1 L/s Plant Testing, Spring 2017

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Abstract

The Spring 2017 semester 1 L/s Plant Testing subteam's objectives were to improve upon the previous work done on the design of the 1 L/s pilot plant in Honduras. This semester, the primary goals of the 1 L/s Plant Testing subteam were to complete the 1 L/s plant and to design and fabricate a tapered flocculator. This tapered flocculator design would be used to decide whether tapered flocculation would improve overall water treatment in the 1 L/s plant.

Introduction

The Spring 2017 1 L/s Plant Testing subteam built upon previous research specific to flocculation in the 1 L/s plant. In Winter 2017, a 1 L/s pilot plant was shipped to and implemented in Honduras. This pilot plant was developed and built through the Spring 2016, Summer 2016, and Fall 2016 semesters. The pilot plant treated influent water very well at first, but the effluent water quality started to decline over time. There was a theory that the coagulant dosed to the plant was sticking to the walls of the flocculator pipe rather than onto the particles in the water. This theory prompted a need for further research to discover which parameters were most significant to the design of the flocculator and whether the size of the first pipe, where coagulant should be attaching to particles in water, should be larger.

This semester, the 1 L/s Plant Testing subteam designed and fabricated a new type of flocculation system, a tapered flocculator, to discover and define those parameters. The tapered flocculator had a larger diameter first pipe that would feed into smaller diameter pipes. The hope was that the tapered flocculator would improve the ability of the coagulant to attach to the particles in the influent water by allowing more room for the coagulant and particles to collide. More room in the first pipe would make it less likely for the coagulant to attach to the walls of the pipe.

The design and fabrication done by the Spring 2017 team had significant impact on the future growth and design of the 1 L/s pilot plant implemented in Honduras in January 2017. This 1 L/s plant design was crucial to increasing water security in small communities where full-scale AguaClara water treatment plants are not an affordable option.

Previous Work

Spring 2016

In the Spring 2016 semester, the 1 L/s Plant Testing team did not exist. During Spring 2016, AguaClara created the PreFabrication 1 L/s Plant to create a method to treat waters for Honduran villages. While the team had created excellent designs for towns and small cities, they had not yet succeeeded in creating a low cost, climate friendly, high performing treatment plant for villages that rely on turbid surface waters. The goal in Spring 2016 was to develop a new fabrication method for small scale plants that would be easy to operate, high performing and low cost to deploy. The main challenge was to select fabrication materials and develop fabrication methods to have a design ready for pilot testing in Honduras in Summer 2016. During the spring semester, the team determined the optimal size of the modular unit, the fabrication materials and tested fabrication methods. The team found that traditional AguaClara flocculation, sedimentation and filtration constraints could be applied on a smaller scale to meet the needs of small communities. The team successfully designed and fabrication a 1/9 scale model of the sedimentation tank and showed that a large, plastic corrugated pipe was a potential low-weight, low-cost solution to the traditional concrete tanks and determined that plastic welding was a viable fabrication method for tank construction in Honduras.

Summer 2016

In the Summer of 2016, the main design of the plant was finalized with the first full scale construction of the plant. The design requirements for the key components such as the plate settlers, flocculator, inlet, and sedimentation tank were based off of traditional AguaClara technology and codified for future construction of the plant. These technologies scaled down easily and effectively, but were not fully tested for effectiveness compared to full scale.

Fall 2016

In the Fall 2016 semester, there were two teams conducting research on the 1 L/s plant. The Small Scale Plant Testing team focused on confirming the functionality of 1 L/s plant built in Summer 2016. The team was able to confirm that the 1 L/s plant was working well and was able to ship it to Honduras. The results the team produced in clay testing were similar to a traditional AguaClara plant and Chemical Dose Controller (CDC) tests proved that the CDC was working as expected (Barrientos et al., 2016). The team also came up with a new flocculator baffle design. However, the baffle design was eventually replaced with a similar baffle design that was used in Spring 2017, as well as in the 1 L/s plant shipped to Honduras.

The Prefabrication 1 L/s Plant Team focused on building an additional 1 L/s plant while developing better fabrication techniques to reduce the overall cost of the plant and labor in Honduras. The sedimentation tank, which was described as the "centerpiece of the plant", was cut first with the help of I-Beam supports and jigs (Herrera et al., 2016). The team created a plywood board jig, shown in Figure 1, which was utilized to make a 30°cut in the 0.91 m pipe. The team also created a jig to keep the reciprocating saw used to cut the tank parallel to the plywood board jig and another additional jig to cut the plate settlers.

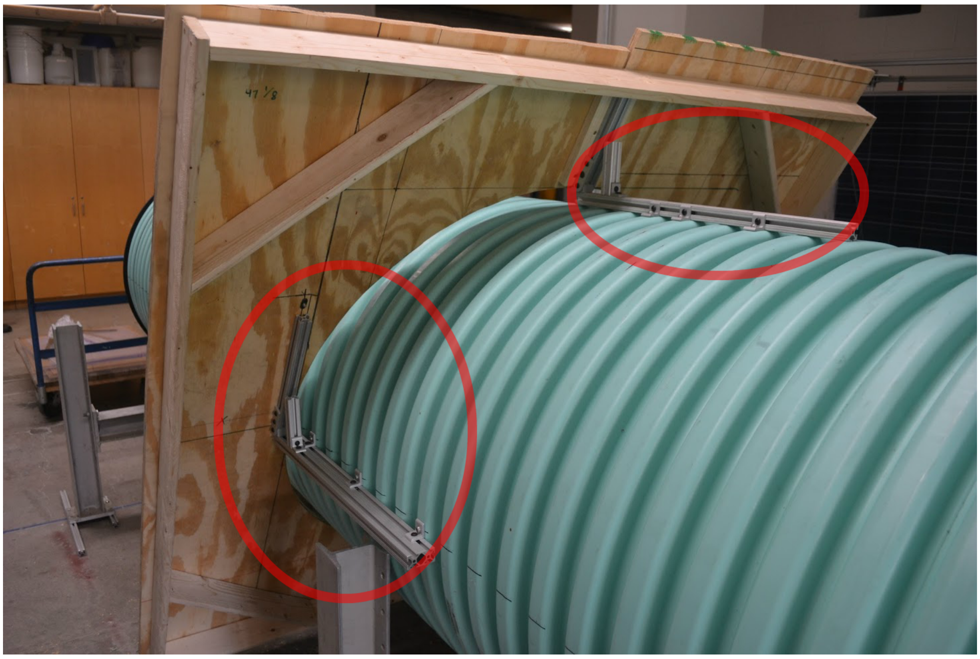

Figure 1: The plywood board jig used to make the 30°cut, circled in red.

Methods

Ensuring Watertight Sedimentation Tank

Upon completion of the base plate installation in the bottom of the sedimentation tank, there were considerable leaks when water testing. Many steps were taken to fix this, including re-welding, re-tacking of the joint, and solvent welding.

For the process of identifying leaks, the sedimentation tank bottom was elevated open-side up on two I-beam supports so that leaks could be identified by sight from under the tank. The tank was filled, leaks were identified, actions were taken to patch the leaks, and the process repeated until no more leaks could be identified.

Eventually, the processes of re-welding and tacking the joints proved fruitless, and the process of solvent welding was adopted. The team built a small-scale rectangular tank, welded it poorly, and patched holes in the welded plastic by solvent welding. The solvent welding proved very effective and quickly patched the leaks. In order to further confirm the effectiveness of solvent welding, the team drilled a hole in the bottom of the tank and patched it with PVC glue as seen in Figure 2. The tank was tested once again for watertightness and was successful. After the solvent welding technique was adopted, leaks in the sedimentation tank were quickly absolved.

Figure 2: Solvent welding test

Welding Together the Sedimentation Tank

With the leaks resolved, the next step was to weld both parts of the sedimentation tank together. Both parts of the tank were elevated onto 4 I-beams and aligned at the proper angle (Herrera et al., 2016) (shown in 3).

Figure 3: Sedimentation Tank Aligned

In order to hold the alignment in place, sides of the tank were clamped (shown in 4) and turn-buckled on the top and bottom (shown in 5).

Figure 4: Sides of Sedimentation Tank

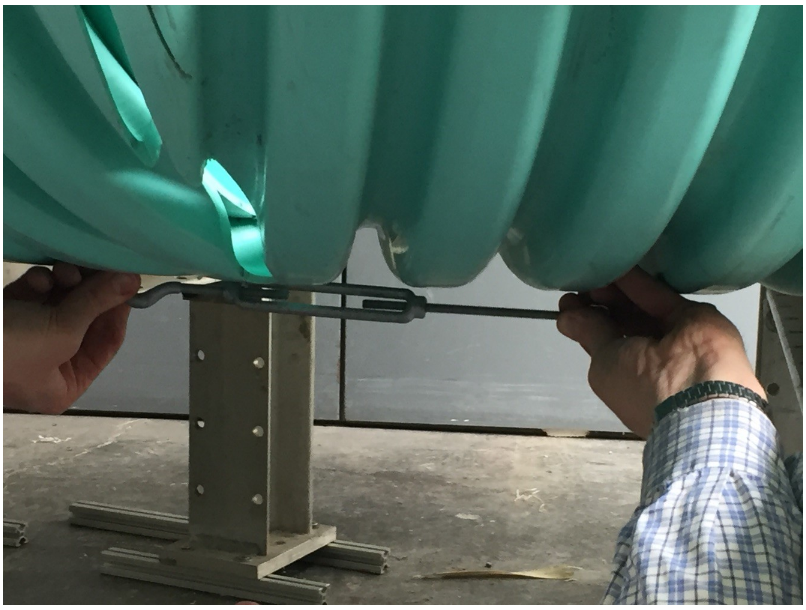

Figure 5: Close up on Turn Buckles

In order to place the turn buckles, the team carefully drilled two holes on the top and bottom section of the sedimentation tank corrugations, respectively, without puncturing the inside. These two turn buckle holes were drilled on either side of the sedimentation tank cut for security. Despite aligning the cut of the sedimentation tank (Herrera et al., 2016), the cut was not perfect and resulted in a few large gaps. The team had rotated welding over the gaps and was able to start water testing. (shown in 6).

Figure 6: Welding to Fill in Gaps

Water Testing the Sedimentation Tank

Initially, the water testing of the sedimentation tank was delayed due to unforeseen administrative lab problems and lack of manpower. Last semester, when the previous sedimentation tank was water tested, the team was able to complete the task outside. However, the team was unable to use the outside hose to water test. This caused water testing to span a longer time frame because the tank took much longer to fill up with two small water outlets. In addition, with two people, the sedimentation tank could not be safely lifted upright to water test. Therefore, the team had to rely on a at least a third person to be in the lab to help lift the sedimentation tank for water testing.

However, the difference between Fall 2016 and Spring 2017 team was that the previous sedimentation tank was water tested all at once. This meant both the bottom supports and the mid-joint welds were water tested at once, instead of separately. Because the team had water tested the bottom supports in advance, we were allowed to water test in the lab.

Before lifting the sedimentation tank upright, the team had to plug the sludge drain to not flood the lab. This was because when the sedimentation tank was upright, the sludge drain connector was too far down to reach and plug from the top.

Figure 7: Sedimentation Tank upright for Water Testing

It took the team roughly an hour to fill up the sedimentation tank with water past the the seam where the bottom and top parts of the tank were welded together. There were two leaks that were found near the welded seams of the tank. The tank was drained of water and when the tank was dried, the team solvent welded over the plastic welded area and water tested. During the second round of water testing, there were an additional two leaks directly in the area where the turnbuckles were attached. Because the turnbuckles were attached on the top and bottom of the cross sectional area of the sedimentation tank, the area around the turnbuckles were difficult to weld over. The team removed the turnbuckles and welded over. Before water testing again, the team solvent welded over the outside and inside of the main welds. These methods proved successful in making the sedimentation tank water tight.

Entrance Tank

The entrance tank for this plant has a design based off of the entrance tank shipped to Honduras in Fall 2016, but with the slight modification: the total length was reduced by two inches. This was to account for the mount of the counterweight water level reader. Otherwise, the team planned to take the same construction steps as illustrated in the Summer of 2016 (Hintenberger et al., 2016).

However, there were still issues with the construction of the entrance tank. One of the first problem areas was the section where the entrance tank would be attached to a wooden pole support (shown in Figure 9). The team did not realize the colloquial term ”4-by-4” for a wooden pole does not allude to a 10.16 cm (4 in) by 10.16 cm (4 in) cross section of the wooden pole. In fact, this term refers to a wooden pole with a 7.62 cm (3.5 in) by 7.62 cm (3.5 in) cross section. Therefore, the team created enough space for a 10.16 cm (4 in) width pole rather than a 7.62 cm (3.5 in) width pole. This issue was resolved by solvent welding a 1.27 cm (0.5 in) PVC sheet to the inside of the space (shown in Figure 8).

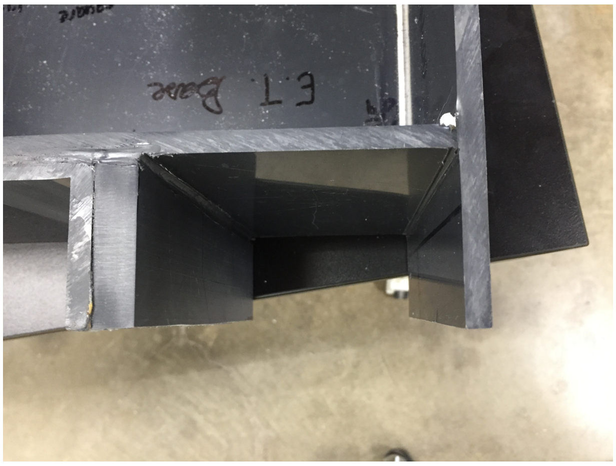

Figure 8: The 0.5 inch PVC sheet is glued to the inside of the space.

Another issue was that the entrance tank was built backwards. The entrance tank that was shipped to Honduras in Fall 2016 was attached to the wooden pole on the left. The entrance fabricated by the Spring 2017 team was built to attach to a wooden pole on the right. However, it was determined that this would not be an issue with the rest of the plant because it would not affect the design or function of the overall plant.

The third issue addressed was the problem of having the first pipe of the tapered flocculator too close to the wooden pole. In the original design, the wooden pole is directly next the the first pipe of the flocculator. This first pipe had a diameter of 7.62 cm (3 in), which made it feasible for it to fit next to the pole. However, the tapered flocculator will have a first pipe with a diameter of 20.32 cm (8 in). As shown in Figure 9, the 7.62 cm (3 in) pipe only barely fit next to the pole, so it would be impossible for a 20.32 cm (8 in) pipe to fit in that same space. To address this issue, the team decided to shift the positions of the Linear Flow Orifice Meter (LFOM) and the entrance pipe to the entrance tank itself. The LFOM is attached to the entrance to the flocculator to ensure linear flow into the first leg of the pipe. Both the LFOM and the entrance pipe were to be attached to the entrance tank as shown in the layout in Figure 10.

A 7.62 cm (3 in) hole saw was used to drill a hole for a straight female socket-connect that would serve as a connector between the LFOM and the first leg of the flocculator. This 7.62 cm (3 in) hole was made where the LFOM position was marked in Figure 10. The straight female socket-connect was glued flesh to the bottom of the tank. A second hole was drilled where the entrance position was marked in Figure 10 with a 5.715 cm (2.25 in) hole saw for the entrance pipe that would direct raw water into the entrance tank.

Figure 9: This is a photo of the entrance tank attached to the wooden pole in Honduras. The first pipe of the flocculator is shown pressed up against the wooden pole.

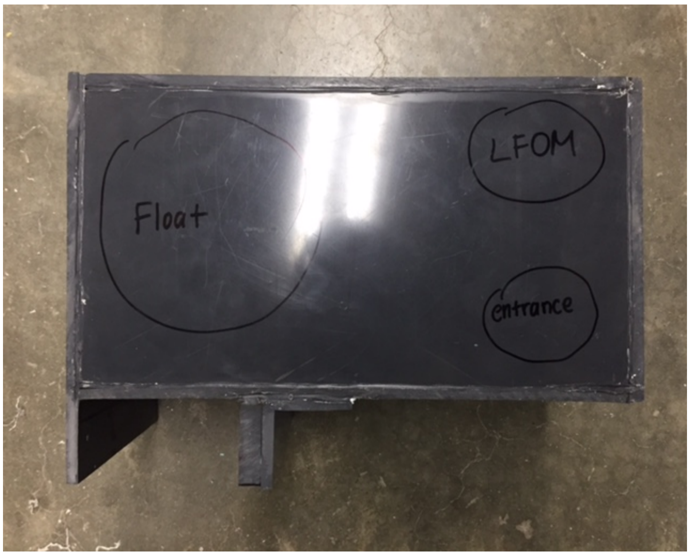

Figure 10: This is a layout of the placement of the float, LFOM, and entrance pipe in the entrance tank relative to the placement of the pole, while will be in between the spacers in this photo.

Wooden Pole Support

A 4 by 4 wooden pole was used as the support for the entrance tank. The dimensions of the pole were The sedimentation tank was attached to the wooden pole at two points centered at the middle of the width of the pole. One point was at 11.43 cm (4.5 in) and another was at 95.25 cm (37.5 in) from the ground. Using the power drill on the corrugations of the sedimentation tank, the team drilled roughly an inch away from the center with a 0.635 cm (0.25 in) drill piece to create a slot. Then, the team drilled a hole at the end of the segment larger than 0.635 cm (0.25 in) to fit the head of the screw 11 that would be attached to the pole.

Figure 11: Close up of the drilled corrugation

After drilling at both points, the team used a 1/4 inch screw to attach the wooden pole onto the sedimentation tank 12.

Figure 12: Sedimentation Tank attached to wooden pole support.

Like the past plant, the entrance tank is attached to the wooden pole support 13 14.

Figure 13: Set up of the entrance tank and wooden pole support.

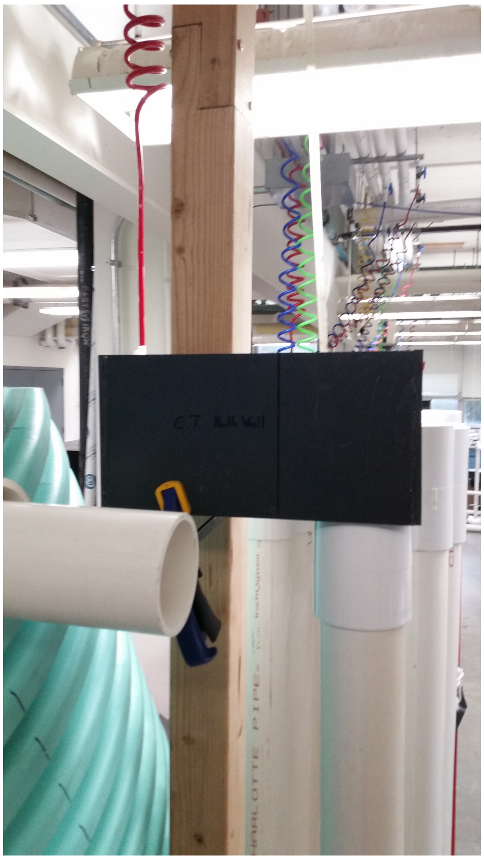

Figure 14: Close up of Entrance Tank with the wooden pole

Linear Flow Orifice Meter

The Linear Flow Orifice Meter (LFOM) was constructed out of a 7.62 cm (3 in) diameter PVC pipe. The pipe was cut at 1 m in length in order to allow abundant room to determine and draw the placement of the 0.9525 (0.375 in) holes. First, a "baseline" was drawn at the top of the PVC pipe to leave room for the LFOM to fit inside of the coupling that would ultimately attached to the bottom of the entrance tank. This "baseline" was determined by measuring the length of space between the edge of the coupling to the middle area of the coupling and subtracting the thickness of the PVC ring the team glued against the middle mark of the coupling. The PVC ring was glued inside the middle of the coupling to ensure security of the LFOM and minimize the slipping and sliding inside of the coupling during experiments. The placement of these holes were determined through calculations in Mathcad with results as shown in Figure 15 below. The total height of the holes was 10 cm, including the spacing between the holes, with each hole spaced 1 cm apart vertically. The horizontal spacing is irrelevant in the design of the LFOM. The positioning of the holes were determined by using the LFOM template (shown in Figure 16 below) created by the Design subteam in AutoCAD.

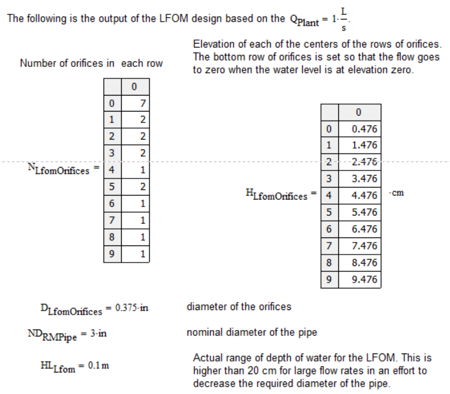

Figure 15: This shows the results of the Mathcad design file for number of holes in each row and vertical spacing between the centers of the holes for the LFOM, as well as the size of the holes.

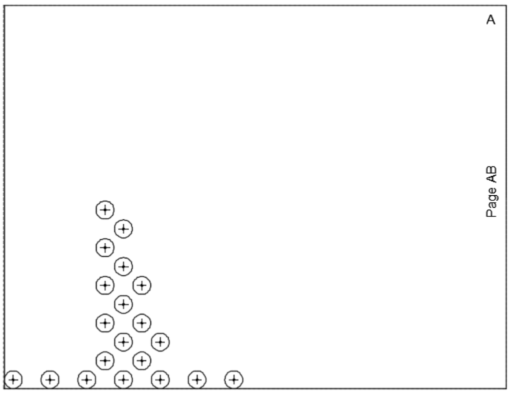

Figure 16: This was the resulting template once the Mathcad text file was copy and pasted into the command line of AutoCAD.

The template was printed out and attached to the "baseline" of the PVC pipe for drilling as shown in Figure 17. In order to drill the holes into the pipe precisely, a mill (shown in Figure 18) was used to make 0.9525 (0.375 in) holes in the pipe.

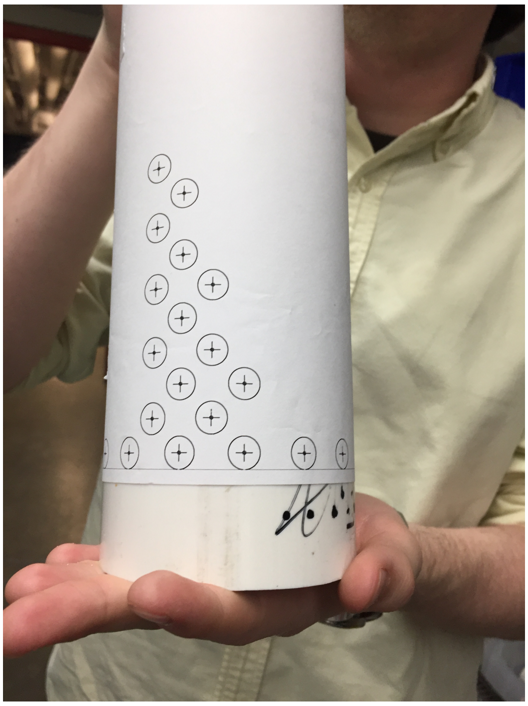

Figure 17: The printed template is shown above, taped to the pipe.

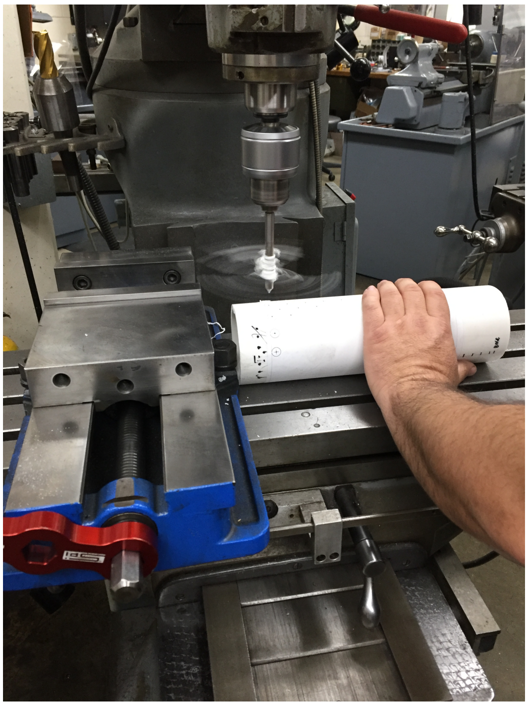

Figure 18: The mill was used to create precise holes in the LFOM. The pipe is pressed against a stopper and the exact position of the pipe could be located using a digital positioning system attached to the mill.

Flocculator

Orifices

A major part of the new flocculator design involves a brand new orifice design. The previous flocculator was made by crimping the pipe itself to make oval shaped orifices to create turbulence. This time, the orifices were made from PVC semicircles with the diameter of the inside of the flocculator pipes. These semicircles will be 3” in diameter with a section cut out of one side starting 3/8” from the center. They will be slid onto threaded 1/4” rods at a spacing of 11.25 inches apart and inserted into the flocculator pipes from above. This system provides various advantages, such as easier fabrication and the option to adjust orifices and perform maintenance while the plant is running.

In order to create the orifices, rectangular pieces of PVC were cut and given a center hole which could be used to mount them on a circle cutting jig and cut using a band saw. To make roughly fifty orifices easily and quickly, the team was able to set a drill press with a jig to make a hole in each PVC orifice and then put on the circle cutting jig which cut exactly the same parabola-shape every time.

Figure 19: The shape of new orifices for the flocculator, 3” in diameter with 1/4” holes drilled in the centers.

Flocculator Construction

The main body of the flocculator was constructed in largely the same manner as the flocculator from the previous plant. The main difference for construction was the use of T-joints on the higher elevation pipe joints with an open end facing upwards to allow for the baffles to be inserted easily. PVC glue was used to seal the joints and keep the flocculator together.

Figure 20: The T joint tops of each flocculator branch allow for easy interchangeability of orifice baffles.

The second main difference is the incorporation of the tapered flocculation option, which requires a slightly different setup for the first down pipe of the flocculator. Since an 8" pipe is going to be tested for the tapering flocculator, a geometric problem arises to determine how far out the center of the pipe needs to sit to properly align with the entrance tank outlet, the post holding the entrance tank and the flocculator. This was handled experimentally, by setting the entrance tank, aligning the flocculator body with the LFOM and working through possible orientations for the 8" pipe joint that connects the first flocculator pipe with the rest of the flocculator.

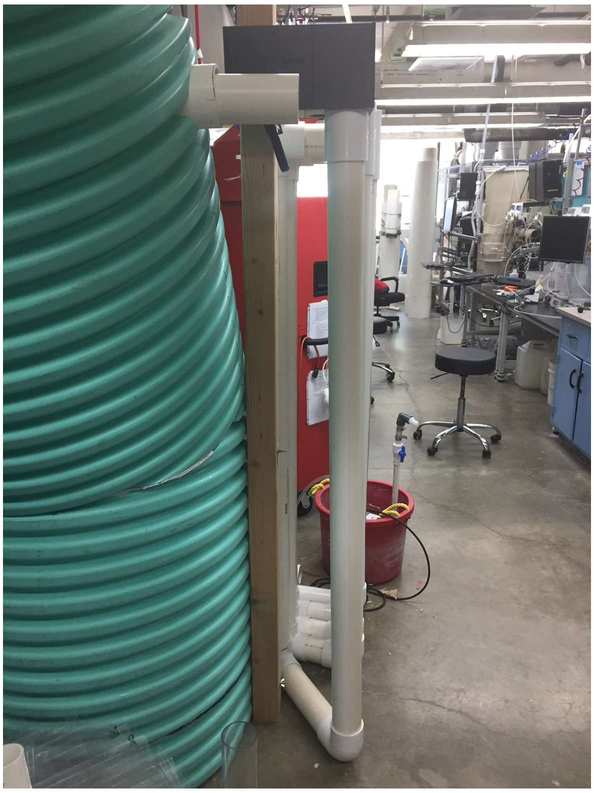

Figure 21: The experimentally determined geometry of the tapered flocculator.

The bottom joint for the interchangeable pipe was set with solvent welding, leaving the connection with the variable diameter pipe free to be changed for experimentation. A system to connect the other end of the flocculator to the inlet manifold of the sedimentation tank is also being designed for optimum geometry.

Figure 22: The connection for the flocculator to the inlet manifold of the sedimentation tank.

Conclusion

During the Spring 2017 semester, the team finished assembly of the plate settlers, welding of the supports, base plates and jet reverser for the sedimentation tank, the majority of the entrance tank, water tested the tank and LFOM. The team was able to finish the large majority of the fabrication necessary to complete the 1 L/s plant and has started a fabrication manual to help decrease the time spent on future teams searching for fabrication instructions for the plant.

Future Work

The Spring 2017 1 L/s Plant Testing team finished a majority of the fabrication needed to complete the plant, but there were a few parts of the plant that still need to be fabricated and attached. These parts include the sludge drain, entrance pipe, and the chemical dose controller. These parts will need to be made by the next 1 L/s Plant Testing team, building off of the fabrication already completed by the Spring 2017 1 L/s Plant Testing team.

It is crucial for the next 1 L/s Plant Testing team to continue to document their fabrication work in the manual created by the Spring 2017 1 L/s Plant Testing team. This will be an important reference for future fabrication efforts of a 1 L/s Plant for testing in the lab, for use in Honduras, and beyond.

As the team's focus shifts from fabrication to experimentation, it will be important for future teams to run experiments with the new tapered flocculator design. This will help determine whether or not tapered flocculation improves the performance of the 1 L/s Plant and, if so, should be implemented in future construction of 1 L/s Plants in the Honduras.

References

Barrientos, A., Marroquin, E., Queijeiro, M., and Pei, Y. (2016). Small Scale plant Testing, Fall 2016 Report.

Herrera, D., Hua, Y., Kim, S., King, S., and Yang, F. (2016). Pre-Fabrication 1 L/s, Fall 2016 Report.

Hintenberger, J., Guzman, J., and Marroquin, E. (2016). Pre-Fabrication 1 L/s, Summer 2016 Report.

Semester Schedule

Task Map

Task Maps should be created in Microsoft Word and then copy and pasted into the Detailed Task List in Overleaf. Save your word document on Google Drive so that you can make adjustments later in the semester. To Create one, open Microsoft Word. Under Insert, go to Smart Art, click Hierarchy, then Horizontal Hierarchy. Click the arrows on the left side of the box to open up a bulleted list of how your Map is organized. Make sure your map is as large as possible on the page (it may be necessary to increase the font size), then copy and paste it into the Google Doc.

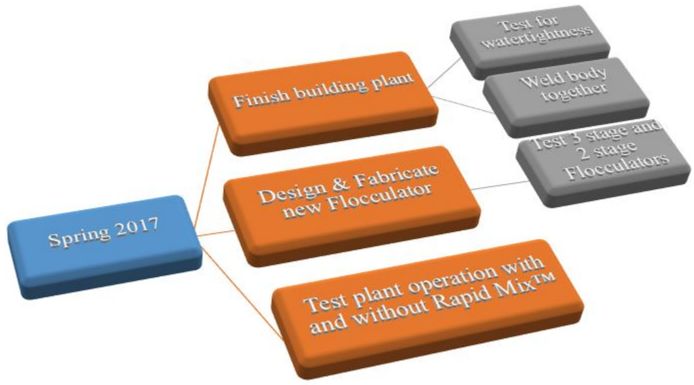

Figure 23: This is the Spring 2017 team's task map for this semester. More detail may be found below in the Detailed Task List.

Task List

You should keep and update your detailed task list from the first assignment in each of your reports. Denote completed tasks and modify your deadlines to reflect your most recently completed progress and any delays.

1. ✓Patch and water test the bottom half of the sedimentation tank until it is watertight (2/22/17) - Sidney Lok
2. ✓Put the two halves of the sedimentation tank together (3/8/17) - Sung Min Kim
3. ✓Design and fabricate a tapered flocculator (3/29/17) - Sean King
4. Run a test with the tapered flocculator and analyze performance results (5/4/17) - Sidney Lok
5. Run tests with and without rapid mix component and compare the two performance results (5/8/17) - Sung Min Kim

Report Proofreader: Sung Min Kim