DEM Project Final Report
Team VelBros (Team #5)

The Velcro Joint

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Mission Statement:

Our product uses Velcro to create a smooth and firm attachment between the greenhouse joints and the glazing. The product is designed not only to create a durable connection between the joints and the glazing, but also to prevent the glazing from tearing apart. It is intended to be an efficient yet cost-effective solution to the ongoing problem of the glazing tearing apart. We would like the product to be introduced before the end of the 2015 spring semester, with a 40% gross margin and a 25% share of African greenhouse market. Although our primary target is African farmers who rely on their greenhouses to sustain their crops, our secondary market are poor farmers in almost any country. Another potential market for our product is the casual, do-it-yourself farmers who would like a higher yield and year round crops that can be attributed by the controlled environment that a greenhouse allows. To have this idea come into fruition, we need to make sure that we have the required materials, i.e. velcro and nails and proper installation. Our stakeholders would include the user, retailer, sales force, HESE international, producer of glazing, and poor African communities (Research Ideas.)

Concept Development Summary: Prototype 1

Background Research:

Our group first started to develop our ideas for the joint solution when we did the background research project. We looked up the climate information in Tanzania to start getting acclimated to the requirements our prototype would need to meet. From here we knew that our prototype would need to stand up to high levels of wind, heat, and humidity (Tanzania- Weather and Climate.) Our first basic ideas were using rubber caps, some sort of putty casing to cover the joints, and then adding velcro to the joints. Using a selection matrix we decided that the best solution would be adding velcro, because it would be strong, cost efficient, and be durable even under the strenuous conditions. From here we developed the tests we would use to judge our prototype.

Tests relating to user needs

1. Strength- solution needs to hold the glazing to the joint strongly enough to limit wear and tear, and improve the overall durability of the green houses
2. Easy to Implement- design solution is simple for builders & African farmers to implement during construction
3. **Cost efficient**- The joint solution must be cost effective in order to keep the overall cost of the greenhouse down; the cost limit has been set at below $2 per joint
4. **Works under 100 degrees Fahrenheit condition**- the joint solution must be able to withstand and still function under high temperatures to withstand the climate in African countries
5. **Works under 90% humidity**- the joint solution must be able to withstand and still function under high humidity to withstand the high humidity in African countries
6. **Works under 15 mph winds**- the joint solution must be able to withstand and still function under high wind speeds in order to limit the movement and wear down of the glazing
7. **Long-lasting**- The solution needs to extend the life of the greenhouse without significant maintenance

### Table 1: Prototype 1 Testing Results

<table>
<thead>
<tr>
<th>Strength (Holding 3.7 lb. weight)</th>
<th>Works in 100°F Temperature (Using Hair Dryer at 160°F)</th>
<th>Works Under 90% Humidity (Splash Velcro with Water)</th>
<th>Withstands 15 mph Winds (Using Wind Fan)</th>
<th>Cost Efficient</th>
<th>Long-Lasting (Repeat Strength test at end)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prototype 1: Velcro nailed into joint is connected to Velcro that is attached to the glazing.</td>
<td>Pass. We attached glazing to Velcro on joint and then hung a 3.7 lb. weight off of the joint. The connection between joint and glazing still held up.</td>
<td>Pass. After heating the Velcro to 160 degrees, the Velcro was still able to pass the strength test.</td>
<td>Pass. When the Velcro was splashed with water, the joint-glazing connection was still able to pass the strength test.</td>
<td>Pass. 4x1 of Velcro costs 8 cents along with the four nails which are about 1.5 cents a nail. This total cost will be around 14 cents per joint which is under our budget of $2 per joint.</td>
<td>Pass. After undergoing the various tests, the joint-glazing connection still upheld when undergoing the strength test.</td>
</tr>
</tbody>
</table>
Figure 1: Original Strength Test
Glazing joint successfully held 3.5 lbs.

Figure 2: Humidity Test
After fully dowsing joint the Velcro still held.

Figure 3: Preparing for Heat Test
The velcro joint was heated to 180°F for the heat test.

Figure 4: Heat Test

Figure 5: Wind Test

Figure 6: Reapplied Wind Test
Observation Summary:

I. The six distinct tests that were performed were all meant to test the strength, longevity, and overall quality of the design under normal conditions prevalent in Tanzania. As shown in figure 1, the strength test was performed several times to see how the Velcro holds up. Additionally, the strength was performed after the humidity, heat, and wind test and the design held up after every test (Figures 2, 4, 5, 6). Additionally, the Velcro held up an astounding weight of 3.5 lbs. We learned that the heat and wind test actually made the Velcro stick better to the glazing because they reduced the amount of air bubbles between the Velcro and glazing. We conducted one final strength test after all the other tests were completed and found that the glazing-joint connection stayed firmly intact while holding the 3.5 lb. weight.

II. The most important information that the tests revealed was that we need to fix the design so that the Velcro does a better job of sticking to the wood. We also found that the placement of nails is essential in keeping the Velcro firmly attached to the wood. We found that with only 3 nails attaching the Velcro to the wood that the edges of the Velcro began to tear off during the various tests.

III. The most surprising part of the tests we performed was that the velcro held up with three nails attached to the wood and it did a good job of sticking to the glazing. However, we conclude that if we attached the Velcro to the wood with more nails, the Velcro would stick better to the wood. Surprisingly, we didn’t face any issues with the Velcro and glazing sticking to each other. The Velcro’s adhesive back was able to stay firmly attached to the glazing without any outside intervention such as nails, staples, etc.

Takeaways for Prototype #2

I. The biggest area where we could improve the tests would be to find a better way to create and manage the conditions for temperature and humidity and keep them consistent during the strength tests. For the temperature test, we were able to heat the joints up properly, but it was difficult to keep them at a constant temperature during the strength test. This...
was due to the fact that once the heat was no longer applied to the joints, they immediately began to cool down which possibly provided us with inaccurate data. This could be improved by maintaining heat from the hair dryer while completing the strength test. The humidity test can be improved by finding a better way to have the material wet for an extended period of time to simulate the effect that being under intense humidity for an enhanced period of time. This could be accomplished by splashing water over the Velcro multiple times until it is wet throughout to see how it would hold up in the worst case scenario.

II. There aren’t any tests that we would replace, they all worked well and gave pretty good information. With that being said, we have modified some of the tests such as the temperature and humidity tests to provide us with more credible and accurate information. After building our second prototype we decided to add a horizontal strength test in which we tested how well the Velcro was able to stop the movement of the glazing in a horizontal direction.

III. The biggest piece of information we weren’t able to get was how well the Velcro limited horizontal movement of the glazing against the wood. When we perform the tests with the next prototype we will have to also take this into account, probably under the durability or long lasting test.

IV. We also learned from the HESE students that one of the big problems was the rough surface of the wood that the glazing is connected to. It is important that the design almost fully eliminates the horizontal movement of the glazing against the rough wood joints.

**Concept Refinement Summary: Prototype 2**

**Changes for Prototype 2:**
With the information we gathered from the first prototype we knew that the velcro solution had a lot of potential. We also decided to use stronger velcro, and a different nail placement that spread the strain out more evenly. With these changes we wanted to see how well the joint would be able to handle both vertical and horizontal stress.

**Tests relating to user needs**

1. **Strength** - solution needs to hold the glazing to the joint strongly enough to limit wear and tear, and improve the overall durability of the green houses
2. Horizontal Strength Test- the solution prevents the side to side movement of the glazing when weight is attached to put horizontal stress on the joint.
3. Cost efficient- The joint solution must be very cost effective in order to keep the overall cost of the greenhouse down, the cost limit has been set at below $2 per joint
4. Works under 100 degrees Fahrenheit condition- the joint solution must be able to withstand and still function under high temperatures to be viable at improving the durability of the greenhouses
5. Works under 90% humidity- the joint solution must be able to withstand and still function under high humidity to be a viable option for improving the durability of the greenhouses
6. Works under 15 mph winds- the joint solution must be able to withstand and still function under high wind speeds in order to limit the movement and wear down of the glazing
7. Long-lasting- The solution needs to extend the life of the greenhouse without significant maintenance

<table>
<thead>
<tr>
<th>Table 2: Prototype 2 Testing Results</th>
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</table>
| **Prototype 2:** Industrial-strength Velcro nailed with six 1.5” nails into joint is connected to Velcro that is attached to the glazing. Three nails are evenly placed on each side of the joint.  
Pass. We attached glazing to Velcro on joint and then hung a 6.1 lb weight off of the joint. The connection between joint and glazing still held up.  |
| **Strength (Holding 6.1 lb weight)**  |

Pass. After heating the Velcro to 160 degrees, the Velcro was still able to pass the strength test.

Pass. When the Velcro was splashed with water, the joint-glazing connection was still able to pass the strength test.

Pass. When prototype was put above fan, the joint was still able to stay firmly attached to the glazing.

Pass. 4x2 inches of Velcro costs 16 cents along with the six nails which are about 2.5 cents a nail. This total cost will be around 31 cents per joint which is under our budget of $2 per joint.

Pass. The Velcro-glazing connection was upheld when the 6.1 lb weight was applied from the horizontal position

Pass. After undergoing the various tests, the joint-glazing connection still upheld when undergoing the strength test.

**Cost Efficient**

Pass. The Velcro-glazing connection was upheld when the 6.1 lb weight was applied from the horizontal position

**Horizontal Strength Test (Attaching weight from side)**

Pass. After undergoing the various tests, the joint-glazing connection still upheld when undergoing the strength test.

**Long-Lasting (Repeat Strength test at end)**

Pass. After undergoing the various tests, the joint-glazing connection still upheld when undergoing the strength test.

**Note:** Red text indicates changes from prototype 1.
**Figure 7:** Prototype 2

Joint built with industrial strength velcro.

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**Figure 8:** Prototype 2 Glazing and Joint

Note: The information in red indicates the differences in testing prototype 1 vs. prototype 2.

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**Figure 9:** Prototype 2 Strength Test

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**Figure 10:** Prototype 2 Horizontal Strength Test
Observation Summary:

1. Similar to the first prototype we performed several overlapping tests to test the renewed and improved prototype. The description and results of these tests can be seen in the tables and the pictures provided in the report. The different tests performed were used to determine if the prototype was a successful design that met our user needs. In addition, we changed and added couple of tests to improve our understanding and results of the second prototype. For instance, the table above and figure 9 reveal our modifications to the strength test. Unlike the last prototype this one can hold up to 6.1 lbs. which is almost double the weight from the first prototype. The picture clearly reveals that the second prototype passes the strength with flying colors. This test gives us concrete proof of the longevity and durability of the improved design. In addition to the strength test, we did the horizontal test, indicated in the table with red. The results of this test can be seen in figure 10; we performed this test to apply real environmental conditions that our design could face, for example strong wind shaking the greenhouse. During this test we pulled the glazing horizontal to see if the Velcro would still stay intact with strong force pulling it opposing direction. As indicated by picture 10, the joint-glazing connection is firmly upheld and passes the horizontal strength test with 6.1 lbs attached to the wood. This goes
to show how effective our design is if faced with these concerns. Several other tests were duplicated from the original prototype testing, indicated in the table, and prototype 2 passed all of these tests just as we predicted. After performing all of these tests, the design still holds up with minimal wear and tear which goes to show that the design passes the longevity/durability test. Overall, we improved our design from the first prototype as it can hold up more weight and sticks better to the glazing and the wood than the first prototype all the while costing us merely a quarter. This prototype used 3 more nails in carefully placed locations on the wood (figure 8). This allowed the prototype to create a more firm attachment with the wood, which is one of the problems we had with our first prototype.

II. All the tests that were performed, as described in the table, revealed to us that our hypothesis of increasing the strength and quality of the Velcro would improve the overall design and its effectiveness was true. With the new industrial-strength Velcro and six nails attached to the wood, the Velcro sticks and holds up better to the glazing than the original prototype. The tests reveal to us that our design can withstand the normal and harsh conditions of the African countries, while still preventing wear and tear on the product.

III. Some of the surprises we encountered were that super glue and regular glue to a terrible job of sticking the Velcro to the glazing. However, the adhesive part of the Velcro did an excellent job of sticking directly to the glazing even with 6.1 lbs attached to the prototype with no glue actually necessary. The fact that a 4 X 2 in. strip of Velcro attached with a handful nails can hold up 6.1 lbs is astounding and goes to show that if the right product is used with the right design it can work wonders.

Cost analysis:

For our joint protection design, we were able to meet the cost requirement of keeping our product less than $2 per joint. This was largely due to our choice of cheap, yet reliable materials. Our product consists of six 1.5” nails which would cost 2.5 cents per nail (Amazon.) And the 4 x 2 inch strip of industrial-strength Velcro would cost 1 cent per inch squared (Joann.) Altogether, our final prototype estimated to about 25 cents per joint which is well under our goal of $2 per joint. This number is relatively accurate to describe the costs of our final design that will be put into production across the 250 greenhouses. This is because our materials used for prototyping proved to hold up throughout our various tests so we feel that changing these materials would not
improve our design. We also noticed that if the velcro is too strong, the velcro-velcro connection was stronger than the velcro-glazing connection. This caused the glazing to rip off the velcro which was detrimental to our product. However, because our product may not be available in African countries, we may be forced to ship the product over. This would result in additional shipping and handling costs that would make the total cost of our product a bit more expensive. We expected the shipping costs to be minimal because our product is so small and weighs less than one pound.

User Guides:
Re-design Ideas/Thoughts:

If we were given the opportunity to redesign our product and recreate it for a 3rd prototype, I think we would want to focus on the issues of the product being in Africa. One of the first areas of possible problems we were told about by the HESE students was that the Velcro we had used was black. Black has a habit of absorbing the sunlight and heating up to extreme temperatures in constant sunlight. This constant light could heat up the glazing and Velcro, and even with the test we conducted with the hair dryer, it may not pass the test of time. This could be harmful to both the glazing and the plants because too much extra sunlight can cause the greenhouse plants to dry out. To remedy this, we could use a lighter colored Velcro like white. Velcro comes in many colors so finding a Velcro of equal strength in white should not be a problem. Another challenge faced by our design is what is available to the people who we are trying to help. The solution to that could be 2 things. One thing to do would be do research in local markets to find what types of Velcro you could purchase in that area and for how much.
Another fix could be to send the rolls of Velcro with the HESE students when they go to Africa. Considering the Velcro in our experiment was 25 feet for only $17.00, bringing that amount in a carryon bag or even checking it would be relatively easy and cost-effective. Our dream prototype would consist of white industrial-strength Velcro and 6 nails placed as they were in prototype 2.

References:


"Research Areas." Humanitarian Engineering and Social Entrepreneurship @ Penn State University. N.p., n.d. Web. 05 Mar. 2015.


