Fabrication Team Reflection Report

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AguaClara Reflection Report
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Abstract

The fabrication team developed fabrication methods and designs to be used at AguaClara construction sites that are feasible and economical. We worked to improve hole cutting/drilling methods, designed entrance tank components such as trash racks and an adjustable overflow weir, investigated methods to attach pipes to the inlet manifold, and sought a longer lasting on-site power source. We developed a much better understanding of the AguaClara project and made several valuable contributions to implement in future construction sites.

Introduction

The mandate of the Fabrication Sub team was to develop improved fabrication methods for AguaClara plant components. We designed a jig to drill holes in plate settlers and found the optimal tools for cutting and drilling PVC pipe and sheets. We developed several ideas for creating an adjustable height overflow weir for the entrance tank, so the flow through the plant can be regulated, and tested the feasibility of a flexible coupling option. We evaluated alternate power sources to provide longer runtimes for cordless power tools at plant sites that lack electricity. We developed preliminary designs for the entrance tank trash racks to prevent clogging of the plant orifice meters, and we investigated appropriate materials and design parameters for such gratings. Lastly we experimented with a few methods to attach small vertical pipes to the inlet manifold to aid in floc blanket formation.

Experiments and Results

Cutting and Drilling through PVC tubing and sheets

For the cutting of holes into PVC we compared standard and modified drill bits to standard and specialized hole saws. We looked for the cleanest and quickest cut while trying to solve the problem of PVC plugs forming that require maintenance time in between cuts. We thought about the possibility of using a hole punch, but the ability to cut holes without cracking the corrugated sheets, as well as the speed of this method, were questionable. This is the basic equation to determine the force needed to puncture the sheets:

$$F = 0.7 \cdot t \cdot L \cdot UTS \qquad (1)$$

Where t is the thickness, L is the perimeter of the hole, and UTS is the ultimate tensile strength.

We looked at several options to address the difficulties being found with cutting and drilling PVC tubing and sheets, which depend on the specific hole saw and material. For cutting small (< 2 cm diameter) holes into PVC pipe, a Plexiglas/plastic drill bit is the best option. These can be bought or made from an ordinary drill bit by grinding down the edge for a flatter tip. The holes cut with this method were cut more quickly and cleaner than with a hole saw, however, this method is only feasible at holes with smaller diameters. For larger holes, a good option is to buy a self-ejecting hole saw arbor (Lenox 300077L) that uses long pins to knock out the plug after the hole is drilled, depicted in Figure 1, below.

Figure 1. Arbor with pins retracted (left) and with pins extended (right).

Although little consideration was put forth for the cutting of corrugated sheeting, during our construction of the jig we attempted cutting the straightest and cleanest lines with scissors, utility knives, and shears, and tin snips. The cleanest cut came from the straight pattern snips however; the straightest cut came from a pair of heavy duty scissors. The utility knife failed completely and the shears resulted in fracturing. There is the future possibility of testing a Plast-Kut knife (http://www.signwarehouse.com/TT-CUTT-p-HT-PLASTKUT.html) or Coro-Claw (http://www.amazon.com/Saw-Trax-CCD4-Coro-Claw-4mm/dp/B000MPMCQS) that are additional plastic cutting tools.

For our drilling jig, we fabricated a spacing mold out of a sacrificial plate settler to space the plates being drilled appropriately. To do this, we constructed a set of precut PVC sheets that have been evenly spaced and glued with PVC glue. This design allows the PVC sheets for the plate settlers to be inserted into the jig at the set spacing of 2 cm (or the spacing required to achieve the correct distance between the plate settlers). The current design is set for 8 sheets to be used at a time. The next step in the process is to construct a frame to help hold the sheets, clamp them down, and align the holes that need to be cut. This piece can have preset holes that can be drilled with a drill press to ensure the holes for the sheets are straight and aligned. See Figure 2, below, for our constructed spacer piece.

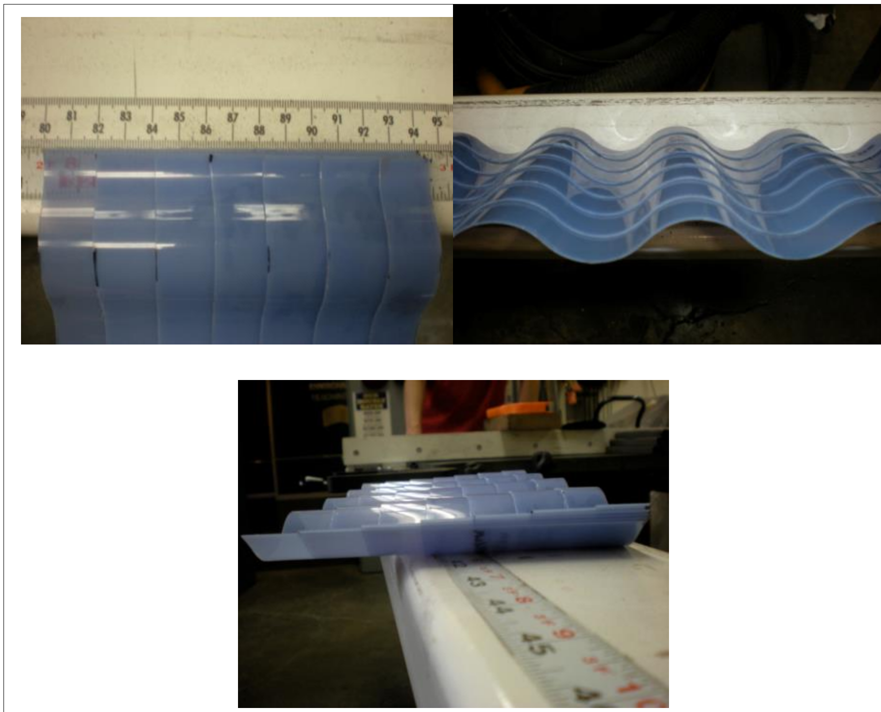

Figure 2. PVC sheet spacer with scale bar (top left). Front view, showing where sheets would slide in from (top right). Side view, showing stair-like constructing of the sheet spacer, where PVC sheets to be drilled would slide in from the left (bottom).

The construction of the tiered and offset PVC sheets for the jig took less than an hour to complete and held tightly with the glue. Additionally, initial testing showed little deviation of inserted sheets. Depending on how much actual work time it takes to finish the jig, we think it is a viable method for cutting holes quicker, as constructing the jig with a few initial hours can save more time and effort as the number of modules increase.

Entrance Tank Adjustable Weir

We constructed an adjustable entrance tank weir by connecting a large diameter pipe (6 inch) to a small diameter pipe (4 inch) via a flexible coupling that would allow the large pipe to slide up and down over the range of the water level fluctuations in the entrance tank. We tested the coupling and found that the sliding is easy if you have full access to the pipe. Therefore we propose that this idea could work if, when the height needs to be adjusted, this pipe could be taken out of the entrance tank and temporarily replaced with another 4-inch pipe. Then the height can be adjusted by the operator and replaced into the entrance tank. We tested the seal and found that it successfully holds water with no leak even after loosening and moving the coupling up and down.

Figure 3. Flexible Coupling (right) allowing sliding of 6” PVC pipe over 4” PVC pipe (left).

The flexible coupling is a feasible option. Other ideas for this task are to create a rotating weir on an elbow to a horizontal pipe, a piece of corrugated tubing that could extend/contract for adjustable height, or a weir with pluggable holes present at different levels. We did not discard these ideas, but the flexible coupling is the most feasible design at present.

Trash Racks

The design team has put space in the entrance tanks for trash racks to collect large debris and prevent clogging of the LFOM. The design constraints are that the racks must have negligible head loss (less than 1 cm) and the holes should be smaller than the LFOM orifices. This means that the square openings should have dimensions of about 1.5 cm assuming 2 cm diameter LFOM orifices.

With these dimension criteria we calculated the necessary dimensions of the grid itself by considering the head loss equation below.

$$H = K\left(\frac{w}{x}\right)^{\frac{4}{3}}\frac{V^2}{2g} \quad (2)$$

where H is the head loss, K is a shape factor, w is the bar width, x is the minimum open spacing between bars, V is the upstream fluid velocity, and g is acceleration due to gravity. From the design of entrance tanks, we know that the horizontal velocity in the entrance tank will increase with plant flow, but approaches a maximum around 16 cm/s. Using a K value of 1.79 for circular bars, and a head loss of 1 cm, we found that the bar width should be no more than 3 times the open spacing, or less than 4.5 cm (1.75 inch). Smaller bars will lead to even less head loss, which might be useful as blockage will occur and increase the flow velocity. Also smaller bars would mean the spacing could be decreased to prevent even more debris from passing.

We derived several feasible designs for the trash racks. The AguaClara engineers in Honduras indicated their desire to use Honduran materials, specifically a mesh sieve (metal), called hardware cloth, mounted on a wooden frame. This design is adequate assuming the sieve follows the head loss constraint. Another option is to build a grid out of rebar. Larger (3/4 inch) rebar could be used for horizontal support and smaller (1/2

Commented [mlws1]: Can you give the reference for this equation.

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inch) rebar could be used for vertical bars, with the horizontal spacing much smaller than the vertical spacing (i.e. rectangular openings). Also, a PVC frame is a good alternative to wood, and a plastic mesh can be purchased from McMaster-Carr for a reasonable price (http://www.mcmaster.com/#plastic-mesh/=bv68f0), which has the advantage of not rusting, though tearing might be a concern. The simplest way to attach this to a frame would probably be using zip ties like in Figure 4.

Commented [mlws3]: I'd guess that 3/8 inch rebar will be more than adequate for the tiny forces involved.

Figure 4. PVC frame with zip ties attaching net (left) and zip ties attaching mesh to metal frame. (right).

Powering Handheld Tools

For our power considerations, we estimated battery run time based upon the 2.4 Amp-hour battery packs and the 12 V cordless drill in use. The drill was rated for a maximum power output of 285 Watts. Using the below equations, we found a runtime of approximately 6 minutes at maximum power. This situation would draw about 24 amps of current, which requires a 12 gauge wire for 4-5 meter of wire length.

$$I_{\max} = \frac{P_{\max}}{V} = \frac{285W}{12V} = 23.75A \qquad (3)$$

$$Runtime = \frac{Capacity}{I_{\max}} = \frac{2.4A \cdot hr}{23.75A} = 0.101hr = 6.06\min \qquad (4)$$

A possible longer lasting power source is a 12 V car battery. A typical lead-acid car battery has a capacity around 45 Amp-hrs, which should last about 20 times longer than a single battery pack, and should be suitable for a whole day of work. We contacted AguaClara Engineers Dan Smith and Sarah Long, who agree that this idea is worth looking into further. The connection can be set up with an old battery pack and proper gauge wire with alligator clips. The battery pack can be dismantled and one end of the wire can be spliced or connected to the battery packs terminals. This way the drill can still switch between the standard battery and a car battery for given situations where portability matters. Also, the alligator clips seem like a more practical connection to the battery, but a more fixed connection may also be used.

Commented [mlws4]: We need a source for a drill battery that is about to be recycled.

Inlet Manifold

We investigatied the best way to attach small vertical pipes perpendicular to the inlet manifold of the sedimentation tanks, used to reduce the horizontal fluid velocity and help create a floc blanket. One idea was to cut the top of the 1" PVC into quarters, then heat the PVC in boiling water and fold back the quarters to make flaps that could be glued to the 6" PVC. We tried this and proved that is workable, but looked for alternate solutions. Similar options that we tested were cutting more flaps (cutting the 1" PVC into eighths), or cutting narrower flaps to wrap around the 6" PVC. The narrower the flap, the less misfit that ensues due to the arc in the 1" PVC. See Figure 5 for some of our trials.

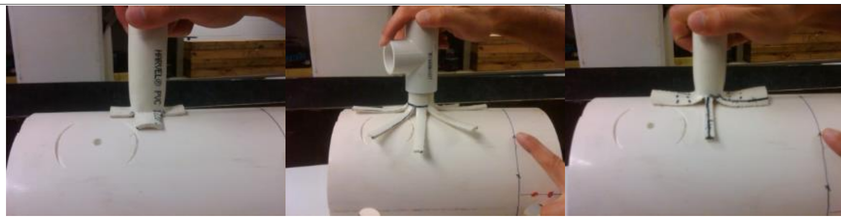

Figure 5. Attachments for inlet manifold; 1” quarters (left), 3” eighths, 2” variable width (right).

We discussed the idea of creating miniature guides for the 1” PVC pipe with pieces cut from extra 6” PVC. The goal was to have extra surface area for the 1” pipe to be glued to, as well as provide a sturdier attachment in terms of shear stress. The 1" pipe should be able to be pushed into the guide and stop at the edge of the 6" pipe because of sizing. This idea is shown in Figures 6 and 7, below.

Figure 6. Varied sizes for guide (left) and sizing comparison, with inner hole being 1” and outer hole being closest size of outer diameter of 1” PVC pipe.

Figure 7. This attachment show how the 1” PVC pipe could fit into guide.

In addition, we devised a tool that can be fabricated to make molding the boiled PVC easier. This involves a tube with an inner diameter slightly larger then the 1" PVC outer diameter, so that it could slide over the pipe. On the end would be a piece or 6" quarter-pipe to press the flaps down onto the inlet manifold curvature. This tool does not take long to make and may really help the contact area of the vertical pipes, ensuring a good surface for gluing and structural integrity. This tool is shown in Figure 8.

Figure 8. The tool for molding boiled PVC (left) and in use (right).

Future Tasks

For the future, several tasks remain necessary. More work on constructing a drilling jig may lead to a faster drilling mechanism. A deep-cycle or car battery needs to be wired to a cordless drill and tested, with appropriately gauged wire connection, which can be purchased online for about $13 for a 10 foot cord (http://www.amazon.com/Cable-EC123-3FER10-Black-Gauge-Extension/dp/B00387G1QO/ref=sr_1_4?ie=UTF8&qid=1304452730&sr=8-4). Further investigation into the trash racks could test the relative benefits of one design over another, making sure to include the wire cloth being proposed for use by AguaClara engineers. Also, the future fabrication team should attempt to test the strength of the different PVC connections for the inlet manifold.

Team Reflections

Our team is worked very well together. We approached several challenges at once and made significant progress throughout the semester. We did a great job of giving each other ideas and making constructive alterations. We were also in frequent contact, making planning and scheduling easy. We did a good job of dividing up responsibility and both contributing our part to the team. We are happy with our teach-in and our work over the past semester. We finally realized some of the goals we proposed at the onset of the semester