Multidisciplinary Senior Design
Project Readiness Package

Project Title:	Belasenp Arborloo Base Manufacturing System
Project Number: (assigned by MSD)	P18416
Primary Customer: (provide name, phone number, and email)	Sarah Brownell, sabeie@rit.edu, 585-330-6434, Dr. Brian Thorn bkteie@rit.edu
Sponsor(s): (provide name, phone number, email, and amount of support)	MSD, NSF I-corps ($500)
Preferred Start Term:	Fall 2017
Faculty Champion: (provide name and email)	Sarah Brownell
Other Support:	
Project Guide: (assigned by MSD)	Sarah Brownell or John Kaemmerlan?

Sarah Brownell

Prepared By Date

Received By Date

Project Information

*** Overview:**

In rural Haiti, 81% of the population lacks adequate sanitation facilities and a third or more still practice open defecation (UNICEF 2015 data). On top of the poor state of the infrastructure, Haiti has been in the midst of a cholera crisis since 2010 leading to thousands of unnecessary deaths. Numerous MSD teams and RIT graduate students have worked to develop a simple latrine model called the "Belasenp" designed to reach rural Haitians. The Belasenp is a variation on Peter Morgan's arborloo latrine that was developed in Malawi (figure 1).

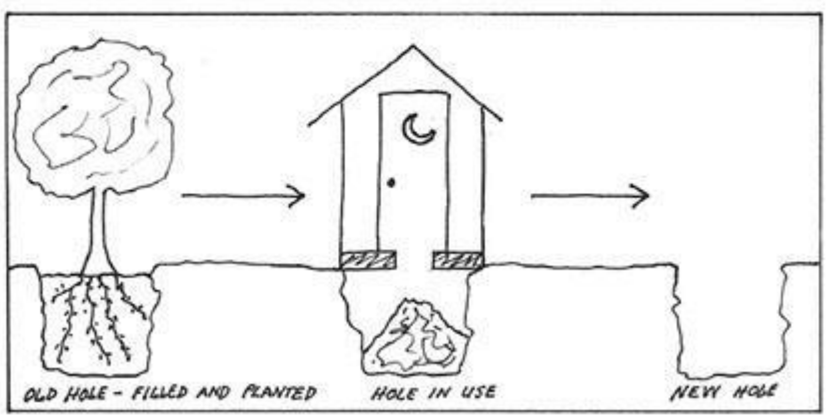

Figure 1: Schematic of the working logistics of an arborloo.
Source: http://abundaculture.org/images/arborloo.jpg

Arborloos are simple and inexpensive movable pit latrines that facilitate composting human waste into organic fertilizer to provide nutrients for a fruit tree. Although the arborloo has yielded positive field results in numerous cases, including Haiti, it has the limitations of having a relatively heavy base that needs to be constructed on site and requiring masonry skills and tools to be built (figure 2). Another disadvantage of the current arborloo designs is that it takes 2 days to install them because of the need to wait for the concrete to set.

Figure 2: Conventional arborloo concrete base (left), low cost conventional shelter (middle), and improved shelter (but too expensive) (right).

Informed by an extensive background study on sanitation in developing countries (a summary can be made available to the team), multidisciplinary teams of RIT students developed four inexpensive prototype arborloo bases that could be manufactured and deployed in rural Haiti (see P14415 and P14416). Each design had advantages and disadvantages. From a cost perspective, the $3.78 the lightweight concrete arborloo dome design made by team P14416 from a mix of cement, sand, coconut shell and coconut husks (figure 3, left) was least expensive and performed well. Still, some improvements were needed. The design was heavy to carry and the edges chiped causing it not to sit flat on the ground. MSD Team P15416 took the design further, refining the concrete mix by adding biochar, replacing the husks with plastic bottle strings, and dividing the design into three stacking rings for better portability (figure 3, right).

Figure 3: P14416's Light-Weight Concrete Dome (left) and P15416's three piece dome (right)

A mechanical engineering graduate student then refined the dome shape to reduce the curvature while maintaining strength. The new design came to be called the "Belasenp" latrine or "Simpy beautiful" latrine (figure 4). The Belasenp consists of lightweight stacking concrete rings that cover the latrine hole. Each ring can be purchased individually to break up the capital cost of investing in the latrine. The material for the Belasenp is a lightweight concrete mixture that includes biochar, coconut shells, and string from plastic bottles. The Belasenp materials and design leverage the benefits of local manufacturing techniques and local materials while creating a *modern-looking, desirable* product that can be purchased in town and installed at home in the hills the same day.

Various one-off prototypes of the Belasenp have been made over the years, but this MSD team is given the task of developing a robust manufacturing process for the Belasenp to include prepping the materials and developing a repeatable method for molding the stacking rings.

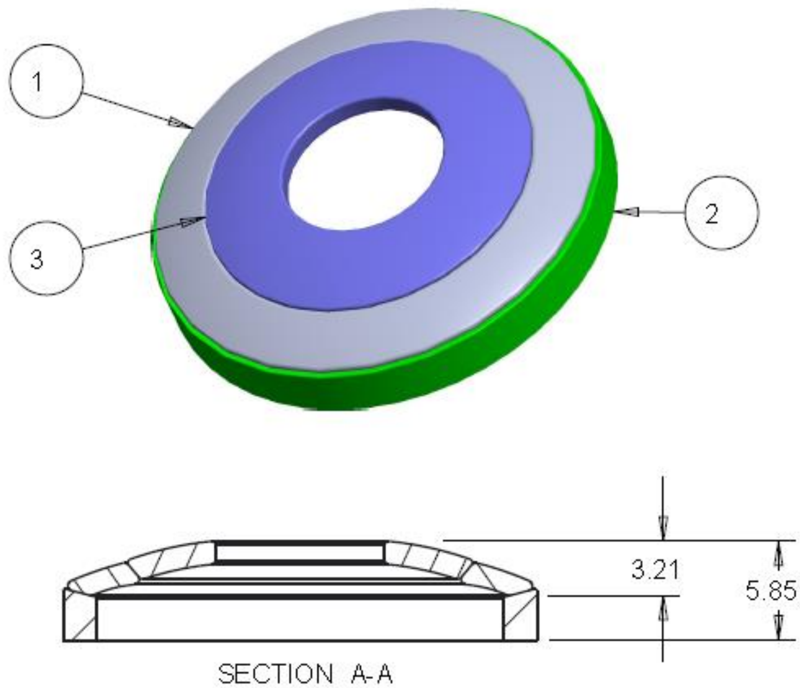

Figure 4: Current Belasenp design

Concrete Mix: The mix developed by the last arborloo team consisted of the ingredients in Table 1. A team working on a similar lightweight concrete mix for roofing sheets for Nicaragua (P17485) discovered that the biochar content could actually be as high as 20% by volume, along with 35% Portland cement and 45% sand and an additional 0.42lb per cu ft plastic bottle strings added after mixing. In Haiti, the cement is purchased in bags and sand and gravel are available from rivers with the manufacuturer paying labor costs for delivery by truck or wheelbarrow. Biochar will likely be made from sugarcane bagass or corn cobs. Haitians have experience with making charcoal from wood, but not necessarily making biochar from agricultural wastes. The size of the biochar particles--which act as small air spaces in the concrete to reduce weight--may be a factor in the overall strength of the concrete mix design. The plastic stings help distribute the tensile load in the concrete and also provide a measure of safety—if a ring breaks, it would not completely fall apart. This safety feature helps prevent people from falling in the pit. Previous teams have tried to mimic the size and length of plastic reinforcements available on the market in the US (these are available in the MSD cubical) and an MSD team last year, P, looked at how to create rope from bottles. This team should experiment early on in MSD I to try to optimize the particle size and amount of biochar in the mix as well as the shape of the plastic reinforcments. The roofing team suggested the possibility of weaving the plastic into a mesh instead of adding them as short strings.

	Mix Amount (Dry Weight)					Other Materials			
	Cement	Sand	Small Coconu	Large Coconu	Biochar	Water	Glenium [ml]	Coconut Husks	Chicken wire
Cylinder Mix (lb)	2.14	2.87	0.65	0.65	0.17	0.99		n/a	n/a
Percentage by Weight	28.6%	38.4%	8.7%	8.7%	2.3%	13.3%			
Volume (in^3)	39.33	52.96	42.89	42.89	17.63	27.40	1.98 [ml]		
Percentage by Volume	17.6%	23.7%	19.2%	19.2%	7.9%	12.3%			

Table 1: Lightweight Concrete Arborloo Mix Recipe from team P15414 (2014-2015)

In order to manufacture Belasenp arborloos in Haiti, this team must develop the methods and/or tools to create each of the materials needed:

- Biochar of the recommended particle size (currently about 1/8”-1/4” diameter particles)
- Coconut pieces of the right size (if used—currently about ¼” – ½” square pieces)
- Sand of the recommended particle size (coarse sand)
- Gravel of the recommended size (if used—pea gravel 1/4” maximum)
- Plastic bottle strings of the right size/shape (currently 1/8” wide x 2” long strings)

Shape Molding: This is one of the most ciritical aspects of the project for the team to address—how can we quickly and repeatibly make Belasenp arborloos in Haiti? The team should keep the current ring shape design unless they discover a clear need for improvement or would like to make aesthetic/feature improvements. At the manufacturing site, we would like to be able to make at least 5 Belasenp bases a day in Haiti.

The team is welcome to explore all options for each task from purchasing equipment to borrowing from or collaborating with other teams, to creating the appropriate tools themselves.

References

Previous Concrete Arborloo teams:

http://edge.rit.edu/edge/P14416/public/Home
http://edge.rit.edu/edge/P15416/public/Home

Lightweight Concrete Roofing tile teams:

http://edge.rit.edu/edge/P16485/public/Home
http://edge.rit.edu/edge/P17485/public/Home

Bottle Rope Team

http://edge.rit.edu/edge/P17432/public/Home

Standard Concrete Mix Info and ASTM standards:

https://www.concretenetwork.com/aggregate/

Ingredient	Range
Cement	7% - 15%
Aggregate	60% - 80%
Water	14% - 18%
Air	2% - 8%

* Preliminary Customer Requirements (CR):

Manufacturing System/Tools:

Produces

- Biochar from sugar cane bagass, corn cobs, or other ag wastes
- Consistent Biochar particles (currently about 1/8” – ¼” diameter particles)
- Consistent Coconut pieces (if used—currently about ¼” – ½” square pieces)
- Consistent Sand particles (coarse sand--research concrete standards)
- Consistent Gravel of the recommended size (if used, pea gravel—research concrete standards)
- Consistent Plastic bottle strings of the right size/shape (currently 1/8” wide x 2” long strings)
- The three molded Belasenp rings, interchangeable

Production rate of at least 25 complete bases per week
Utilizes no more than 4 laborers and a mason/director (8 hour work days 5-6 days per week)
Efficiently utilizes labor hours
The system can be shipped by boat to Haiti or produced there
Can be transported by 2 people (ideally for long distances)
Made with robust parts or parts that can be replaced in Haiti
Utilizes minimal non-human energy (eg. Small generator)
Base produced can support a 200 lb. person squatting or sitting
Base production cost estimate is less than 1000 HTG (approx. $15 USD)

* Preliminary Engineering Requirements (ER):

These are the initial requirements based on the work of previous teams. This team should begin concrete research, expert consultation, and experimentation early to verify that these are in fact the best designs for the system.

ER	Units	Ideal	Marginal
Particle size diameter of biochar	in	1/16 – 1/8	1/16 – 3/16

Percent of biochar particles in the range	%	90	80
Particle size of coconuts	in	1/8 – 1/4	1/8 – 5/16
Percent of coconut chuncks in the range	%	90	80
Particle size of sand		Coarse sand	
Particle size of gravel (pea)	in	1/8 – 1/5	1/8 – 1/4
Bottle String width	in	1/8	1/8-3/16
Bottle string length	in	1.75-2.15	1.5-2.5
Full line Production rate	Bases/week	>25	20-25
Workers required	# workers per bases produced each week	1/5	1/4
Manufacturing system part/tool weight	lbs	<50	<100
Number of people required to carry each part	#	1	2
Piece size (to fit in truck bed)	ft (lxwxh)	<4'x8'x4	
Parts that can be made/replaced in Haiti	% by number	90	70
External power required per week	BTU per week (kW-hr per week)	<34000 (10 kW-hr)	<85000 (25 kW-hr)
Person's weight supported sitting on base	lb	>400	>300
Person's weight supported squatting on base	lb	>400	>300
Production cost	HTG	<1000	<1500

*** Constraints:**

Use materials and skills available in Haiti
Total production cost for the base less than 1000 HTG
Keep existing ring shape (unless there is a clear reason to improve upon it)
Project budget $500

*** Project Deliverables:**

Minimum requirements:

- All design documents (e.g., concepts, analysis, detailed drawings/schematics, BOM, test results)
- working prototype (molds, any tools designed by the team)
- technical paper
- poster
- All teams finishing during the spring term are expected to participate in ImagineRIT

Additional required deliverables:

- Workspace layout/requirements, energy requirements, water requirements, labor requirements
- 2 minute video

*** Intellectual Property:**

NA

Project Resources

† Required Resources (besides student staffing):
Describe the resources necessary for successful project completion. When the resource is secured, the responsible person should initial and date to acknowledge that they have agreed to provide this support. We assume that all teams with ME/ISE students will have access to the ME Machine Shop and all teams with EE students will have access to the EE Senior Design Lab, so it is not necessary to list these. Limit this list to specialized expertise, space, equipment, and materials.

Faculty list individuals and their area of expertise (people who can provide specialized knowledge unique to your project, e.g., faculty you will need to consult for more than a basic technical question during office hours)	**Initial/ date**
Environment (e.g., a specific lab with specialized equipment/facilities, space for very large or oily/greasy projects, space for projects that generate airborne debris or hazardous gases, specific electrical requirements such as 3-phase power)	**Initial/ date**
Access to concrete lab	
Equipment (specific computing, test, measurement, or construction equipment that the team will need to borrow, e.g., CMM, SEM,)	**Initial/ date**
Concrete testing equipment in materials science lab	
Materials (materials that will be consumed during the course of the project, e.g., test samples from customer, specialized raw material for construction, chemicals that must be purchased and stored)	**Initial/ date**
Manitou Concrete has donated materials in the past	
Other	**Initial/ date**

† Anticipated Staffing By Discipline:
Indicate the requested staffing for each discipline, along with a brief explanation of the associated activities. "Other" includes students from any department on campus besides those explicitly listed. For example, we have done projects with students from Industrial Design, Business, Software Engineering, Civil Engineering Technology, and Information Technology. **If you have recruited students to work on this project (including student-initiated projects), include their names here.**

Dept.	# Req.	Expected Activities
BME		
CE		
EE		

ISE	2-3	Ergonomics, manufacturing engineering, DFx, materials science, materials processing, mold design, Engineering Economics, Shop Floor IE, project management (prioritizing)
ME	3-4	3D CAD, machining, mold design, materials selection, GD&T, Composites, Machine elements
Other		