less concern. Adjustments can be made to counter any settlements that occur during the competition or afterwards (all foundation set bolts will remain accessible).

Figure 22: Foundation Slab (1st Iteration) Connection Details
The primary structure will be connected to the foundation at the protruding steel angle at the exterior edge of the foundation by means of a steel plate and bolt. The steel plate of the primary structure will be placed flush with the vertical side of the foundation steel angle, and the two components will be attached using a steel bolt. This connection will allow for relatively quick construction during the competition. The bolted connection is aligned vertically with the steel bolt acting as a footer, to ensure the load from the structure is transferred directly to the footing.

At the center of the dome, there is a 1.2m diameter hole. This hole will give us a means to horizontally connect each of the foundation slabs at the center of the dome. It will also act as a penetration to the building envelope for any mechanical, electrical and plumbing equipment located on the outside of the dome to be connected to the appropriate systems in the dome’s interior. This hole will be capped and sealed with a concrete slab to create a consistent floor type for the final finish to be adhered to.

Finally, thermal losses through the slabs will be minimized by the addition of 4 inches of rigid foam insulation to the underside of the slab. To connect the insulation to the slab, slender insulation clips will be attached to the slab, then impaled in the rigid foam. At the exterior edge of the dome, the insulation covering the entire structure will be extended over the edge of the concrete slab to the rigid insulation, thus creating one cohesive building envelope assembly.

### 3.3.2 Final Foundation Design

At a Solar Decathlon workshop in late January 2019, the team learned that a cast in place concrete slab would be provided as a foundation for the dome, effectively rendering the initial design obsolete. Instead, plans a cast in place slab on grade foundation were developed and sent to the Solar Decathlon competition coordinators to be constructed. In this design, the slab will be circular with a 10.1 diameter, as shown in Figure 23.
This is larger than the footprint of the structure which provides a level of tolerance to ensure that the geometry of the dome will fit in the area properly. Connections to the primary structure and secondary wicker structure will be drilled directly into the concrete. The foundation slab has two elevations. An outer ring 50 cm wide sits 30 cm above grade. The connections to primary structure will be drilled directly into this outer ring. Having the top edge of the slab 30 cm above grade will provide enough space for the secondary wicker structure will be drilled into the side of the slab. The interior circle of the slab will be leveled 20 cm above grade, creating a 10 cm drop between the inner circle and outer ring of the foundation. This is visible in the section view of the foundation in Figure 24.
The purpose of this change in elevation is to provide space for the Moroccan tile floor finish that will cover the majority of the floor. This 10 cm gap will provide enough space for the Moroccan tile to sit flush with the outer concrete ring.

### 3.3.3 Challenges

While this system is significantly simpler than the original design, it still presents some challenges. First, while construction drawings for the foundation were provided to the competition coordinators, our team will not be responsible for constructing this component of the building. Relinquishing this component of the construction process gives our team less control over the final outcome of the slab. To overcome this, the foundation slab had to be designed with higher tolerance levels than what was originally anticipated.

Additionally, due to the differences in elevation of the slab, the Zelig design of the Moroccan tile will not extend to the exterior walls of the dome. The floor finish at the exterior wall will be exposed concrete instead of the tile, which interrupts the cohesion of interior design.

### 3.4 Health and Safety Plan

In addition to designing a building envelope for the home, it was the responsibility of the Building Envelope Sub-team to provide a detailed Health and Safety Plan for the construction methods and safety practices for the building of this home. The complete plan is included in Appendix F. The following paragraphs give a quick summary of the Health and Safety Plan.

Team OCULUS commits to a health and safety policy that minimizes the risks associated with the prefabrication, transportation, and the on-site construction and deconstruction of the team’s 2019 Solar Decathlon house. We will comply with OSHA standards as well as various other codes and standards listed in the Health and Safety Plan Statement of Policy. This Health and Safety Plan applies
to all participating members on the construction site, including contractors and the student construction team. Every team member will be briefed about our health and safety policy before the starting the work. All personnel present onsite during the construction phase and during the competition are entitled to workers’ rights regarding a safe and healthful work environment.

The Health and Safety Plan outlines possible risks during the construction phase as well as the severity and likeliness of those risks. In addition, emergency procedures are included for the possible accidents and incidents on site. In an effort to prevent these occurrences, general rules and regulations for Team OCULUS’s construction site are outlined in detail. Furthermore, detailed hazard and hazardous activity analyses for each construction phase of the project were created and will be made available to all personnel handling equipment or simply working onsite. Team OCULUS house has seven major construction phases provided in the following figures.
Figures 25 to 31: Construction Process

There are many construction site hazards and regulations in place to avoid and manage the risk of those hazards. The Health and Safety Plan also includes sections outlining appropriate clothing and personal protection equipment, access control, proper hoisting and rigging, fall protection, fire protection, presence of electrical systems and equipment, power tools, chemicals and material handling, hot work activities, vehicle and equipment operation and finally laborer training. All of these sections are based upon standards practiced in the industry and regulated by OSHA, the Occupational Safety and Health Administration of the United States Department of Labor. Lastly, a list of local hospitals as well as OSHA incident forms and 30 hour certifications for the construction project managers are included and provided as measures taken to ensure safety on site before and during the Solar Decathlon Competition.
Chapter 4: Results and Conclusion

After going through countless design changes and overcoming many challenges along the way, the building envelope group produced results and a conclusion. First of all, we proposed an envelope design that consists of five layers. First, a layer of ⅛”, custom-cut with a Computer Numeric Control (CNC) marine grade plywood sheathing is attached directly to the wooden structure. Second, a self-adhered roofing underlayment from Grace Ice and Water Shield HT is added on top of the plywood sheathing to provide a waterproof barrier to the interior. This specific membrane provides a barrier using UV resistant polymeric film and it is commonly used in high temperature applications. Third, attached to the plywood sheathing, there are two layers of Rockwool Cavity Rock insulation. The Rockwool Cavity Rock insulation boards are made of mineral wool that is naturally fire resistant and bacteria resistant. Due to the unique geometry of the dome exterior, we proposed two, 4 inch layers of this insulation are utilized to achieve an R value of 34.4 hr.ft²°F/Btu at 75 degrees. Fourth, we will install a 1” steel rod external structure to support the wicker. Finally, a wicker facade is mechanically attached to this steel rod exoskeleton. The reason for an exterior wicker facade is not only to accomplish the goal of utilizing local Moroccan craftsmanship in the architectural design, but also because the woven wicker panels are the best fit for our design concept and construction method.

The two glass doors will serve as the main entrances and penetrations in the building envelope. The two doors are placed within a door frame that consists of eight adjustable custom cut wooden panels attached to each other with door hinges. The specific design of the door frame will allow the load to be carried across the frame and transferred to the foundation. The adjustable wooden panels of the door frame can be cut to the exact length so the frame will lay right under the structure with little to no gap in between. Detailed drawings can be found in section 3.2.2

For the construction plan, the building envelope team created detailed drawings to be used during the construction process. The detailed drawings can be found in Appendix A. We recommended that the base steel connection for the primary structural members to be drilled directly into the precast slab. On the top of the primary structural members, layers of the envelope should be directly attached to it, where the wood blocks will be placed between Rockwool insulation and the concrete slab. The wicker facade will be attached to both the foundation and the structural ring at the top of the dome. The structural ring is where members of the primary structure and wicker facade meet together, which also supports a dome shaped skylight. There will be adjustments to be made to the angle of the wicker structure during construction. The floor will be finished with typical Moroccan tiles.

During the foundation design process, there are many requirements for foundation that need to be fulfilled. Based on the criteria, the building envelope team designed a cast in place slab on grade foundation. The foundation will be larger than the footprint of the structure which provides a level of
tolerance to ensure that the geometry of the dome will fit in the area properly. The slab will be circular with a 10.1 diameter. The foundation slab consist of an outer ring 50 cm wide sits 30 cm above grade, where the primary structure and secondary wicker structure will be drilled directly into the outer ring. In order to provide space for the Moroccan tile floor finish, the interior circle of the slab will be leveled 20 cm above grade, creating a 10 cm drop between the inner circle and outer ring of the foundation. The detailed drawing can be found in section 3.3.2.

The Building envelope team has also created a Health and Safety Plan that minimizes the risks associated with the prefabrication, transportation, and the on-site construction and deconstruction of the team’s 2019 Solar Decathlon house. The plan complies with OSHA standards, the Code of Federal Regulations (CFR) Title 29, Part 1910 General Industry Safety and Health Standards and Part 1926 Safety and Health Standards for Construction Industry, NFPA 70E Standard for Electrical Safety in the Workplace, DOE Hoisting and Rigging Standard, ANSI Z359.1 Safety Requirements for Personal Fall Arrest Systems, Subsystems and Components, and ANSI Z359.3 Safety Requirements for Positioning and Travel Restraint Systems. The plan consists of the following criteria: Assignment of health and safety responsibilities, emergency procedures, accidents and incidents, general rules and regulations, hazard analysis, activity hazard analysis, appropriate work clothing and personal protective equipment, access control, hoisting and rigging, fall protection/work from elevated heights, firefighting system, electrical safety system and equipment, hand and power tool safety, chemical safety, hearing conservation, hot work activities, housekeeping, material handling, motor vehicle operation, other safety consideration as well as training. Our team also documented a list of local hospitals and our manager has filled the OSHA incident forms and 30 hour certifications for the construction project to ensure safety on site before and during the Solar Decathlon Competition.
Chapter 5: Recommendations

Based on the conclusions drawn, the building envelope group has created the following list of technical and project management recommendations regarding MQP projects on Solar Decathlon Competitions.

To begin, among the various technical recommendations we have, the constructability of the house is one of the most important. Constructability includes the time and methods involved in constructing and deconstructing the house post competition. Having an innovative sustainable design on engineering paper is great, but the competition relies on the final built product, not the ideas a team can imagine. Team OCULUS has experienced firsthand that creating mock up sections of the envelope and actually assembling the skylight feature have been imperative in the design process of the house. Making sure that the parts fits together, that you are not missing any key elements, and assessing the behavior of the mock up significantly helped our team learn more about sustainable envelope design and construction. In addition, it is very helpful to keep consistent documentation of steps and challenges from the mock up assembly throughout the mock up process for the purpose of strengthening the shop drawing instructions for the actual competition.

As for project management recommendations, we suggest to keep the team subdivision for future solar decathlon projects, as it mimics the way that professionals of different disciplines interact and coordinate in a real world setting. This experience working where students specialized in the Building envelope, mechanical, structural, marketing, social media and other aspects has prepared them for team coordination in their future careers. Furthermore, the opportunity for students to work with other faculty and students from other countries is extremely beneficial for all parties involved. There is always room for improvement and from this experience, we recommend that assigning a trained project manager within the team to solely coordinate the disciplines and keep the team on schedule. Having clear distinction of roles and titles may help the future WPI Solar Decathlon teams.

Lastly, having students contact and work with professionals and manufacturers in the field was exceptional practice for their careers. We suggest that WPI MQP students continue to gain real world experience through project learning and interaction with the outside professional world. Overall, the entire Solar Decathlon experience prepares and equips students with tools for their future professional careers, and is a valuable experience for all who partake.
References


World Weather and Climate Information. (n.d.). Climate and average monthly weather in Marrakech (Marrakech-Tensift-Haouz), Morocco.


Appendices

Appendix A: Building Envelope Detail Drawings
Appendix B: Foundation Detail Drawing
Appendix C: Envelope Materials Properties

Table C-1: Grace Ice & Water Shield HT Product Data

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Performance Properties

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Table C-1: Rockwool Cavity Rock Insulation Product Data

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Exterior Insulation for Cavity Wall and Rainscreen Applications

ROCKWOOL CAVITYROCK® is a semi-rigid, mineral wool insulation board designed for exterior cavity wall and rainscreen applications.

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<td>Stress Corrosion Cracking Tendency of Austenitic Stainless Steel - Passed</td>
<td>ASTM C795</td>
</tr>
<tr>
<td>Corrosion of Steel - Passed</td>
<td>ASTM C665</td>
</tr>
<tr>
<td>Thermal Resistance</td>
<td></td>
</tr>
<tr>
<td>R-Value / inch @ 25°F</td>
<td></td>
</tr>
<tr>
<td>RSI value @ 25.4 mm @ 24°C</td>
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</tr>
<tr>
<td>4.3 hr ft²/F Btu</td>
<td></td>
</tr>
<tr>
<td>0.75 m²/KW</td>
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</tr>
<tr>
<td>Moisture Sorption - 0.03% by volume</td>
<td>ASTM C1104</td>
</tr>
<tr>
<td>Reaction to Moisture</td>
<td></td>
</tr>
<tr>
<td>Water Vapor Transmission, Desiccant Method - 1555pg/ft³ [27 perm]</td>
<td>ASTM E86</td>
</tr>
<tr>
<td>Determination of Fungi Resistance - Passed</td>
<td>ASTM C1338</td>
</tr>
<tr>
<td>Thickness Dimensions</td>
<td></td>
</tr>
<tr>
<td>1” (25.4 mm) to 4” (101.6 mm) in 1/2” increments</td>
<td></td>
</tr>
<tr>
<td>5” (127 mm) and 6” (152.4 mm)</td>
<td></td>
</tr>
<tr>
<td>24” x 48” (610 mm x 1219 mm) and 16” x 48” (406 mm x 1219 mm)</td>
<td></td>
</tr>
<tr>
<td>Thickness</td>
<td></td>
</tr>
<tr>
<td>1.5”</td>
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<tr>
<td>1.05 Hz 0.19</td>
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<td>1.05 Hz 0.55</td>
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<td>1.05 Hz 1.01</td>
<td></td>
</tr>
<tr>
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<td></td>
</tr>
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<td>1.05 Hz 0.97</td>
<td></td>
</tr>
<tr>
<td>2”</td>
<td></td>
</tr>
<tr>
<td>2000 Hz 0.06</td>
<td></td>
</tr>
<tr>
<td>2000 Hz 0.71</td>
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<tr>
<td>2000 Hz 1.14</td>
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</tr>
<tr>
<td>2000 Hz 1.04</td>
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<tr>
<td>2000 Hz 1.03</td>
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</tr>
<tr>
<td>2000 Hz 1.03</td>
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<tr>
<td>2000 Hz 0.97</td>
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<td>2000 Hz 0.97</td>
<td></td>
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<tr>
<td>3”</td>
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</tr>
<tr>
<td>1900 Hz 0.08</td>
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<tr>
<td>1900 Hz 0.88</td>
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<td>1900 Hz 0.84</td>
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<tr>
<td>1900 Hz 0.97</td>
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</tr>
<tr>
<td>Acoustical Performance</td>
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</tr>
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<td>Issued 01-01-18</td>
<td></td>
</tr>
<tr>
<td>Supersedes 06-23-19</td>
<td></td>
</tr>
</tbody>
</table>

NOTE: *Master Format: 1995 Edition **Master Format: 2014 Edition. As ROCKWOOL has no control over installation design and workmanship, accessory materials or application conditions, ROCKWOOL does not warrant the performance or results of any installation containing ROCKWOOL’s products. ROCKWOOL’s overall liability and the remedies available are limited by the general terms and conditions of sale. This warranty is in lieu of all other warranties and conditions expressed or implied, including the warranties of merchantability and fitness for a particular purpose.
Appendix D: Wicker Exoskeleton Calculations

Dowel Design (Beam)

Section 1

\[ W_w \]

\[ L = 2800 \text{ mm} @ \text{max width} \]

\[ A = 10,000 \text{ mm}^2 \]

\[ 200 \text{ mm} \]

\[ 100 \text{ mm} \]

75 grams / 5 sticks = 15 grams / 1 stick

\[ 75 \text{ g}(10) = \frac{690 \text{ g}}{2} = 345 \text{ g} \text{ dead} \]

\[ 2800 \text{ mm} / 40 \text{ sticks} = 70 \text{ mm} \]

1 stick = 75 grams

L wicker stick = 31.8 cm = 318 mm

Dowels spaced every 2300 mm = 1 foot spacing

Load combination

\[ W_w = 1.21D + 1.6L + 0.5W \]

\[ = 1.2 \left( \frac{1 \text{ KN}}{\text{ m}^2} \right) (2800 \text{ m}) + 1.6 \left( \frac{1 \text{ KN}}{\text{ m}^2} \right) (2800 \text{ m}) + 0.5 \left( \frac{5 \text{ KN}}{\text{ m}^2} \right) (2800 \text{ m}) \]

\[ = 33,600 + 44,480 + 700 \]

\[ W_w = 85400 \text{ KN/m} \]

\[ M_u = \frac{W_wL^2}{8} = \left( \frac{8540 \text{ KN/m}}{2800 \text{ m}} \right)^2 = 83692 \text{ KN} \cdot \text{m} = M_u \]

83692 KN.m = 83692 N.m = 9172.8 ft-lb
DOUBLE DESIGN (BEAM)

- Anchor Rods: steel
- 36 ksi grade rods are weldable ASTM F1554
- Round size chosen bc no LT8 LIMIT STATE
- Can be manu @ any length
- Threaded for grip
- LIMIT STATE = yielding 10.1 - 14.5 F1.1

\[ M_n = M_p = F_y Z \leq 1.0 F_y S_x \]

\[ \left( \frac{16}{1000} \right) (17.2) (10) (1.21) = (30 \text{ kips})^2 \]

\[ 2057 \text{ in}^3 = Z \]

\[ Z = \frac{d^3}{6} \]

\[ 2057 \text{ in}^3 = \frac{d^3}{6} \]

\[ d = 23" \quad \Rightarrow \quad d = 2.5" \]

CHECK

\[ M_n = M_p = F_y Z \leq 1.0 F_y S_x \]

\[ S_x = \frac{\pi d^3}{3 \sigma} = \frac{\pi (2.5)^3}{3 \times 30} = 153 = S_x \]

\[ (17.2) \left( \frac{1}{1000} \right) = 7.4064 \leq 1.0 (30) (153) \]

\[ 7.4064 \leq 88.128 \]

\[ 74.064 \leq 88.128 \checkmark \]
### Appendix E: Precast Foundation Calculations

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Dead Load</td>
<td>20 psf</td>
<td></td>
</tr>
<tr>
<td>Live Load</td>
<td>40 psf</td>
<td></td>
</tr>
</tbody>
</table>

|      | 0.3927 kips |      |
|------| 2.8 kips |      |

<table>
<thead>
<tr>
<th>Fixed Shear Strength</th>
</tr>
</thead>
<tbody>
<tr>
<td>$P_F = 1.2 DL + 1.6 LL$</td>
</tr>
<tr>
<td>$P_L = 4.95124$ kips</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Material Properties (Table 2-4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ASTM designation: A36</td>
</tr>
<tr>
<td>$F_y = 36$ ksi</td>
</tr>
<tr>
<td>$F_u = 58$ ksi</td>
</tr>
</tbody>
</table>

**WITH BOLTS**

<table>
<thead>
<tr>
<th>Shear Lag Factor</th>
<th>Choose shape from table 5-2</th>
</tr>
</thead>
<tbody>
<tr>
<td>$Ag = 3.19$ in^2</td>
<td>$Ae = 1$ in^2</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>from table 1-1</th>
<th>$Ag = 1$ in^2</th>
</tr>
</thead>
<tbody>
<tr>
<td>$b = 9$ in</td>
<td>$t = 6.3$ in</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>(Ph)P_e</th>
<th>kips</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.1 $\sqrt{\frac{b}{t} E/1000}$</td>
<td>13.4039</td>
</tr>
<tr>
<td>1.37 $\sqrt{\frac{b}{t} E/1000}$</td>
<td>42.2903</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>AISC Specification D4.3</th>
</tr>
</thead>
<tbody>
<tr>
<td>$d_e = 0.6255$ in</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>An</th>
<th>$Ag - 0.6255 + 1/2(1/16)$ in</th>
</tr>
</thead>
<tbody>
<tr>
<td>$An = 1.84$</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>AISC Specification D9</th>
</tr>
</thead>
<tbody>
<tr>
<td>$A_e = An$</td>
</tr>
<tr>
<td>$A_e = 1.84$</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Does yielding or rupture govern?</th>
</tr>
</thead>
<tbody>
<tr>
<td>$Ae/Ag = 0.512535$</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Nominal Shear Strength</th>
</tr>
</thead>
<tbody>
<tr>
<td>$C_{02} = 1$</td>
</tr>
<tr>
<td>$C_{02} = 1$</td>
</tr>
<tr>
<td>$C_{02} = 14.59967$</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>AISC Specification D8</th>
</tr>
</thead>
<tbody>
<tr>
<td>$V_n = 0.6 F_y b t$</td>
</tr>
<tr>
<td>$V_n = 54$ kips</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Available Shear Strength</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\Phi V_n = 48.6$ kips</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Will the member fail in shear?</th>
</tr>
</thead>
<tbody>
<tr>
<td>PASS</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>AISC Specification D15: Slenderness Limit</th>
</tr>
</thead>
<tbody>
<tr>
<td>$L = 15.48$ ft</td>
</tr>
<tr>
<td>$t = 0.25$ in</td>
</tr>
</tbody>
</table>

| $\frac{L}{t} = 61.92 < 300$ |
| PASS |
# Appendix F: Health and Safety Plan

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1 STATEMENT OF POLICY

Team OCULUS commits to a health and safety policy that minimizes the risks associated with the prefabrication, transportation, and the on-site construction and deconstruction of the team’s 2019 Solar Decathlon house. We will comply with OSHA standards, the Code of Federal Regulations (CFR) Title 29, Part 1910 General Industry Safety and Health Standards and Part 1926 Safety and Health Standards for Construction Industry, NFPA 70E Standard for Electrical Safety in the Workplace, DOE Hoisting and Rigging Standard, ANSI Z359.1 Safety Requirements for Personal Fall Arrest Systems, Subsystems and Components, and ANSI Z359.3 Safety Requirements for Positioning and Travel Restraint Systems. This Health and Safety Plan applies to all contractors (construction team) OCULUS brings on site. Every team member will be briefed about our health and safety policy. We acknowledge workers’ rights and responsibilities regarding a safe and healthful work environment in accordance with the worksite OSHA poster. This health and safety plan covers work in Morocco during the Solar Decathlon Africa 2019 and where applicable work performed by students and faculty on the construction site in Massachusetts.
2 ASSIGNMENT OF HEALTH AND SAFETY RESPONSIBILITIES

Team OCULUS’s primary contact person for all health and safety related activities and concerns while working in Morocco will be the primary faculty advisor:

Professor Steven Van Dessel

A Safety Coordinator and a Construction Site Coordinator will be present on site at all times, they will consult about safety issues. If an incident or accident occurs, the safety coordinator will notify the faculty advisor, who if necessary will contact Worcester Polytechnic Institute, ENSIAS, ENSAM or the African University of Science and Technology for matters related to insurance and documentation. The Safety Coordinator will not take part in any type of construction.

The Safety Coordinator and all workers on site have the right to stop work if they perceive a serious safety concern. He or she will notify the construction team that a stop work order is issued by blowing a whistle. This supervisory role for all health and safety matters is not assigned to the Construction Site Coordinators as they remain dedicated to completing the required work in a timely manner.

The Safety Coordinator present at the construction site should be contacted for all health and safety matters. The health and safety plan will be distributed to all on site personnel. All personnel (students, faculty, staff, etc.) will be briefed on the details of the health and safety plan prior to onset of construction activities. Furthermore, at the beginning of each shift, the entire construction team of that shift will receive a summary of all health and safety matters applicable to that shift. These introductions will be logged. We will refer to this moment as the toolbox.
3 EMERGENCY PROCEDURES

In case of an emergency, the following steps will be taken. First, there must be an evaluation of the emergency in which the whole picture must be taken in.

Secondly, the following procedure will take place in the event of an emergency:

1- Secure the scene to prevent further injuries.

2- Call 120 (or equivalent) for an emergency response.

3- Provide first aid, if needed, and if trained

4- Remain at the scene until a public safety officer takes charge.

5- Call or notify Solar Decathlon Africa 2019 headquarters, organizers or event staff.

To add, a First Aid kit will be present on site at all times, including basic medical equipment for small injuries like cuts and similar.

Emergency numbers Morocco

Fire fighters : 150
Police : 190 or 177
Ambulance : 150
Maroc Assistance : 05 22 30 30 30
SOS Médecin : 05 22 44 44 44

A list of local clinics and hospitals in the Ben Guerir area can be found in Appendix 01. This information can also be obtained from the Solar Decathlon headquarters During the assembly and disassembly phases of the event, an ambulance will be on site 24 hours per day.

During the public exhibit hours, an emergency medical technician (EMT) and an ambulance will also be on site. At all times, a Police officer will be on duty at the event.

Several team members including all Safety Coordinators, several Construction Site coordinators and constructors will have attended a 4-day first aid course.

A First Aid kit will be present on site at all times, including basic medical equipment for small injuries like cuts and similar.

Several team members will have attended fire training. If a fire occurs, first responders will be called before any attempt to extinguish the fire will be undertaken. Any attempt to extinguish a fire will be undertaken by 2 persons. Only 1 attempt is allowed, if not successful we leave it in the hands of the fire brigade, who will be contacted as soon as a fire is detected.
4 ACCIDENTS AND INCIDENTS

If an incident occurs it will immediately be brought to the attention of the Safety Coordinator present on site. If it is possible that the incident will happen again, the Safety Coordinator will stop all work. After taking measures to prevent a recurring of the incident, the Safety Coordinator will contact the faculty advisor, the Solar Decathlon headquarters and the event safety officer. The faculty advisor will, if necessary, contact for insurance related matters. Work will only continue when the incident can’t recur and a Safety Coordinator is present on site.

The standard Incident Report Form Solar Decathlon Africa 2019, a form to file a report about any incident at the worksite, can be found in Appendix 02. This form aims to prevent further occurrences of the incident.

If necessary all construction workers and supervisors will be gathered for an intermediate toolbox where the incident and appropriate safety measures are explained. If similar work activities are scheduled for the next shift, the incident and safety measures will be treated in the next toolbox.
5 GENERAL RULES AND REGULATIONS

Because Do-it-yourself is one of the underlying principles of our concept, all the structural elements of our house are being designed so that they can be managed and handled by a crew of 1 or 2 persons or with the help of a crane. The weight of components will be limited and kept within pre-set weight limits, according to European Council Directive 90/269/EEC. The maximal load that may be lifted by one person shall not exceed 30 kg. The maximal load that may be lifted together by two persons shall not exceed 60 kg. These guidelines apply in cases when there is sufficient space available to lift the load safely. Special caution will be made in cases when the load is not easily manageable, for example when lifting overhead or lifting large or bulky items where the center of gravity makes the load hard to handle. A simple mechanical aid will be provided to lift, transport, assemble, or disassemble components when the weight of an element exceeds the above mentioned allowable limit, or when there are any other concerns that may present a safety concern. As we are assuming a non-experienced construction crew, extra care shall be given to make building procedures as simple and safe as possible, according to OSHA requirements:

Foot Protection

Safety-toed footwear is worn at all times at the construction site to prevent crushed toes when working around heavy equipment or falling objects. Construction workers should wear work boots or boots with slip-resistant and puncture resistant soles.

Hand Protection

Workers wear the appropriate gloves for the job (for example insulated gloves and sleeves when exposed to electrical hazards). Gloves should fit snugly.

Head Protection

Workers shall wear hard hats at all times while at the construction site whenever there is a potential for objects falling from above, bumps to their heads from fixed objects, or of accidental head contact with electrical hazards. Hard hats are routinely inspected for dents, cracks or deterioration. Hard hats are replaced after a heavy blow or electrical shock. Hard hats are maintained in good condition.

Eye Protection

Safety-glasses with side shields are worn at all times during assembly and disassembly of the house, and whenever any eye hazard exists.

Electrical Safety

Work on new and existing energized (hot) electrical circuits is prohibited until all power is shut off and grounds are attached. An effective Lockout/Tagout system is in place. All extension cords will have grounding prongs and on site generators will be grounded. Flexible cords and cables shall be protected from damage. Sharp corners and projections should be avoided. We will ensure that ladders, scaffolds, equipment or materials never come within 10 feet of electrical power lines.
All electrical tools must be properly grounded unless they are of the double insulated type.

**Elevated Surfaces**

Surfaces elevated more than 1,18 m above the floor or ground will have guardrails. All elevated surfaces (beneath which people or machinery could be exposed to falling objects) have standard 10 cm toe boards. A permanent means of entry and exit with handrails is provided to elevated storage and work surfaces. A PFA system will be used to access the roof after assembly and during the competition (for example to inspect PV in thermal solar panels).

**Moving loads**

Every team member will receive instructions on how to move loads. Construction workers who are required to move heavy loads are required to take regular breaks.

**Access to the building site**

Only authorized construction workers and supervising personnel is allowed on the construction site. People who are permitted onto the construction site will be easily recognizable, for example by wearing identical colored T-shirt, etc. This could mean different T-shirts for each 8-hour shift.

**Sanctions**

Personnel that doesn’t respect personal or general safety measures will be removed from the site until he or she meets the personal safety measures or understands all safety regulations. Personnel that continue to make the same mistakes will be (permanently) removed from the construction team.

**Drug and Alcohol policy**

Our alcohol and drug policy is zero tolerance. If there are deviations from this policy, these persons will be removed from the construction site for 8 hours.
**6 HAZARD ANALYSIS**

**Identifying scope of work**
Our main goal is to build a house in the most efficient and safe way as possible. The construction process will be divided in several tasks whereby the general risks associated with all or a large group of tasks will be described and general mandatory safety measures will be described. An Activity Hazard Analysis will be performed for each task.

**Controlling the hazards**
All risks will be controlled in the following order with the emphasis on prevention before protection:

![Risk Control Hierarchy](image)

**Performing work within the scope utilizing the controls**
Everyone performing a task will read and understand the hazard analysis and safety matters before starting work. The hazard analysis is documented through the activity hazard analysis (AHA). In the toolbox, safety and working methods will be discussed prior to a working shift. If a task starts in the middle of a shift and continues into a following shift, procedures on how to handle that task will be discussed by the persons performing the task, the Safety Coordinator and the Construction Site Coordinator. Verifying these controls will be performed by the Safety Coordinator.

**Improving safety**
If, while performing work, safety controls seem insufficient, work on that task will be stopped and reevaluated. The measures taken then will be repeated in subsequent tasks.
## 7 ACTIVITY HAZARD ANALYSIS (AHA)

In the following grid, the probability and consequences of all risks are defined. The preventive measures of all risks will be listed in the next paragraphs.

<table>
<thead>
<tr>
<th>Key:</th>
<th><strong>Probability of the event</strong></th>
<th>Key:</th>
<th><strong>Consequence of the risk</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Extremely Remote</td>
<td>1</td>
<td>Negligible</td>
</tr>
<tr>
<td>2</td>
<td>Remote</td>
<td>2</td>
<td>Marginable</td>
</tr>
<tr>
<td>3</td>
<td>Occasional</td>
<td>3</td>
<td>Critical</td>
</tr>
<tr>
<td>4</td>
<td>Reasonably Probable</td>
<td>4</td>
<td>Catastrophic</td>
</tr>
<tr>
<td>5</td>
<td>Frequent</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Risks identifications and its causes

<table>
<thead>
<tr>
<th><strong>Risks identifications and its causes</strong></th>
<th><strong>Probability of the Event</strong></th>
<th><strong>Consequence of the Risk</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Person gets run over by truck</td>
<td>Remote</td>
<td>Catastrophic</td>
</tr>
<tr>
<td>Hand gets caught in crane hooking process</td>
<td>Remote</td>
<td>Critical</td>
</tr>
<tr>
<td>Swinging equipment from crane strikes person</td>
<td>Extremely remote</td>
<td>Catastrophic</td>
</tr>
<tr>
<td>Materials are set down on workers limbs</td>
<td>Remote</td>
<td>Critical</td>
</tr>
<tr>
<td>Unmarked hazards, resulting in injury</td>
<td>Reasonably probable</td>
<td>Marginable</td>
</tr>
<tr>
<td>Temporary structures become unstable</td>
<td>Occasional</td>
<td>Marginable</td>
</tr>
<tr>
<td>Worker falls off of scaffolding</td>
<td>Remote</td>
<td>Catastrophic</td>
</tr>
<tr>
<td>Personal fall protection fails</td>
<td>Extremely remote</td>
<td>Catastrophic</td>
</tr>
<tr>
<td>Worker gets caught in envelope or wicker</td>
<td>Remote</td>
<td>Marginal</td>
</tr>
<tr>
<td>Person gets particles in eyes</td>
<td>Reasonably possible</td>
<td>Marginable</td>
</tr>
<tr>
<td>Worker is pinned between frame and skylight</td>
<td>Extremely remote</td>
<td>Critical</td>
</tr>
<tr>
<td>Worker obtains injury due to machinery</td>
<td>Reasonably probable</td>
<td>Critical</td>
</tr>
<tr>
<td>Civilian enters job site and gets injured</td>
<td>Occasional</td>
<td>Critical</td>
</tr>
</tbody>
</table>
### 7.1. AHA Tasks/Activities: General activities

<table>
<thead>
<tr>
<th>Hazards</th>
<th>Preventive measures</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Yet to be identified</strong></td>
<td>This AHA is a dynamic document and shall be revised as additional activities are identified. For major revisions, BE- MA-NY shall review analysis prior to work being performed. All personnel on-site shall, before construction starts, participate in a toolbox to summarize all health and safety matters.</td>
</tr>
</tbody>
</table>
| **Eye/Head/Foot/Hand injuries from work activities** | - Safety-glasses with side shields are worn at all times during assembly and disassembly tasks, and whenever an eye hazard exists  
- Hard hats meeting ANSI Z89.1 or equivalent Type I Class G or better are to be worn at all times with the brim facing forward  
- Safety boots meeting ANSI Z41 PT99 or equivalent with ankle supports are required in all working areas  
- Gloves are to be worn during sharp material handling. The glove type shall be matched with the task.  
- Safety boots meeting ANSI Z41 PT99 or equivalent with ankle supports are required in all working areas  
- Gloves are to be worn during sharp material handling. The glove type shall be matched with the task. |
| **Fire hazardous material/equipment**  | - Fire extinguishers (Dry Chemical Extinguishers) shall be fully charged at all times  
- Fuel not in a vehicle or motorized device, shall be in an approved metal fuel can with safety cap and flash arrestor  
- Flammables are to be stored in an enclosed area until use is needed  
- Smoking is not allowed on the jobsite  
- Workers on the site shall have “Hands On” training in the use of fire extinguishers as necessary |
| **Slips, trips and falls**             | - All hazardous work areas, especially around vehicular traffic, shall be properly barricaded with barricades and signage giving specific direction  
- Caution tape shall always be present on the working site; all caution tape shall be inspected for rips and tears on a daily basis |
| **Electrical shock** | - A GFCI shall precede all connected extension cords and electric tools  
- Personnel shall follow ‘Living Light’ lockout/tagout procedures if necessary  
- No work on existing wiring without verification of deactivation shall be done  
- Electrical cords must always be away from standing water on ground  
- Whenever feasible, all cords shall be run 7 cm from the ground |
| **Noise** | - Potential high noise sources shall be identified (e.g. generators, heavy equipment, power tools) and posted  
- Hearing protection shall be required for entry into areas where noise level exceeds 85 dBA |
| **Unsafe equipment, tools, ladders and electrical cords** | - All equipment tools, ladders and electric cords shall be inspected prior to each use  
- Defective and/or damaged items shall be dispositioned for repair or disposal from the work site  
- Electric cords shall be free of breaks, splices, tapered repairs, or otherwise dispositioned for disposal  
- A metal spreader or locking device shall be provided on each stepladder to hold the front and back sections in an open position when the ladder is being used |
| **Illumination** | - There will only be work done during the daylight |
| **Back injuries, ergonomics-repetitive motion and vibration injury** | - Proper lifting techniques—lift with legs, maintain the back straight, keep the load balanced and close to the body  
- If the load is too heavy, several people will be used or mechanical assist to lift or move the load  
- The use of job/task rotation may also be used to eliminate these hazards |
| **Inadequate housekeeping causing hazards or improper material** | - All areas and walking/working surfaces will be kept neat and clear of unnecessary materials, tools, etc.  
- Materials, tools, etc. will be placed in secondary storage containers, so they can’t cause tripping hazards - Nails and any other objects that |
### Storage
- can cause injury or damage machinery, must always be picked up
- Trash must be placed in provided and marked trash receptacles
- Combustible materials may not be allowed to accumulate

### Hazards associated with equipment on site
- combustion engines (i.e. forklifts, scissor lifts, power generators, etc.)
- All necessary equipment is subject to safety inspections prior to entry into the site
- All necessary equipment shall be operated by a competent operator, in good repair without cooling, hydraulic, lubricant, and fuel leaks
- Applicable operator restraints shall be worn at all times of operation when necessary
- Prior to initial operation, all equipment shall be inspected daily
- For equipment requiring an inspection, the inspection shall be recorded on the supplied inspections sheet and the sheet signed by the device operator
- All stationary combustion engines shall have fire extinguishers located adjacent to the work area (within 10’).
- All mobile equipment (scissor lifts, etc.) shall have fire extinguishers within 10’ of the working area
- Before refueling equipment, a cool down time shall be observed
- Appropriate signs shall identify all locations where trucks or vehicles shall be leaving the work site and entering normal traffic lanes

### Improper use of hand, power and pneumatic tools
- All workers shall be properly educated on how to use tools
- All tools must be inspected before use
- Tools may only be used for the work the tool is designed for
- It must be insured that all proper guards are installed - If any tool is not safe for use, it must be tagged and removed from service

### 7.2. AHA Tasks/Activities: Vehicle and crowd control

<table>
<thead>
<tr>
<th>Hazards</th>
<th>Preventive Measures</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vehicle movement</td>
<td>- Proper PPE (i.e. reflective vests, portable radios, and light wands) is</td>
</tr>
</tbody>
</table>
| and on-site crowd control | to be worn and used by team members at all times  
- Transport vehicle(s) are not to exceed 5 km/h on the jobsite  
- A direct line of site is to be kept by team members when vehicles are being used on site.  
- Non-construction personnel and guests shall only access the site with the approval and guidance of the on-site Health and Safety Manager  
- Barricades shall only be moved with consent of the safety manager |
### 7.3. Construction Phase I - Foundation

#### Construction Event

<table>
<thead>
<tr>
<th>Event</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.1</td>
<td>Crane and Flatbed Truck transporting prefabricated foundation slab pieces arrive onsite, crane is hooked up to foundation slab pieces.</td>
</tr>
<tr>
<td>1.2</td>
<td>Crane lifts slab pieces and swings them into their corresponding place on foundation frame, two workers will guide the slab into position using guide cables. One worker will be standing in the center and one on the outside of the slab circle.</td>
</tr>
<tr>
<td>1.3</td>
<td>Slab pieces are lowered down and placed onto frame, one after another.</td>
</tr>
<tr>
<td>1.4</td>
<td>Slab pieces are connected/fastened to each other, one worker standing in the center and one on the outside of the foundation assembly.</td>
</tr>
</tbody>
</table>

#### Preventive Measures

<table>
<thead>
<tr>
<th>Event</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.1</td>
<td>An area around the truck should be clear to allow the truck entrance to the site safely and allow for easy access to the material. Beware of hands being caught/pinched in crane hooking process.</td>
</tr>
<tr>
<td>1.2</td>
<td>Swinging of the slab piece is dangerous to those in the path of the piece, perimeter of path/zone to be distinguished and clearly indicated by workers with whistles standing on the perimeter of the area.</td>
</tr>
<tr>
<td>1.3</td>
<td>Two workers in charge of guide cables be careful not to get caught under slab piece as it is lowered.</td>
</tr>
<tr>
<td>1.4</td>
<td>Possibility for fingers to get caught, extreme care to be taken as pieces are connected.</td>
</tr>
</tbody>
</table>
### 7.4. Construction Phase 2 - Mechanical and Electrical Equipment

<table>
<thead>
<tr>
<th>Construction Event</th>
<th>Preventative Measures</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.1 Flatbed trucks transporting preassembled mechanical units and electrical meter with control panel arrives on site.</td>
<td>An area around the truck should be clear to allow the truck entrance to the site safely and allow for easy access to the material.</td>
</tr>
<tr>
<td>2.2 Mechanical and electrical equipment will be hoisted from the flatbed by a crane and two workers with guide ropes will guide the equipment to the allocated location on site.</td>
<td>The area around the crane and truck should be clear to allow the equipment to be moved and set in place, one person is needed to guide the crane towards the dome structure. Other workers will set a boundary around the active working area.</td>
</tr>
<tr>
<td>2.3 Mechanical equipment is to be lowered onto the slab in the designated area. Two workers are to guide the equipment properly into place, one standing in the center and one on the outside of the slab circle.</td>
<td>The active working area is to be cleared to allow for the placement of the equipment. Again a proper boundary will need to be set around the active working area.</td>
</tr>
<tr>
<td>2.4 Electrical meter equipment is to be placed in the designated location off to the side of the house.</td>
<td>The active working area is to be cleared to allow for the proper installation.</td>
</tr>
</tbody>
</table>
7.5 Construction Phase 3 - Structure Assembly

<table>
<thead>
<tr>
<th>Construction Event</th>
<th>Preventative Measures</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.1 Flatbed truck transporting structural members/connections arrives onsite. Members are light enough to be manually removed from the truck by workers and carried to the allocated location.</td>
<td>An area around the truck should be clear to allow the truck entrance to the site safely and allow for easy access to the material. No person is to lift weights heavier than 30kg as outlined in the general safety instructions. Structural members above 30 kg will be identified and lifted by two or more workers.</td>
</tr>
<tr>
<td>3.2 Structure will be assembled in phases by ring, ring 1 will be completed using temporary props.</td>
<td>Properly secure temporary construction props to avoid structural failure</td>
</tr>
<tr>
<td>3.3 Ring 2 will be completed using temporary props and attached to ring 1 through the structural connections intended in design.</td>
<td>Properly secure temporary construction props to avoid structural failure</td>
</tr>
<tr>
<td>3.4 Ring 3 will be completed using temporary props with the aid of a temporary scaffolding assembly to properly install the structural members above reaching height. Ring 3 will be attached to ring 2 as designed.</td>
<td>Properly secure temporary construction props to avoid structural failure</td>
</tr>
<tr>
<td>3.5 The last ring, ring 4 will be attached to</td>
<td>Properly secure temporary construction props</td>
</tr>
</tbody>
</table>
ring 3 and installed with the use of the temporary scaffolding in place. The scaffolding will be moved as needed as the opening at the top of the dome gets smaller after the addition of ring 3. to avoid structural failure

7.6 Construction Phase 4 - Envelope Installation

<table>
<thead>
<tr>
<th>Construction Event</th>
<th>Preventative Measures</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.1 Unload the envelope package off of the flatbed truck and unravel envelope section piece on the ground</td>
<td>An area around the truck should be clear to allow the truck entrance to the site safely and allow for easy access to the material. No person is to lift weights heavier than 30kg as outlined in the general safety instructions. Structural members above 30 kg will be identified and lifted by two or more workers.</td>
</tr>
<tr>
<td>4.2 Tie one end of rope onto envelope and feed rope to workers on scaffolding in the center of the dome structure.</td>
<td>Workers should be tied off with personal fall protection equipment while on scaffolding, to ensure that they will be safe while pulling up the envelope.</td>
</tr>
<tr>
<td>4.3 Have two workers standing on scaffolding pull the rope, therefore pulling the envelope, into position. Have workers inside the</td>
<td>Workers should be tied off with personal fall protection equipment while on scaffolding, to ensure that they will be safe while pulling up</td>
</tr>
</tbody>
</table>
structure guiding the envelope over the structural connections to ensure the envelope does not get caught or torn.

4.4 Attach envelope to structure by hook connections at the top and bottom. Use scaffolding to access connection located at the top of the structure. Workers should be tied off with personal fall protection while on scaffolding, to ensure that they will be safe while pulling up the envelope.

**7.7 Construction Phase 5 - Wicker**

**Phase 5 - Wicker Installation**

5.1 Flatbed truck transporting premade wicker panels will arrive onsite. A crane will be hooked onto the wicker panels.

5.2 Crane is to lift the wicker panels and swing them over into place. Panels will be guided by two workers with guide ropes.

**Construction Event**

**Preventative Measures**

<table>
<thead>
<tr>
<th>Construction Event</th>
<th>Preventative Measures</th>
</tr>
</thead>
<tbody>
<tr>
<td>5.1 Flatbed truck transporting premade wicker panels will arrive onsite. A crane will be hooked onto the wicker panels.</td>
<td>An area around the truck should be clear to allow the truck entrance to the site safely and allow for easy access to the material. The area around the crane and truck should be clear to allow the wicker to be moved and set in place, a person will need to guide the crane and others will set a boundary around the construction site.</td>
</tr>
<tr>
<td>5.2 Crane is to lift the wicker panels and swing them over into place. Panels will be guided by two workers with guide ropes.</td>
<td>The area will need to stay clear to allow for the placement of the wicker. Again a proper boundary will need to be set.</td>
</tr>
</tbody>
</table>
5.3 Wicker panels will be lowered into place and fastened to the previously installed envelope assembly. The area should stay clear, to ensure that the wicker is placed onto the proper area.

### 7.8 Construction Phase 6 - Skylight Installation

<table>
<thead>
<tr>
<th>Construction Event</th>
<th>Preventative Measures</th>
</tr>
</thead>
<tbody>
<tr>
<td>6.1 Flatbed truck transporting plexiglass skylight will arrive onsite. A crane will be hooked onto the skylight.</td>
<td>An area around the truck should be clear to allow the truck entrance to the site safely and allow for easy access to the material. The area around the crane and truck should be clear to allow the skylight to be moved, a person will need to guide the crane and others will set a boundary around the construction site.</td>
</tr>
<tr>
<td>6.2 Crane is to lift the skylight and swing it over into place. The skylight will be guided by two workers with guide ropes.</td>
<td>The area around the crane and truck should be clear to allow the skylight set in place, a person will need to guide the crane and others will set a boundary around the construction site.</td>
</tr>
<tr>
<td>6.3 Skylight is to be lowered into place and fastened to the completed envelope assembly.</td>
<td>Workers should be tied off with personal fall protection equipment while on scaffolding, to ensure that they will be safe while installing</td>
</tr>
</tbody>
</table>
7.9 Construction Phase 7 - Interior Finishes

### Construction Event

<table>
<thead>
<tr>
<th>7.1 Truck transporting interior finish materials will arrive onsite and be unloaded by crane, forklift or manually depending on material bundling or weight.</th>
</tr>
</thead>
</table>

### Preventative Measures

| An area around the truck should be clear to allow the truck entrance to the site safely and allow for easy access to the material. A boundary will be set based off the removal of the item. |

<table>
<thead>
<tr>
<th>7.2 Install interior finish materials. Materials will be fastened to the exposed structural members or installed on the foundation slab pieces.</th>
</tr>
</thead>
</table>

### Preventative Measures

| Ensure that all people are wearing proper personal protective equipment when installing or around the installation of finish materials. |

### 8 APPROPRIATE WORK CLOTHING, PERSONAL PROTECTIVE EQUIPMENT

The minimum level of Personal Protective Equipment (PPE) required for anyone accessing the site while construction activities are occurring, is a hard hat, safety glasses with side shields, safety boots with ankle protection, long pants (which reach at least the top of safety boots and cover the
ankles), and shirt with sleeves (7.6 cm minimum). This minimum level of PPE is referred to in the Activity Hazards Analysis as the ‘Standard safety outfit’.

For work on the roof, a personal fall arrest system is required (see paragraph 11: ‘Fall protection/work from elevated heights’).

If the work requires gloves, construction workers will have to wear the right gloves for the job (for example, heavy-duty rubber gloves for concrete work, welding gloves for welding, insulated gloves and sleeves when exposed to electrical hazards). If needed, construction workers will wear ear protection, namely ear plugs or ear laps.

If any hot work activities such as welding or cutting are done, the appropriate mask needs to be worn.

Protection from the sun is required and will be made available onsite to all construction personnel under the form of sunscreen.

9 ACCESS CONTROL

The caution tape provided by the organization will serve as our primary barricade, we will inspect and assess the barricade to ensure its effectiveness, at the end and beginning of every shift.

There will be one access point to our construction site. Every shift will receive safety instructions and will be inspected on the use of the appropriate PPE at the beginning of the shift (toolbox). Every shift will have clear visual characteristics.

If a media representative or VIP requests access to our site during construction, they will be asked to wear the minimum level of PPE before they can enter the construction site. If it’s possible, work will be stopped and the safety officer will check the site for hazards before allowing the visitors on the site.

10 HOISTING AND RIGGING

Elements too heavy to be installed manually will be lifted using lifting equipment described further.

The containers and the atrium roof need to be picked up by a crane truck. All rigging and manipulation of the crane truck will be done by the crane company. The tag lines will be handled by team members. Before any lifting is done, all people involved to the lifting will be briefed on a pre-lift meeting.

Before lifting, a perimeter will be demarcated with caution tape so that no one that is not briefed about the lifting can walk close to the crane truck. The safety coordinator will keep an eye on the
work and stop people when they are coming too close to the works.

When things need to be lifted, the professionals of the crane company will attach the items to the crane. No team member will interfere with these works.

11 FALL PROTECTION/WORK FROM ELEVATED HEIGHTS

Fall Protection

Fall protection systems shall comply with the OSHA Fall Protection Systems criteria and practices (standard number 1926.502). Fall protection systems will comply with all pertinent requirements before workers can begin work that necessitates the fall protection. Construction workers performing duties at unprotected sides and edges which are 1,8 m or more above a lower level shall be protected from falling by the use of a personal fall arrest system, as described by OSHA.

The temporary scaffolding assembly will be safeguarded by a personal fall arrest system with anchor points to protect the user from falling.

The global fall protection system will consist of a self-retracting lanyard securing the connection of the full body fall arrest harness to the anchor point. The self-retracting vertical lifelines must limit the free fall distance to 0,6 m or less and must have a minimum capacity of 1 360 kg. The systems cable length should be a minimum of 2,5 m so a person can reach the next anchoring point.

On the anchored side of the lanyard a carabiner is used to attach to the D-ring anchor. On the other side a snap hook is used. Each connector has a minimum tensile load of 2268 kg. Following pictures are examples of the D-ring anchor, self-retracting lanyard with carabiner and snap hook, and a full body harness with centered anchor on the back near shoulder level.
A demonstration by the safety coordinator on how to put on a body harness, to correctly hook-up, and how to safely adjust and use the self-retracting lanyard will be provided to every person.

**Ladder Usage**

A stairway or ladder shall be provided at all personnel points of access where there is a break in elevation of 48 cm or more, and no ramp, runway, sloped embankment, or personnel hoist is provided. We shall provide and install all stairway and ladder fall protection systems required and will comply with pertinent requirements before employees begin the work that necessitates the installation and use of stairways, ladders, and their respective fall protection systems.

For certain work on the of the house we will use mobile ladders. Working heights won’t exceed 3m and the work carried out from a ladder will be light work of short duration.

Ladders will comply with CE coding and will be used properly:

1. Make sure the ladder is suited for the type of job
2. Self-supporting ladders will be able to support at least four times the maximum intended load
3. Before using a ladder inspect it for cracks or broken joints
4. Place the ladder on a stable, even, flat surface. Never place a ladder on top of another object
5. Use the 1:4 ratio to ensure a stable working platform. Place the base of the ladder 1 foot away of whatever it leans against for every 4 feet of height to the point where the ladder contacts at the top
6. When using an A-frame stepladder, make sure the brace is locked in place
7. If climbing onto another surface, make sure the ladder extends at least three feet past the platform you're climbing onto
8. Secure tall ladders by lashing or fastening the ladder to prevent movement
9. Always face the ladder when climbing or descending
10. Keep both feet on the ladder - never put one foot on a rung and the other foot on a different surface. Do not climb higher than the second rung on step-ladders or the third rung on straight or extension ladders 11. Never stand on the top or the paint shelf of a stepladder
12. Keep your belt buckle (if you have one) positioned between the rungs so it doesn't catch
13. Never leave ladders unattended
14. When working with electricity, use a ladder made of wood or fiberglass

**Lifting**

We will be using a forklift for lifting components such as solar panels. This lift will only be used to move equipment and house components and not for transporting people. The maximum weight limit as prescribed by the manufacturer on the CE coding will be respected and a safety zone will
be defined.

We shall comply with the manufacturer's specifications and limitations applicable to the operation of all manual lifts being used.

12 FIRE FIGHTING SYSTEM

During construction, at least two fire extinguishers will be present at the construction site. Before workers start working, they will be informed about the location of the fire extinguishers and how to use them properly. Each fire extinguisher will have a configured minimum extinguishing level of 2A and the maximum protected area of 75 m2/A for a unit extinguishing level.

Fire detection will be established by installing 3 residential smoke detectors on the hanging on the internal structural members. In the kitchen there is a residential fire extinguisher.
13 ELECTRICAL SAFETY, SYSTEM, AND EQUIPMENT

General requirements

All electrical conductors and equipment, and work and maintenance of electrical conductors and equipment, shall comply with the OSHA General Safety and Health Regulations for Construction (standard number 1926.403):

All electrical conductors and equipment shall be approved and their suitability for an identified purpose may be evidenced by listing, labeling, or certification for that identified purpose. Listed, labeled, or certified equipment shall be installed and used in accordance with instructions included in the listing, labeling, or certification. Electric equipment shall be firmly secured to the surface on which it is mounted. Electrical equipment which depends upon the natural circulation of air and convection principles for cooling of exposed surfaces shall be installed so that room air flow over such surfaces is not prevented by walls or by adjacent installed equipment. For equipment designed for floor mounting, clearance between top surfaces and adjacent surfaces shall be provided to dissipate rising warm air. Electrical equipment provided with ventilating openings shall be installed so that walls or other obstructions do not prevent the free circulation of air through the equipment. Conductors shall be spliced or joined with splicing devices designed for the use or by brazing, welding, or soldering with a fusible metal or alloy. Soldered splices shall first be so spliced or joined as to be mechanically and electrically secure without solder and then soldered. All splices and joints and the free ends of conductors shall be covered with an insulation equivalent to that of the conductors or with an insulating device designed for the purpose. Parts of electric equipment which in ordinary operation produce arcs, sparks, flames, or molten metal shall be enclosed or separated and isolated from all combustible material. Electrical equipment shall not be used unless the manufacturer's name, trademark, or other descriptive marking by which the organization responsible for the product may be identified is placed on the equipment and unless other markings are provided giving voltage, current, wattage, or other ratings as necessary. The steel structure of the house will be grounded.

Each disconnecting means required for motors and appliances shall be legibly marked to indicate its purpose, unless located and arranged so the purpose is evident. Each service, feeder, and branch circuit, at its disconnecting means or over current device, shall be legibly marked to indicate its purpose, unless located and arranged so the purpose is evident. Sufficient access and working space shall be provided and maintained about all electric equipment to permit ready and safe operation and maintenance of such equipment. Working space is not required in back of assemblies such as dead-front switchboards or motor control centers where there are no renewable or adjustable parts such as fuses or switches on the back and where all connections are accessible from locations other than the back. Working space required shall not be used for storage. When normally enclosed live parts are exposed for inspection or servicing, the working space, if in a passageway or general open space, shall be guarded. At least one entrance shall be provided to give access to the working space about electric equipment. Where there are live parts normally exposed on the front of switchboards or motor control centers, the working space in front of such
equipment shall not be less than 914 mm. The minimum headroom of working spaces about service equipment, switchboards, panelboards, or motor control centers shall be 1.91 m. Live parts of electric equipment operating at 50 volts or more shall be guarded against accidental contact by cabinets or other forms of enclosures. Entrances to rooms and other guarded locations containing exposed live parts shall be marked with conspicuous warning signs forbidding unqualified persons to enter.

**Construction safety requirements**

**Extension cords and on site generators**

All extension cords will have grounding prongs and on site generators will be grounded. Flexible cords and cables shall be protected from damage. Sharp corners and projections should be avoided. We will ensure that ladders, scaffolds, equipment or materials never come within 10 feet of electrical power lines. All electrical tools must be properly grounded unless they are of the double insulated type. Worn or frayed electrical cords or cables shall not be used. Extension cords shall not be fastened with staples, hung from nails, or suspended by wire. The following tests shall be performed on all cord sets, receptacles which are not a part of the permanent wiring of the building or structure, and cord- and plug-connected equipment required to be grounded: All equipment grounding conductors shall be tested for continuity and shall be electrically continuous. Each receptacle and attachment cap or plug shall be tested for correct attachment of the equipment grounding conductor. The equipment grounding conductor shall be connected to its proper terminal. All required tests shall be performed before first use; Before equipment is returned to service following any repairs; Before equipment is used after any incident which can be reasonably suspected to have caused damage (for example, when a cord set is run over); and At intervals not to exceed 3 months.

No worker shall be permitted to work in such proximity to any part of an electric power circuit that the worker could contact the electric power circuit in the course of work, unless the worker is protected against electric shock by de-energizing the circuit and grounding it or by guarding it effectively by insulation or other means. In work areas where the exact location of electric power lines is unknown, workers shall be provided with insulated protective gloves. Before work is begun it shall ascertained whether any part of an energized electric power circuit, exposed or concealed, is so located that the performance of the work may bring any person, tool, or machine into physical or electrical contact with the electric power circuit. Proper warning signs will be posted and maintained where such a circuit exists.

Barriers or other means of guarding shall be provided to ensure that workspace for electrical equipment will not be used as a passageway during periods when energized parts of electrical equipment are exposed. Working spaces, walkways, and similar locations shall be kept clear of cords so as not to create a hazard to workers. No changes in circuit protection shall be made to increase the load in excess of the load rating of the circuit wiring. When fuses are installed or removed with one or both terminals energized, special tools insulated for the voltage shall be used.

**Safety-related to Maintenance**
Work on new and existing energized (hot) electrical circuits is prohibited until all power is shut off and grounds are attached, and until an effective Lockout/Tagout system is in place. Means shall be provided to disconnect all conductors in the house from the service-entrance conductors (mini-grid and PV system). The disconnecting means shall plainly indicate whether it is in the open or closed position and shall be installed at a readily accessible location nearest the point of entrance of the service-entrance conductors. Each service disconnecting means shall simultaneously disconnect all ungrounded conductors. Conductors and equipment will be protected from overcurrent in accordance with their ability to safely conduct current. Conductors shall have sufficient capacity to carry the load.

Except for devices provided for current-limiting on the supply side of the service disconnecting means, all fuses which are accessible to other than qualified persons and all fuses and thermal cutouts on circuits over 150 volts to ground shall be provided with disconnecting means. This disconnecting means shall be installed so that the fuse or thermal cutout can be disconnected from its supply without disrupting service to equipment and circuits unrelated to those protected by the overcurrent device. Overcurrent devices shall be readily accessible. Overcurrent devices shall not be located where they could create an employee safety hazard by being exposed to physical damage or located in the vicinity of easily ignitable material. Fuses and circuit breakers shall be so located or shielded that workers will not be burned or otherwise injured by their operation. Circuit breakers shall clearly indicate whether they are in the open (off) or closed (on) position. Where circuit breaker handles on switchboards are operated vertically rather than horizontally or rotationally, the up position of the handle shall be the closed (on) position.

**Lock out and tag out of circuits.**

Lock out / Tag out (LOTO) procedures will be used to safeguard workers from the unexpected energization or startup of machinery and equipment, or the release of hazardous energy during service or maintenance activities. LOTO procedures will be according to the OSHA Safety and Health Regulations for Construction. Controls that are to be deactivated during the course of work on energized or de-energized equipment or circuits shall be tagged and locked. Equipment or circuits that are de-energized shall be rendered inoperative and shall have tags and locks attached at all points where such equipment or circuits can be energized. Tags shall be placed to identify plainly the equipment or circuits being worked on. Each worker working under a LOTO shall have a personal lock on the system, in order to prevent mistakes an enable each worker to have control over her or his safety. As an additional means of control, one person shall be appointed to approve and log the beginning and end of each LOTO activity, and this person will have a personal lock to release each LOTO.

**Verification of status of de-energized circuits**

The status of all locked and tagged de-energized circuits and equipment shall first be verified before any work can proceed on the circuit or equipment. All persons performing zero-energy tests will be wearing proper safety attire, including proper dielectric gloves, long pants, a shirt with long sleeves, and a facemask, in order to prevent injury upon sudden and unexpected release of energy.
Diagnostic test on energized equipment: All persons performing diagnostic work on equipment, which for diagnostic reasons can’t be de-energized, shall be wearing proper safety attire, including proper dielectric gloves, long pants, a shirt with long sleeves, and a facemask, in order to prevent injury upon sudden and unexpected release of energy.

14 HAND AND POWER TOOL SAFETY

The necessary safety precautions, guarding, and training required for the type of hand and power tools that will be used at the event will be stated in the Activity Hazard Analysis.

A plug and play principle will be followed for the assembly of all house components, therefore the emphasis lies on the assembly of components and not on the construction of the building elements. Most of the tools used on site are simple battery powered tools. Any other power tools that may be required, for example such as the use of a miter saw to repair or replace damaged parts, will comply with U.S. safety standards.

The following safety precautions will be followed when operating a miter saw or similar equipment:

1. Safety goggles or safety glasses will be worn when operating the miter saw and hearing protection will be worn with extended use of a miter saw.
2. Anything that could become trapped into the path of the saw will be avoided, such as loose clothing, jewelry, neck ties, gloves, or any dangling object. Long hair will be tied back or a hairnet will be worn.
3. The miter saw and area around the miter saw should will always be clean and free from debris. Material will be inspected before cutting to assure that it is free from nails and any other foreign objects before cutting.
4. The miter saw blade should be of the proper type for the machine and type of material to be cut, and should be sharp and undamaged.
5. A secure footing is to be maintained and it should not be attempted to reach around the miter saw while it is on.
6. The miter saw will be equipped with an upper hood that covers the top half of the blade along with a lower blade guard, the saw is not to be operated without its guards. The saw will checked regularly to determine if it is securely fastened and aligned.
7. Material will not be cut freehand and will always be cut when secure against the fence of the miter saw. If the piece is unstable, it will be kept in place by using a clamp. The miter saw should be on a smooth and stable surface before operation.
8. The miter saw will remain unplugged and in the off position when not in use. Following this guideline will protect you from any accidents that could occur when turning on your miter saw. Never leave a power tool on while unattended. It is also advisable to wait until your miter saw is completely warmed up and come up to speed before starting a project.
Everyone allowed to work with power tools will have received the safety instructions stated above.

**15 CHEMICAL SAFETY**

To comply with 29 CFR 1910.1200 Hazard Communication, we will develop and maintain a written hazard communication program for the workplace, including lists of hazardous chemicals present; this communication program will be discussed at our toolbox sessions prior to any shift. We will provide labeling of containers of chemicals in the workplace, as well as of containers of chemicals being shipped to other workplaces; preparation and distribution of material safety data sheets to the construction team; and development and implementation of training programs regarding hazards of chemicals and protective measures if required. These last items will be transmitted to the construction team through this Health and Safety plan.

All chemicals stored on site shall be in secondary containment located out of direct sunlight where they will not be damaged during general construction activities. This will be located in the Hand and Power Tool container in a separate cabinet. This cabinet will not be removed from the container and is only accessible through our access point. Using chemicals will only be allowed if the construction plan foresees it or after discussing it with a Safety Coordinator and a Construction Site Coordinator.

All fuels for the generator shall be stored in NFPA-compliant metal flammable cans with sealing spring loaded lids. Fuels storage shall meet the storage requirements listed above. The generator shall be in secondary containment. This secondary containment will also protect the generator from the rain.

Appropriate spill cleanup materials for hazardous materials will be provided on site and it will be ensured that these materials are available. Solar Decathlon organizers will be notified of any spills that occur on the National Mall, whether they are hazardous or not.

Because of the plug and play principle, there is no potential of generating hazardous waste on site. Use of chemicals will be limited to ‘retouch’ paint, glue, and domestic cleaning products.

**16 HEARING CONSERVATION**

The only equipment that has the potential of generating continuous noise levels of 85 dBA or greater is the generator that will be used to power tools and charge batteries during the assembly of the house. The generator will comply or exceed the national park service allowable noise requirements. Other noise generating activities, such as grinding, will be avoided and take place in Belgium, with the aim to limit on site activities to assembly task using small battery powered equipment. The use of a miter saw will be limited to repair and replacement activities, in order to
reduce noise. Ear protection gear will be mandatory for the operator of such equipment.

17 HOT WORK ACTIVITIES

We will not be performing any spark- or flame-producing activities such as grinding, soldering, or welding onsite.

18 HOUSEKEEPING

Waste of one working shift will be gathered in one place. After every shift waste will be removed and recycled. The safety coordinator will survey all work on the construction site and will instruct on removing waste if necessary, for example when the waste becomes a tripping hazard. Standard, waste will be removed after a job is finished. The safety coordinator can instruct intermediate on removing waste if necessary.

19 MATERIAL HANDLING

Handling of materials will be described in the construction manual and in the Activity Hazard Analysis. Every task performed on site will be described and will identify potential hazards and will state what precautionary action and control has to be taken.

If large, heavy or overhead components of the house are manipulated, a safety zone will be set out on site where no one except the construction crew manipulating the component are allowed. All items being lifted by mechanical aid will need to fit in or on the lifting device and the combined weight of workers and items shall not exceed the rated capacity of the equipment.

20 MOTOR VEHICLE OPERATIONS

Multiple trucks will transport building components onto our site, we are estimating about 8 truck loads. At the time of arrival, throughout the duration of the truck’s presence onsite, and especially while maneuvering of materials, there will be team members with adapted high visibility clothing. They will be directing the movement of the deliveries and signaling to keep pedestrians a safe distance away from the truck. See AHA plan for further detail.
21 OTHER SAFETY CONSIDERATIONS

The construction team will plan on working during day time only, working in 2 shifts of 8 hours each day. A 10 minute break will be implemented every 2 hours. Every shift will have 1 lunch break of 45 minutes. Members of the construction team that have to lift heavy loads regularly will be encouraged to rest every hour.

We will be installing exterior lights at the site at night should conditions beyond our control, such as bad weather, require us to work during night time, in order to finish the project in a timely manner. Adequate site lighting will be installed in order to safely perform work at night (type to be decided). A construction lighting plan will be developed in order to assure adequate lighting at all times. Supplemental task lighting such as headlamps and flashlights will be made available and used when necessary.

22 TRAINING

30-hr construction safety training is required for the project manager, construction manager, and safety officer. A copy of the training certificates for individuals holding those positions is provided in the appendix.
## APPENDIX 01 LIST OF LOCAL CLINICS AND HOSPITALS

<table>
<thead>
<tr>
<th>Hospital Name</th>
<th>Address</th>
<th>Phone Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hospital cheikh Zaid OCP</td>
<td>Ben Guerir</td>
<td>+212 5243-21700</td>
</tr>
<tr>
<td>Medical center OCP</td>
<td>Ben Guerir</td>
<td>+212 5243-21700</td>
</tr>
<tr>
<td>Hopital provincial Rhamna</td>
<td>Hay El Farah, Ben Guerir, Maroc</td>
<td></td>
</tr>
<tr>
<td>Hospital Ibn Nafis</td>
<td>Boulevard Al Moustachfayate</td>
<td>+212 5242-90453</td>
</tr>
<tr>
<td></td>
<td>Marrakech</td>
<td></td>
</tr>
<tr>
<td>University Hospital Center</td>
<td>Avenue Ibn Sina Amerchich,</td>
<td>+212 524 300 629</td>
</tr>
<tr>
<td>Mohammed VI</td>
<td>Marrakech</td>
<td></td>
</tr>
<tr>
<td>Clinic Le Grand Atlas</td>
<td>Ménara, Marrakech</td>
<td>+212 5243-93900</td>
</tr>
<tr>
<td>Ambulance - Firefighter</td>
<td>_</td>
<td>15</td>
</tr>
</tbody>
</table>
APPENDIX 02 INCIDENT FORM

Form to be completed in the event of an incident: OSHA Form 301 Injury/Illness Incident Report
OSHA's Form 300
Injury and Illness Incident Report

This Injury and Illness Incident Report is one of the forms you must fill out when a recordable work-related injury or illness has occurred. Together with the Log of Work-Related Injuries and Illnesses and the accompanying summary, these forms help the employer and OSHA develop a picture of the extent and severity of work-related incidents.

Within 7 calendar days after you receive information that a recordable work-related injury or illness has occurred, you must fill out this form or an equivalent. Some state workers' compensation, insurance, or other reports may be acceptable substitutes. To be considered an equivalent form, any substitute must contain all the information asked for on this form.

According to Public Law 91-596 and 29 CFR 1904, OSHA's recordkeeping rule, you must keep this form on file for 5 years following the year to which it pertains.

If you need additional copies of this form, you may photocopy and use as many as you need.

Information about the employee

1. Full name ____________________________
2. Name ____________________________
3. City ____________________________
4. Date of birth ____________________________
5. Race ________
6. Sex ________
7. Date hired ____________________________
8. Work Title ____________________________

Information about the case

9. Case number from the log ____________________________
10. Time of injury or illness ____________________________
11. Date of injury or illness ____________________________
12. Time of exposure ____________________________
13. Date of exposure ____________________________
14. Was the employee doing job before the incident occurred? Yes ________ No ________
15. Was the activity, as well as the tools, equipment, or material the employee was using, as specific as: "climbing a ladder while carrying roofing materials?" "spraying paint from hand-sprayer?" "daily computer key-entry?"

Information about the physician or other health care professional

16. Name of physician or other health care professional ____________________________
17. Place of treatment ____________________________
18. Date of injury or illness ____________________________
19. Was employee treated in an emergency room? Yes ________ No ________
20. Was employee hospitalized overnight or in-patient? Yes ________ No ________
21. If the employee died, what was the cause of death? ____________________________

Public reporting burden for this collection of information is estimated to average 2 minutes per response, including time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Persons are not required to respond to this collection of information unless it displays a currently valid OMB control number. If you have comments that you wish to share, we encourage you to write to us at OSHA General Veterinary, c/o U.S. Department of Labor, Washington, D.C. 20210. Do not send the completed forms to this office.
APPENDIX 03 OSHA CERTIFICATES

OSHA 30-Hour construction safety certificates
*to be added upon completion of course