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EDSGN 100, Section 21
Professor McTernan
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Digital Template for a Universal Joint Cover
Team Viceroy

Alex, Tom, Nick, and Steve

Our final prototype

Mission Statement

Our objective is to increase the durability and lifetime of the HESE greenhouses. By implementing a protective cover over the corners of the structure, where ripping is most common, we will prevent the greenhouse material from wearing out. We aim to make our cover easily manufacturable, cheap (under $2), and simple to install. We have designed a digital template, which can be easily printed and quickly implemented in the construction of the greenhouses. The consumer can use our template to cut a covering out of any suitable material such as: poly tarps, old rice or cement bags, towels, rubber, old clothes etc. This covering will help to prolong the life of their greenhouse, enabling them to continue growing food.

Humanitarian Engineering and Social Entrepreneurship

HESE is a group at Penn State that strives to improve the lives of people throughout the world using entrepreneurship and engineering. By creating self-sustaining businesses that improve the community they are established in, HESE is able to implement long lasting solutions to combat issues in communities throughout the world. At Penn State, HESE is open to all graduate and undergraduate students, and welcomes all majors and colleges. The group is comprised of both students and faculty focused on challenges that face developing countries and communities. They design and construct practical products that provide solutions to these issues.

Several parameters restrict the domain of HESE's problem-solving design. A product must be designed that takes into account the local culture, poverty and limited resources of developing markets. HESE also strives to create products that are environmentally friendly and sustainable.

We are involved in HESE's greenhouse project. HESE has created a greenhouse business to provide cheap greenhouses to people in Mozambique that enable them to grow more crops throughout the year. We have designed a template that can be used to create a protective cover for the corners of the greenhouse frame, prolonging the life of the greenhouse.

Location Research

Like many African countries, Mozambique goes between two distinct seasons, the rainy season and the dry season. The rainy season is when the country gets most of its rain, this occurs between December and March. Around April and May the rains subside and the dry season begins. The dry season is typically from June to October and during the time very little rain falls [1]. Because of its varying climate, crops cannot be grown year round. This leaves many with food shortages. However, with HESE's greenhouses, people can extend the growing season, providing them with more food and improved quality of life. Approximately 64% of the population does not have a secure food source, this is a big problem for the country, especially in the south [4]. A durable and cheap greenhouse would have a large impact on these people, giving them secure food.

Mozambique does not have the most developed electricity grid. Only about 10% of people in the country have access to electricity, in rural areas it is less than 2%. This leaves many in energy poverty [2]. The lack of energy had to be taken into consideration during our design, the use of power tools etc. could be problematic for builders.

A European greenhouse manufacturing company called Richel supplies many African countries with greenhouses, including Mozambique. Greener Solutions is the supplier of Richel

greenhouses, and deliver the packaged greenhouse ready for construction. Like our own project, they will provide a construction crew if necessary. One drawback, though, is that most Richel greenhouses require a source of electricity [3]. By reducing our design's need for electricity we can create a better more accessible product for those without access to electricity.

Potential Solutions

After brainstorming, we knew we wanted to create a product that was cheap, durable, and easy to make. We thought about local and easy to find material. We realized old tires could potentially be used, wood was easy to find as well, and that tarps were a pretty common material too. At this point we had three solid ideas that we needed to rank to decide which prototype to build. The Tire Cover, the Wooden Shell, and the Tarp Cover. The basic design for the Tire Cover and the Wooden Shell was a corner piece that could be placed over top of the sharp greenhouse corner, protecting the glazing. The Tarp Cover was a piece of material that would be tied around the joints, covering the sharp corners and edges and protecting the glazing. Upon evaluating each design (as seen in table 1), we realized the Tire Cover and Wooden Shell ideas would be too difficult to make, more expensive, and take workers a lot of time. This left us with the Tarp Cover idea, which proved to be the best solution. We would now prototype this design.

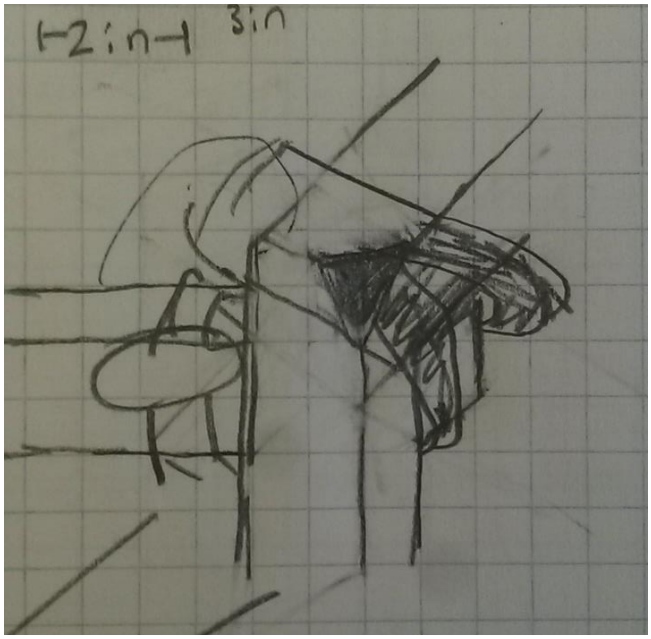
Selection Matrices

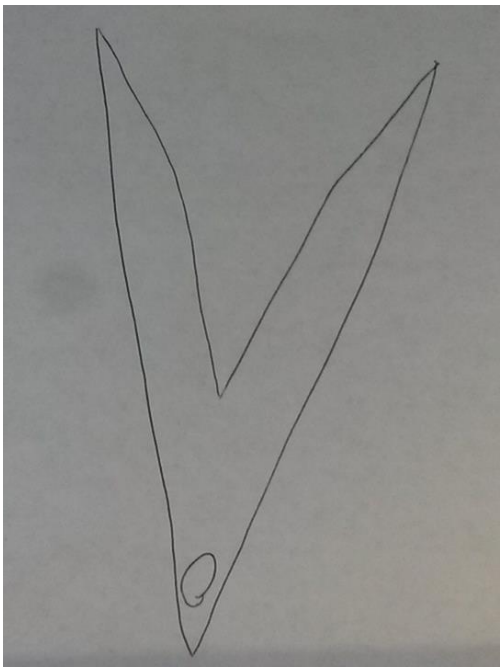
Selection Criteria	**A(reference)**	**B Tire**	**C Wooden Shell**	**D Tarp**
Ease of construction	0	0	-	+
Cost	0	+	-	+
Time	0	0	-	+
Durability	0	+	+	0
Net Score	0	2	-2	3
Rank	3	2	4	1
Continue?	no	no	no	yes

Table 1. We used this table to analyze which of our 3 ideas would be the overall best solution, the Tarp Cover idea proved to be best. We then prototyped this design concept.

Prototyping

After selecting the Tarp Cover idea over the Tire Cover and Wooden Shell ideas for our first prototype, we began sketching out ideas for what our covering should look like and how it would attach to the greenhouse frame (picture 1). Our first idea was a large plus sign, but this would use material inefficiently, we then came up with an "A" shaped design that had a hole in the top corner (picture 2).





Pic 1. Original sketch of first prototype tied to greenhouse frame ***Pic 2. Design for cover unattached to frame***

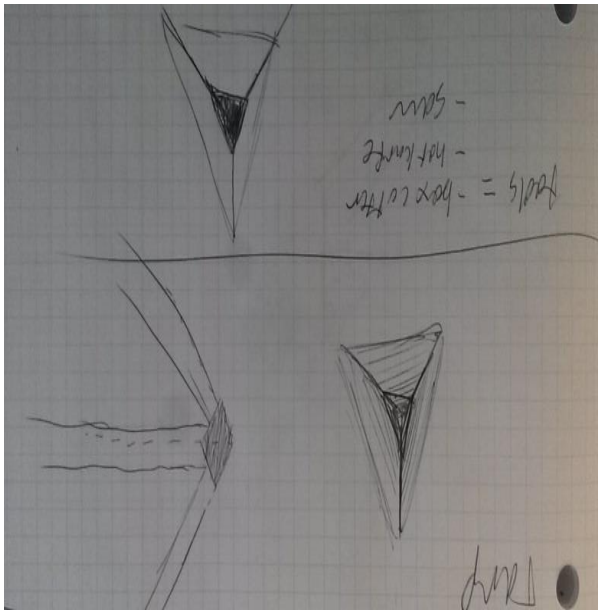
We cut this out of a standard blue poly tarp and affixed it too the model joints we made to represent the greenhouse frame. Before we began testing our criteria, we realized it would not be a good design, as it was awkward to attach, did not cover much area, and was hard to cut out. We scrapped this idea and came up with a better design.

Our new design was a simple rectangle, it used materials efficiently, was simple to cut out, and would hopefully cover more area on the corner joint (picture 3).

Pic 3. Our second prototype design cut out of blue poly tarp.

Each of the four legs for our new design would wrap around the frame, while the center square would cover the corner and protect the glazing.

At this point we also wanted to make a small alteration in HESE's design of the greenhouse frame (picture 4). We decided to cut and file down the sharp corner of the frame that was causing the tears in the glazing, creating a smoother surface for our cover to sit on and reducing the chance of a tear forming (picture 5).



Pic 4. Initial sketches for smoothing the surface of the joint

Pic 5. Sharp corner cut down on our frame model

We then tested our second prototype based on the following criteria (table 2): Abrasion resistance (tested by rubbing another piece of tarp (to simulate glazing) against our cover while it was attached to the frame)(pic 6). Cost (less than $2). Ease of manufacturing (under 5 minutes, no advanced tools) (pic 7,7.1).

Table 2. Showing our testing process for our second prototype.

Requirement	Test	What is a Pass	Did it pass?
Abrasion resistance	Rub 'glazing' on our test cover that is attached to frame.	Survive 100 passes	Yes, after 300, it still had not ripped.
Cost	Calculate cost	Less than $2	Based on price of tarp it cost about 9 cents
Ease of manufacturing	How long did it take to make?	Less than 5 minutes	It took a little less than 5 minutes.

Pic 6. Nick testing abrasion resistance

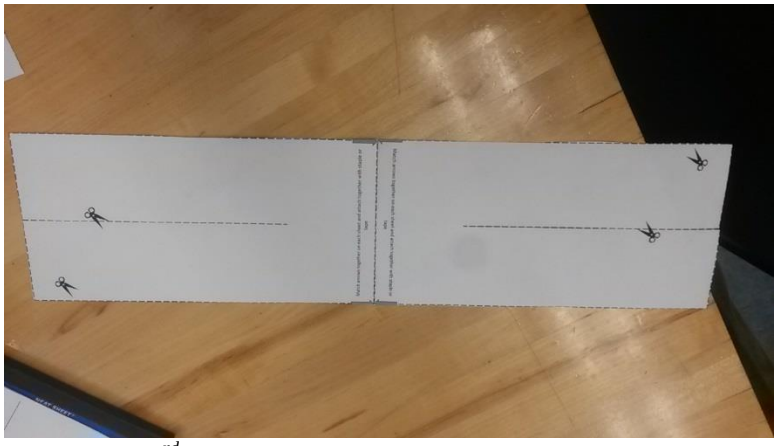
Pic 7. Testing how long it takes to assemble

Pic 8. Testing our substitute glazing on an unprotected corner

Pic 7.1 Further testing ease of assembly (how easy to attach)

Our testing was successful, it showed us that our design worked well, the rounded joint and cover stopped the 'glazing' from being torn on the corner, it was cheap, and relatively easy to make.
We did a control test on an unrounded corner without a cover, and the 'glazing' ripped after only 45 passes (pic 8), with our design, we reached 300 passes and the glazing was still okay.

After the success of our 2nd prototype, we wanted to figure out how to improve it. We came up with the idea of creating a stencil or template that builders could use to create our product out of any material, not just the blue poly tarp we used (template seen in pic 9). Old rice and cement bags are abundant and decently strong, these along with canvas, old irreparable clothing, or any other kind of strong material could be used to make a cover. Based on our second prototype, we created a digital template that could be printed out and traced onto available material, then cut out and used to cover the greenhouse's corner joints. Along with the stencil, we created an instruction guide with pictures to explain how make and attach the cover.



Pic 9. Our 3rd prototype, a stencil used for making joint covers.

Lessons Learned

If our team had had the chance to make another prototype of our final design, we probably would have tried to refine our instructions and figure out how to make the template even easier to use. Better, clearer pictures and more direct instructions for how to assemble and apply the corner cover would make our product over all better and easier to use. We would try to make it understandable for absolutely anyone to use. A good way to test our end design would be to give the instruction manual to people who are unfamiliar with HESE and our project, and see if they could make our cover and understand what it is for. We could then use their feedback to improve our design and instructions.

Our team worked well together. Everyone gave suggestions and came up with ideas. We were good at taking each other's ideas and expanding upon them as well as bouncing different concepts off each other to come up with improved ideas and designs. Fabrication went smoothly and we did not experience many issues when constructing our prototypes.

We did not do a great job of staying organized and keeping track of deadlines. It would have been better if we designated specific tasks for people. We missed the HESE showcase due to just a lack of communication. We could have improved by making a better effort to stay organized and on top of everything.

The HESE project overall was pretty well orchestrated. One improvement could have been a better line of communication between us and HESE. This would have helped with questions we had as well as getting more feedback from HESE on our designs. Overall the project was well organized.

References:

[1] "Mozambique Weather and Climate", Expert Africa, http://www.expertafrica.com/mozambique/info/mozambique-weather-and-climate, last accessed 2/15

[2] Carolina Dominguez-Torres and Cecilia Briceño-Garmendia, "Mozambique's Infrastructure: A Continental Perspective", http://siteresources.worldbank.org/MOZAMBIQUEEXTN/Resources/AICD-Mozambique_Country_Report.pdf, last accessed 2/15

[3] "Greenhouses South Africa", Greener Solutions, http://www.greenersolutions.co.za/greenhouses-tunnels.htm, last accessed 2/15

[4] "SPECIAL REPORT FAO/WFP CROP AND FOOD SECURITY ASSESSMENT MISSION TO MOZAMBIQUE", http://www.fao.org/docrep/012/ak350e/ak350e00.htm, last accessed 2/15