TEAM FTK PRESENTS

THE ITERATIVE GREENHOUSE FOUNDATION GRID

{ Group #8 }

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Mission statement
Our team will construct a cost-effective, yet efficient, greenhouse grid apparatus that can be easily built and operated by persons with limited technical knowledge. Our device is to be constructed of a 2x2 meter tarp, 4 wooden gussets (aka corner pieces to act as ground anchor), and 2 thin pieces of wire. This device will allow greenhouse construction crews in Kenya to efficiently and accurately mark out precise points for which the 6x6 meter greenhouse support poles will be erected. By primarily cornering the greenhouse construction market in technically disabled countries, we hope to provide a low-cost product to third-world regions while simultaneously generating a sustainable level of profit. Our primary market is targeted towards greenhouse construction crews in Kenya, though our product can also serve as a beneficial tool for other low income / non-profit greenhouse contractors. In order for our device to function properly, we were required to assume two separate project variables: the device will be laid on flat ground and the marking posts will be less than .75 inches in diameter. The most relevant stakeholders for our project are the greenhouse owner, construction crew, manufacturer, distributer, and sales force.

**Concept development summary 1**

In order to develop the design for our first prototype, our team first brainstormed individually, and then shared our solution ideas with the rest of the group. We were able to combine some of the concepts that we liked, and use each others ideas for sound inspiration. We then performed environmental background research on some of the regions that our product would be used in. Most of our research was limited to Kenya, where we found that the developing infrastructure is not spread throughout the country. This research allowed for further refinement based on the cultural, economic and physical constraints. After the initial ideas were narrowed down to three options, a selection matrix was used in which the different design requirements were weighted, and each of our ideas were judged on a scale of one to five for their effective completion of each of the design requirements.

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Cost (2)</th>
<th>Weight (1)</th>
<th>Portability (3)</th>
<th>Speed (6)</th>
<th>Durability (5)</th>
<th>Accuracy (4)</th>
<th>Total (Weight)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solid square frame</td>
<td>3 (6)</td>
<td>3 (3)</td>
<td>3 (9)</td>
<td>3 (18)</td>
<td>4 (20)</td>
<td>4 (16)</td>
<td>20 (72)</td>
</tr>
<tr>
<td>String grid</td>
<td>4 (8)</td>
<td>5 (5)</td>
<td>4 (12)</td>
<td>2 (12)</td>
<td>2 (10)</td>
<td>2 (8)</td>
<td>19 (55)</td>
</tr>
<tr>
<td>Tarp</td>
<td>2.5 (5)</td>
<td>3 (3)</td>
<td>2 (6)</td>
<td>5 (30)</td>
<td>3 (15)</td>
<td>5 (20)</td>
<td>20.5 (79)</td>
</tr>
</tbody>
</table>

As is demonstrated from the selection matrix above, each design was judged on a scale of one to five against the design requirements: cost, weight, portability, assembly speed, durability, and accuracy. Each of the requirements were then ranked for importance on a scale of one to six, and each of the raw scores were multiplied by this number to yield the weighted total. After using the design matrix, our team chose to combine the ideas for the iterative square and the tarp.
DEM Project: Greenhouse Grid Layout  
Test Date: 9/02/15  
Test Time: 12:20 pm - 2:10 pm  
Test Location: 312 Hammond

<table>
<thead>
<tr>
<th>TEST TYPE</th>
<th>TEST RESULT ANALYZATION</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Cost</strong></td>
<td>We researched the online cost of all the materials used for our current prototype and the summation of all the costs reached $14.65. This is greatly under $50, which was the limit set by the HESE students.</td>
</tr>
<tr>
<td><strong>Weight</strong></td>
<td>When measured on a scale, our product prototype weighed 0.2 kg. This being said, it is essential to take into account the fact that our current device is only a ½ scale model. After accounting for the scaled weight into our design, we calculated that the final device will weigh no more than approximately 1 kg. This is well within the limits set by our test plan, so the design passed our weight test.</td>
</tr>
<tr>
<td><strong>Portability</strong></td>
<td>Because the majority of the design consists of tarp, the prototype can be easily folded up to make transport simple. It can easily fold within 3x3 feet area and passed the portability test with ease.</td>
</tr>
<tr>
<td><strong>Assembly Speed</strong></td>
<td>We assembled the grid in 7 minutes and 47 seconds which is well within the 10 minute time limit assigned by the HESE students. In order to calculate this number we measured out a 3x3 grid in 2 minutes and 24 seconds. We then multiplied this number by 2 to approximate the time it would take to lay out the grid on a full size scale.</td>
</tr>
<tr>
<td><strong>Durability</strong></td>
<td>While the material for the prototype is somewhat durable, it would still be prone to tearing. As such, when designing the final product a more reliable material will be used for the tarp.</td>
</tr>
<tr>
<td><strong>Accuracy</strong></td>
<td>Because of a construction oversight, our prototype does not make a perfect 1x1 m square. The centers of the gussets are designed to be 1 meter apart on our prototype, however the corners of our tarp were measured and cut to a 1 m length before the gussets were added. In addition, our corner holes were designed ¾ inch in diameter. Although this allows for more variance in the type of marking stick the constructor can use, it also also introduces a likely element of human error.</td>
</tr>
</tbody>
</table>

Prototype #1 Testing Photos
1 Accuracy
2 Weight
3 Heat Resistance
4 Tensile Strength
5 Speed of assembly
1: In picture 1, we measure our tarp for accuracy, it failed this test due to design error.
2: We weighed our prototype on a scale to determine if it will be easily transportable.
3: We tested our tarp against heat to see if the material, and adhesives would hold.
4: We tested the strength of our prototype under strain to see if use would damage it.
5: We laid out the grid while timing ourselves to measure our device’s speed.

Concept refinement summary:

After prototype 1, we realized that we had not left enough room for the wood placement devices located on the corners and as such we decided to leave an extra 2 inches on each side of the tarp so that we are able to place the holes in the wood 2 m away from each other exactly. We used the first prototype to test the strength of the wood from the second prototype because during production the wood cracked when drilling into it. The test was a success as the wood stood up to the test. Prototype 1 was also half the scale of the actual product so for the second prototype we scaled up all dimensions of the tarp by 2 so as to bring it to actual size. Also in prototype 1 the holes had an error of more than 0.5 inches and as such in prototype 2 we corrected this by making sure the holes perfectly lined up using a ruler. We also achieved production of prototype 2 without changing any of the designed features.

DEM Project: Greenhouse Grid Layout
Test Date: 23/02/15
Test Time: 12:20 pm - 2:10 pm
Test Location: 312 Hammond

<table>
<thead>
<tr>
<th>PROTOTYPE #2 TESTING REPORT</th>
</tr>
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<tbody>
<tr>
<td>Test Type</td>
</tr>
<tr>
<td>-----------</td>
</tr>
<tr>
<td>Cost</td>
</tr>
<tr>
<td>Weight</td>
</tr>
<tr>
<td>Portability</td>
</tr>
</tbody>
</table>


In Photo 1, Caleb is measuring the gusset to gusset distance generated by our device. This is the key component to our accuracy test.

In Photo 2, we are measuring the weight of our device. The full scale model weighed in at 0.6 Kg.

In Photo 3, we built the half model of the grid in 3 minutes and 12 seconds as can be seen.

In Photo 4, our group conducted the tensile pressure test section of our durability test. The test consisted of lifting 7.5 lbs of sand with the diagonal section of our device. We switched out the old wood from the first prototype with the new wood from the second prototype so as to see if the wood would endure. As can be seen, the wood passed the test as it did not break.

Observations:

While conducting all the tests and ensuring that the prototype would meet our criteria we learned that whilst the tarp was of very good material and was very durable and would certainly stand up to the harsh hot conditions of Kenya, the wood used to mark the holes would not. The wood was very soft and splintered very easily and as such we recommend that if this design goes into production it should only go into production if the wood used is of stronger standards.

Re-Design Ideas:
To improve tests for prototype 2, we could have conducted a more extensive durability test for the tarp. We could have also designed tests for the wood that was used for the prototype.

We could have conducted a heat test for the prototype 2 so that we could ensure that it would be able to withstand the Kenyan heat. Also instead of just conducting a half grid test and then multiplying the time by 2 we could have built the full grid and seen how much time would have been taken however because of time constraints we were not able to run such tests.

Cost analysis:

- **2x2 meter tarpaulin (1m thick border)**
  
  [ Total area ] (2 meters) x (2 meters) = (4 square meters)
  - [ Area of center cutout ] (1 meter) x (1 meter) = (1 square meter)
  
  \[
  \text{requires 3 square meters of tarp} \quad \text{COST:} \quad \$9.00
  \]
  
  [Link to purchase](http://www.aliexpress.com/item/waterproof-tarpaulin-of-truck-high-strength-trampoline-cloth/2021906145.html)

- **Roll of Duck Brand 1265013 Duct Tape**
  
  ( 2.82 meters ) x (4) = 11.28 total meters of duct tape
  
  \[
  \text{COST:} \quad \$3.39
  \]
  
  [Link to purchase](http://www.amazon.com/Duck-Brand-1265013-1-88-Inch-Single/dp/B002TOL40A/ref=sr_1_1?ie=UTF8&qid=1425515369&sr=8-1&keywords=duct+tape+by+duck)

- **Wooden Gussets**
  
  Standard 2x4 ( 96” long => $2.96 per board => 504 square inches )
  
  $2.96 / 504 square inches = approx $0.006 per square inch
  
  4 corner gussets (1.5”x2”x2”) => 24 square inches of material
  
  \[
  ( 24 \text{ square inches x } \$0.006) = \$0.20
  \]
  
  [Link to purchase](http://www.homedepot.com/p/Unbranded-2-in-x-4-in-x-96-in-Premium-Kiln-Dried-Whitewood-Stud-161640/205533770?N=5yc1vZ1z0ywxv)

  TOTAL APPROXIMATE COST OF MANUFACTURING: $ 12.59

User Guides:

In order to accomplish the initial goal of a design that was simple and easy to use, this product implemented a modular design. In order to create an entire grid, the tarp is initially laid out where a corner of the greenhouse will eventually be. Making sure the tarp is taut, a piece of rebar is then pushed through the hole of the gusset at each corner and into the ground. After all
four pieces of rebar have been set into place the tarp is then lifted off of the rebar and two of the holes are put back on two pieces of rebar as if continuing up the length of the future greenhouse. Two more pieces of rebar are set in place and the process is repeated until the laborer has laid out both sides as well as the front and back of the greenhouse.

This representation shows how the tarp is initially set at one corner where the rebar is then pushed through the holes in the corner of the tarp until they are firmly in the ground.

After the rebar is in place the tarp is repositioned so that two of the pieces of rebar are in the corners of the tarp with two empty holes ready to have rebar placed in them.

Following this pattern would lead to a completed greenhouse grid in as few steps as possible.
Re-design ideas / thoughts:
During our design showcase one of the main features that was addressed by the HESE students was to minimize the area in the middle of the tarp that was cut out. By changing this it would make the design easier to store and less confusing to work with. Another design feature that the HESE students brought up was the quality of the gussets set at each corner. In making a third prototype the wood chosen for the gussets would be of a greater quality in order to add to the durability of the product. A dream prototype would include these alterations, and the final tarp would be cut from a tarp with dimensions slightly larger than 2x2m to increase accuracy and minimize the chance of tearing or other damage to the final product.