Fabrication Team: OStaRS Sub-Team, Spring 2016

Mengqi Jiang and Subhani Katugampala

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Abstract

The construction of Open Stacked Rapid Sand Filters, or OStaRS, has been determined to be a difficult and labor-intensive process. The absence of a uniform installation procedure and proper construction methods leads to the overall inefficiency of the OStaRS assembly process. The Spring 2016 OStaRS Fabrication Sub-Team was tasked with developing three design modifications to ease with installation, which include a spacer system to be installed between filter modules, a movable platform for operators to stand on during assembly, and a holder system to fixate the dead end of the filter trunk line. The team has designed and fabricated the spacer and the platform systems. These designs were successfully stress tested, approved for field implementation, and are currently set for installation in one AguaClara treatment plant.

Introduction

OStaRS

In an AguaClara treatment plant, filtration is the last process of the treatment train. After influent water passes through flocculation and sedimentation, water enters the stacked rapid sand filters for final removal of any residual particles before disinfection and distribution. OStaRS, or Open Stacked Rapid Sand Filters, are currently installed in AguaClara treatment plants in Honduras. These filters differ from traditional sand filters because of their unique stacked geometry. Instead of one large layer of sand in which water enters on top of the sand and exits underneath, the multiple inlets and outlets create varied points of entry and exit within the contiguous sand bed. The stacked nature of the OStaRS filters consolidates the necessity of 6 traditional sand filters.

Since the OStaRS filters are open to the atmosphere, a filter depth of 4 meters is required in order to initiate backwash. These filters are typically constructed in larger communities requiring a plant flow rate greater than 8 L/s. Building an OStaRS filter in plants with flow rates below 8 L/s is unfeasible because the sheer size of the filter will dominate the remainder of the plant and result in unnecessary costs. For these small plants, the preferred filter type is a stacked rapid sand filter with an enclosed top (EStaRS).

OStaRS Design Specifications

OStaRS filters are approximately 4 m deep with a cross-sectional area of 1 m by 1 m (San Matias). They contain six layers of uniformly sized sand divided by four inlet and three outlet modules. One inlet module, shown in Figure 1 below, consists of a trunk line (which is connected to the filter entrance box via a flexible rubber fitting), two manifold lines (which holds the module together and serves as a structural support) and slotted pipe branches in between (which distributes water into and out of the filter). The slotted pipe branches are a feature of all existing plants except for the plant in San Matias. Future plants will adopt the inlet manifold design of the San Matias OStaRS filter, which consists of PVC branches with orifices aligned along the bottom and PVC sheets attached to the sides to serve as wings in order to prevent sand in the manifold system.

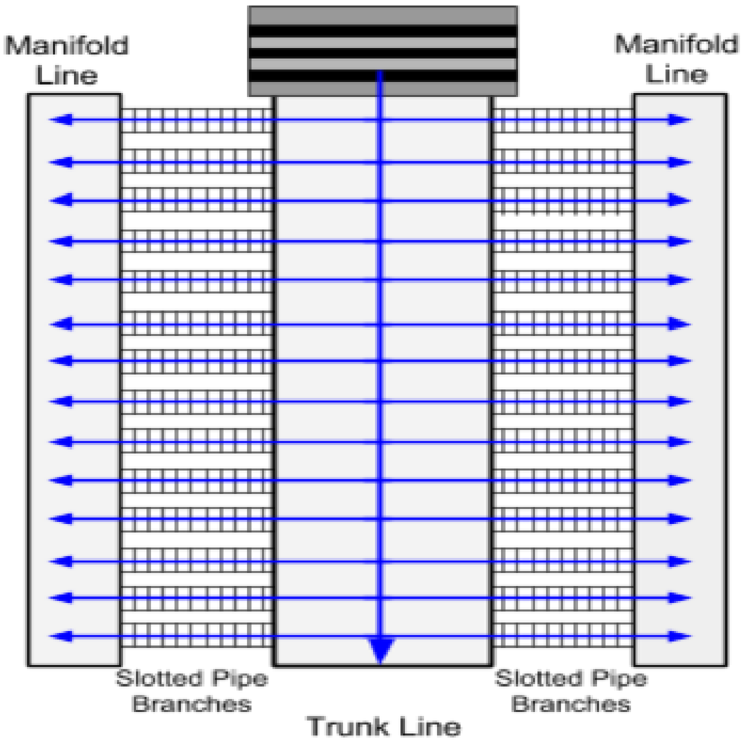

Figure 1: Top view schematic of an inlet module for an OStaRS filter. The arrows depict the flow of water from the filter entrance box to the sand filter via slotted pipes. In newer plants, the distribution of water from the inlet module to the sand filter is through orificed pipes with wings to create a sand exclusion zone.

OStaRS Assembly

To properly install OStaRS filters, an assembly process has been developed that is used in AguaClara plants. First, operators assemble the seven modules outside of the filter. This module assembly process currently includes attaching hose clamps around the entire module to ensure rigidness and stability. Once the modules are completely assembled, the operator enters the filter and begins the installation of the modules. Modules are lowered in one by one by using a cable tied around the trunk line. The operator then guides the trunk line into the flexible rubber (Fernco) fitting and the slotted pipes should be orientated sideways to prevent being deformed by the force given by water. To ensure that the module is securely inside the Fernco fitting, the operator uses a wooden oar to anchor the trunk line tightly in place. Once the trunk line is properly inserted and the module is level, the operator tightens the hose clamps around the Fernco fitting. After this, the PVC support is placed around the trunk line and four spacers are placed under the manifold lines, as shown in Figure 2 below. To provide additional stability and to prevent any movement of modules, hose clamps are attached around every three layers.

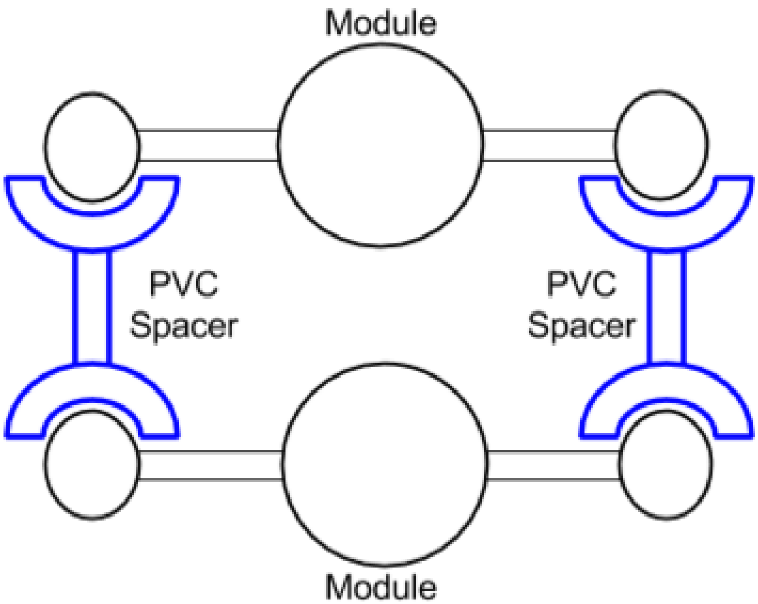

Figure 2: Old design for a spacer system shown with two modules attached in a side view. The spacers are PVC pipe stubs with PVC Tees cut in half to hold manifold lines from above and below.

Challenges

The assembly of the filters in Honduras is an area for much needed improvement. Specific design modifications can aid operators in easily constructing and installing the filters. Currently, operators stand on the previously installed modules or in the gaps between the slotted/winged pipe branches in order to assemble new modules. The disadvantage of this method of assembly is that pressure will be exerted on the modules from the force of standing, causing the PVC module systems to deform. Additionally, the gaps between the slotted pipe branches are 10 cm (San Matias), limiting the range of movement for operators to properly install the manifolds.

Furthermore, the vertical forces exerted during backwash can cause the module itself to shift and deform, considering it is only fixed into the wall in one location (via the trunk line). To fix this issue and to provide additional security, spacers have been added in between the modules in the AguaClara filters. The spacers are designed to hold the manifold lines of two modules together and maintain a fixed distance between modules. The current design implemented in newer AguaClara plants is a slight variation of the design shown in Figure 2 above. Instead of the halved PVC Tees, the spacer is simply a 2" PVC pipe stub of 20 cm length with cables threaded through to tie all modules together, as shown in Figure above.

This semester, the team's primary goals were to design and fabricate filter modifications that would aid in the assembly process. These modifications are in the form of module spacers, a movable platform, and a trunk line support system.

Methods and Discussion

The main task of the Spring 2016 subteam is to determine how to redesign the filter layout to optimize the filter assembly. This optimization is being considered in regards to additions of spacers to fix modules in place and movable platforms to assist with installation.

Spacers

The spacer was meant to serve as a device to hold the modules of a filter in place. Due to the large forces from the initiation of backwash, modules have a tendency to shift from their original position. To prevent any shifting from occurring during filter operation, a method must be devised to firmly attach all modules together and fix them to the filter itself. A potential attachment method is the following spacer design. The team brainstormed various proposals to accomplish this task, which can be found in detail below.

Iteration 1

Initial Spacer Design

The first design for a spacer system is depicted below in Figure 3. The goal for this design was to determine the constraints of the spacers that will be utilized between modules.

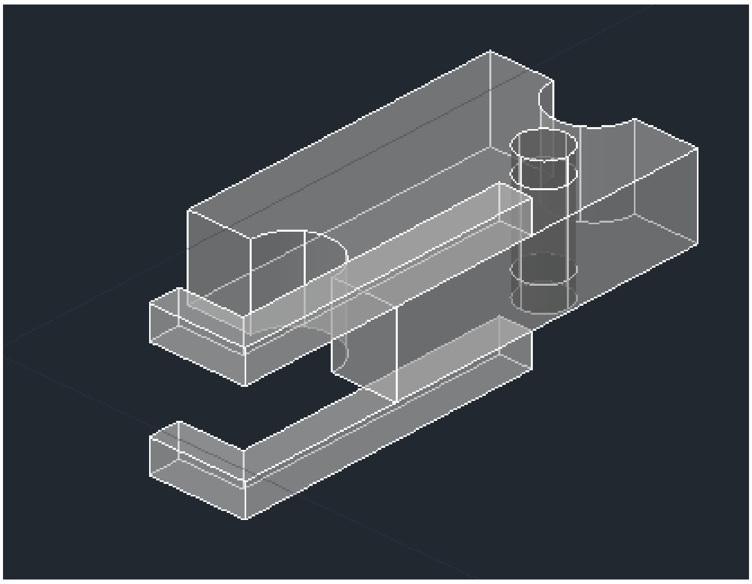

Figure 3: The initial design of the spacer in an OStaRS filter created in AutoCAD. This spacer contains two L- brackets attached to a PVC sheet spacer and a long PVC rod to attach two spacers together. The manifold line of the module will rest in the semicircle shaped cutouts of the spacer.

Design Constraints:

- Spacer length should be no more than the center to center distance between modules (20 cm).
- The cutouts on the top and bottom of the spacer should be no less than the diameter of the manifold line (5.08 cm).
- The L brackets should be long enough to receive the rod from the spacer below.
- The entire front-to-back width of the spacer (including the width of the two L-brackets) should be no more than the space between two slotted pipes (10 cm).

Initial Spacer Design Process

The team drew the initial spacer design in AutoCAD and created a cardboard prototype before completing fabrication with PVC sheets. The cardboard prototype consists of cardboard cutouts of the AutoCAD drawing to represent the spacer and a PVC pipe stub to represent the 2" manifold line. To test the feasibility of the design, team members used the cardboard prototype along with PVC pipes to mimic the installation procedure of modules in AguaClara plants.

Initial Spacer Design Analysis

When the design was tested using the cardboard prototype, the team determined a design flaw. The team had not envisioned how the spacer would have to maneuver around a 2” manifold line. During testing with the cardboard prototype and PVC pipe stub, the team found that the spacer was obstructed from properly attaching due to the presence of the pipe stub. The team decided that the next steps should be to determine a design that can easily be inserted around the manifold line.

Iteration 2

Second Spacer Design

The second design for a spacer system is depicted below in Figures 4 and . The main modification of spacer design was the L shaped latch replaced by a straight latch with slots. The design constraints for the spacer were unchanged.

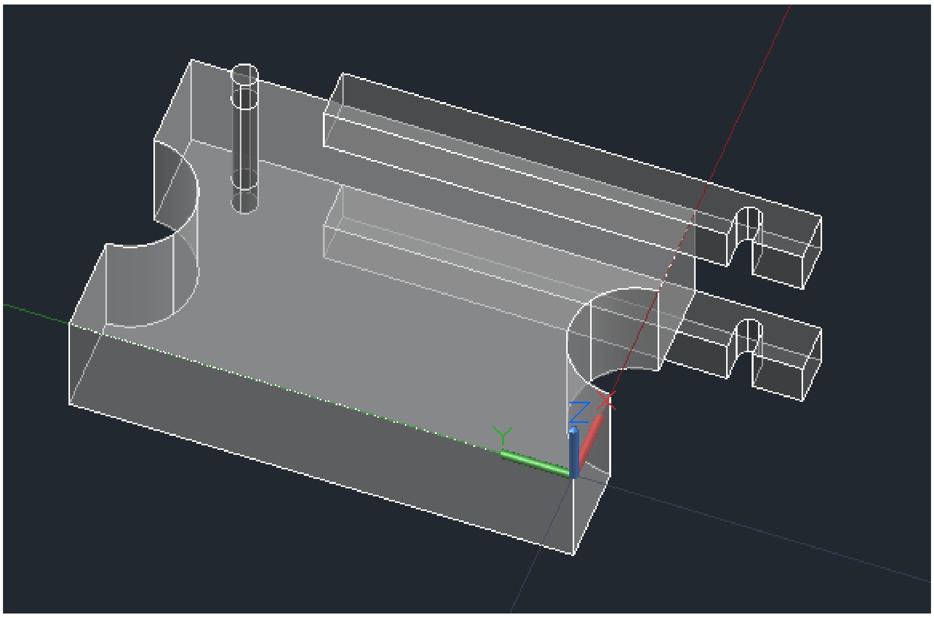

Figure 4: The second design of a typical middle spacer in an OStaRS filter created in AutoCAD. This spacer contains one main modification from the previous design. Instead of having L-brackets attached to the spacer, latches with slots will be attached to the spacer. The PVC rod will not change from the previous design, and it will be inserted into the slot of the latch from the spacer above.

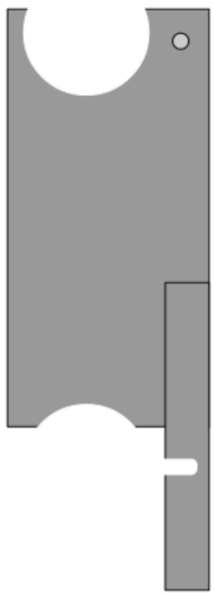

Figure 5: Schematic of a typical middle spacer in front view. This design includes straight latches with slots in the lower right corner and a rod in the upper right corner.

Second Spacer Design Process

Based on the previous design, the team decided to replace the L-brackets with latches to remove any possibility of obstruction by the manifold line during the assembly process. Once this design change was proposed, the director of the AguaClara program, Professor Weber-Shirk fabricated two wooden prototypes. These prototypes were built to scale and made to fit the design constraints listed above in the Initial Spacer Design section. With the aid of the wooden prototypes, the team determined that this new design of the spacer was a more feasible option. The team replicated the insertion of a spacer with the module in place and found that it could be done without difficulty.

After testing the spacer, the team contacted the AguaClara engineers in Honduras, Jonathan Christensen and Walker Grimshaw, to get their feedback on the proposed design. They had agreed that this design was preferred to the previous design. Additionally, they had concerns about how to prevent the natural tendency of module movement during filter operation. This design did not consider the method of fixing the top and bottom spacer to the filter, which would address the concerns of the modules moving during filter operation.

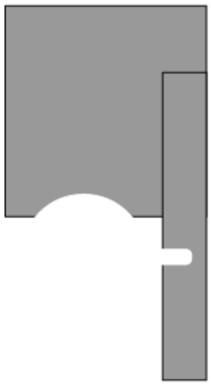

Figure 6: Schematic of the second design for the top spacer in front view. This design includes the straight latch with slot in the lower right corner.

The team then evaluated possible options for attaching the top and bottom spacers to the filter. The top spacer was designed similar to the spacer shown in Figure 6. The top half of the typical middle spacer (including the PVC rod) will not be necessary since there will not be a module resting on top. This spacer will rest on the manifold line and attach to the side of filter to prevent any upwards movement of the system of modules or potential rotation of the spacer system. The exact mechanism of this connection was originally designed as an eye bolt inserted into the side of the filter. The top spacer might contain a hole drilled into the top corner closest to the filter wall to allow for a hose clamp or cable to connect the spacer to the eye bolt.

Figure 7: Schematic for the second design of the bottom spacer in front view. This design includes the rod in the upper right corner.

The bottom spacer was designed similar to the spacer shown in Figure 7. The bottom half of the typical middle spacer (including the latch) will not be necessary since there will not be a module resting below. This spacer was designed to rest on the filter floor and attach to the stainless steel loop that is set into the filter floor via a slot in the body of the spacer. When the spacer is connected to the stainless steel loop, the module is effectively secured. Originally, the team was considering reorienting the stainless steel loop to develop an easier technique to fix the spacer to the filter floor. However, after suggestions from the engineers in Honduras, the team decided to not modify the current filter floor layout in the event that this proposed spacer system does not work as effectively as designed. In that case, the team in Honduras will revert to the previous design of 2" PVC pipe stubs with cables.

After discussion with Professor Weber-Shirk regarding the attachment mechanism of the top spacer, which was a concern of the team, he advised the team to focus on preventing rotation of the spacer as opposed to mounting the spacer to the wall. Due to the upward forces generated during backwash, the rotation of the spacers is a larger concern. To remedy this issue, the team plans to drill a hole through the two latches and the body of the spacer below. During assembly, the operator will insert a screw through the latches and secure the screw in place with nuts on either end. This screw will effectively lock the spacer in the closed position, thus preventing any likelihood of rotation.

Top and Bottom Spacer Design Parameters

The bottom spacer needs to be fixed in the filter in order to constrain its vertical movement. Therefore, the team modified the normal spacer to fit onto the stainless steel loop which is constructed in the floor of the filter. Figure 8 below shows the current filter floor setup for the AguaClara plant in Las Vegas, Honduras. This loop will secure the bottom spacer to the floor to limit any vertical movement during backwash. To impede the rotation of the top spacer, the team adopted the idea of installing a cotter pin through two latches and the body of the spacer below. The rotational issue will not be a concern for middle spacers since the modules resting on the spacers can stabilize them.

Figure 8: The stainless steel loop at the bottom of the tank in Las Vegas, Honduras.

Second Spacer Fabrication

With the design amendments in mind, the team moved forward to fabricate the spacer using PVC sheet, which is the material that will ultimately be used in Honduras. A materials list was compiled and ordered to begin the fabrication process. Figure 9 below shows the pieces needed to fabricate the spacers while figure 10 below shows the proper dimensions for each piece on the PVC sheet.

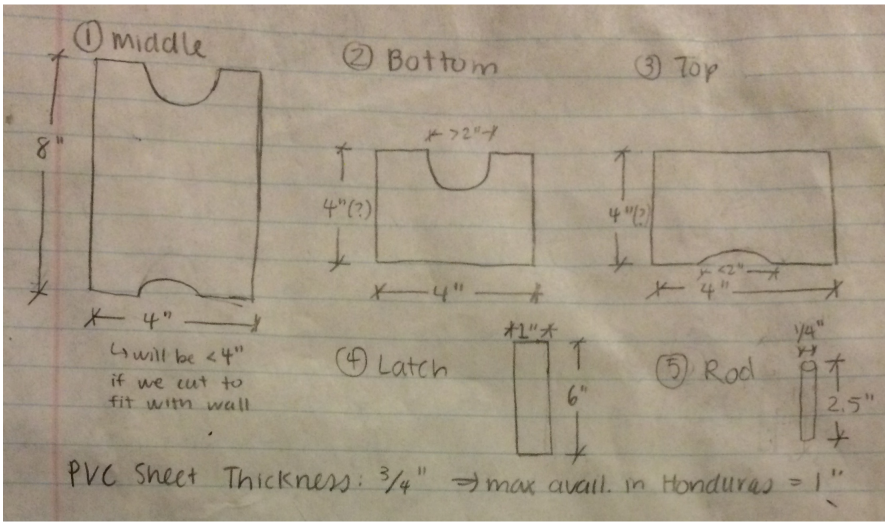

Figure 9: The stainless steel loop at the bottom of the tank in Las Vegas, Honduras.

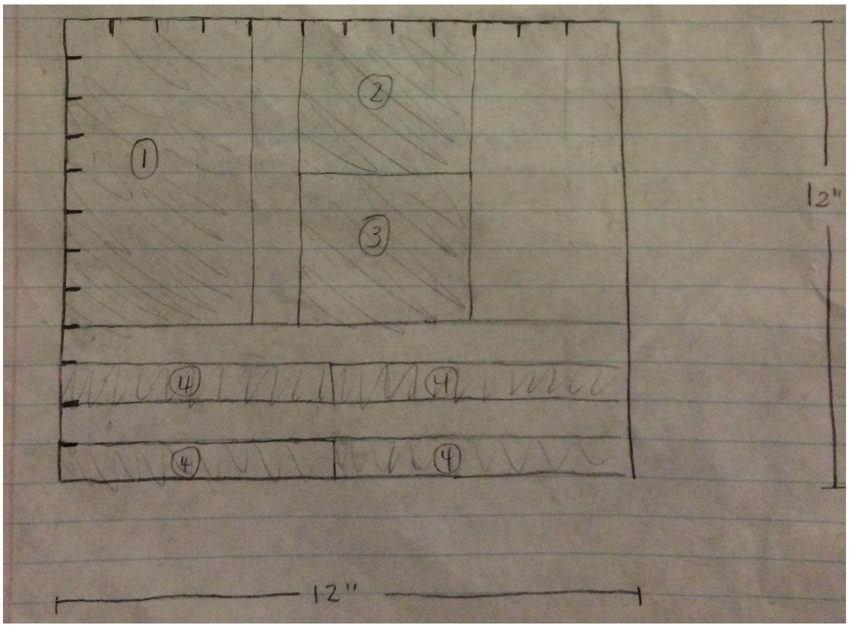

Figure 10: The PVC sheet shown with the respective pieces to create the latches and the top, middle, and bottom spacer bodies.

Materials Required:

- 12" by 12" PVC sheet of 3/4" thickness (based on a maximum 10 cm thickness, dictated by the space between two slotted pipe branches)
- 1/4" diameter unthreaded bolts

The PVC sheet was cut to create three spacers - one middle spacer, one top spacer, and one bottom spacer. The dimensions of each spacer and associated parts are detailed in Figure 9 above.

Top Spacer:

- 4" by 4" PVC sheet to form spacer body with cut out on bottom to hold 2" manifold line from below
- Two 6" by 1" PVC sheets to form latches with 1/4" slots to align with the 1/4" diameter bolt to be used as a rod
- A cotter pin through two latches and the body to lock the top spacer and prevent the rotational movement because there is no module staying on the top spacer.

Middle Spacer:

- 8" by 4" PVC sheet to form spacer body with cut out on top and bottom to hold 2" manifold lines from above and below
- 1/4" diameter bolt to be used as a rod
- Two 6" by 1" PVC sheets to form latches with 1/4" slots to align with the 1/4" diameter bolt to be used as a rod

Bottom Spacer:

- 3" by 4" PVC sheet to form spacer body with cut out on bottom to hold 2" manifold line from below
- Two 6" by 1" PVC sheets to form latches with 1/4" slots to align with the 1/4" diameter bolt to be used as a rod
- A hole on the bottom spacer for the stainless steel loop to rest on

Once the materials were obtained and the PVC sheet was cut to size, fabrication of the three spacers began:

1. Three PVC sheets were clamped together. From top to bottom, the order was top spacer, middle spacer, bottom spacer.
2. A hole saw was used to create 2" diameter cutouts for the 2" manifold line to rest on. Originally, the plan was to cut the holes directly in the center of the two clamped body pieces. However, the 2" diameter holes were not cut directly in the center to solve the problem with the previous design, where the presence of the manifold prevented the spacer from latching on properly.
3. For the spacers with the 1/4" diameter rod (middle and bottom), a 3/16" diameter hole was drilled in the upper right corner. The drilled hole was smaller than the rod to create the tightest possible fit. A drill press was used to insert the 1/4" diameter bolt into the hole so that equal amounts of the bolt were extended from both sides of the spacer body.

4. For the latches, 1/4" diameter slots of 0.5" length were created using a drill press. The latches were glued to the bottom right side of the top and middle spacers. A total of two latches were glued onto each spacer (in front and in back) for the rod to rest in.

The finalized fabrication of the middle spacer is shown in Figure 11 below.

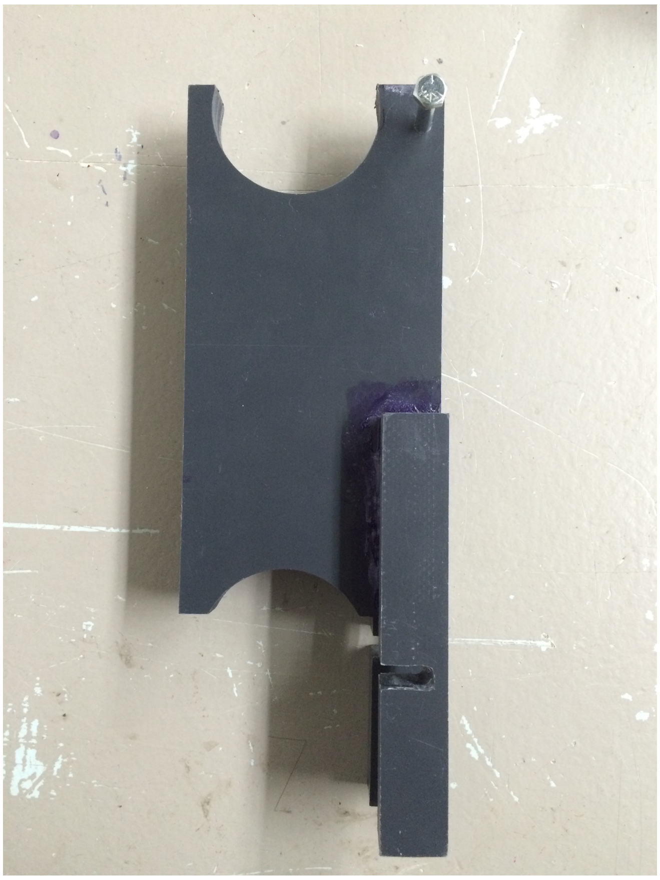

Figure 11: The completed fabrication of a middle spacer. The top right corner depicts the 1/4" bolt that will serve as a rod. The bottom right side of the spacer depicts latches with slots that will hold the rod of the spacer below. The cutouts are shown on the top and bottom of the spacer body. The cutouts are not symmetrical to allow for a greater degree of rotation of the spacers during installation.

Second Spacer Design and Fabrication Analysis

Based on the previous failure of the first design, the team paid special attention to the importance of testing the model with pipes. The wooden prototype displayed success in installation, as the team did not face the same problem of obstruction by the 2" manifold line. Once fabrication in PVC was complete, the team sent a video of the spacer configuration to the engineers in Honduras. The feedback from the team in Honduras was mostly positive, as they determined the

PVC spacers would be the preferred option for spacers in the OStaRS filters. The criticism presented were in the form of erroneous design considerations. The first concern was that the total front-to-back thickness of the spacer was too large. The spacer should be modified to account for a maximum allowable thickness of 5 cm, as opposed to the current thickness of 6 cm, for the spacer to fit comfortably between the slotted pipe branches. Additionally, the proposed locking mechanism of placing a screw through the latches and the body of the spacer below with nuts on either side of the latch was determined to be too complex. A preferred option was determined to be a locking mechanism without the necessity of threading. Finally, the bottom spacer was asked to be redesigned to aid in simplicity of installation. With the bottom spacer resting on the filter floor, the insertion of the bottom spacer would have been difficult, especially with the stainless steel loops in place.

Iteration 3

Final Spacer Design

Based on the comments and suggestions from the engineers in Honduras and Professor Weber-Shirk, the team found a locking mechanism that did not require the use of threading. To prevent rotation of the spacer, a hole will be drilled through the latches of the spacer as well as the body of the spacer below. Instead of placing a screw and locking the screw into place with nuts, cotter pins will be used. The cotter pins do not require threading, thus simplifying and shortening the locking process. Modifications to the bottom spacer will also be made, since the team determined that the combination of the cotter pin locking mechanism and the stainless steel loop slot will be enough to secure the bottom spacer.

Figure 12 below depicts a detailed view of the exact placement of the components for the spacer.

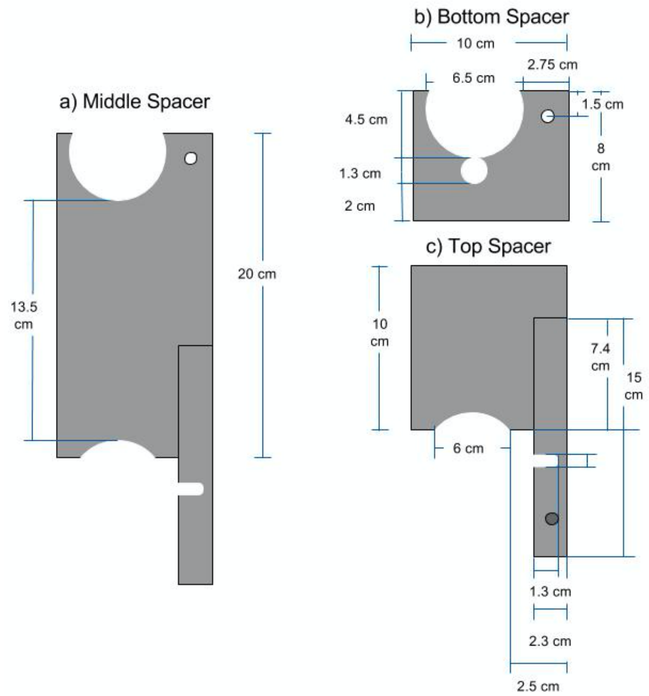

Figure 12: Detailed schematic of the (a) middle, (b) bottom) and (c) top spacers with their respective dimensions.

The team moved forward to purchase cotter pins and make holes through the spacer body and latches. The location of the holes for the cotter pins is shown in Figure below.

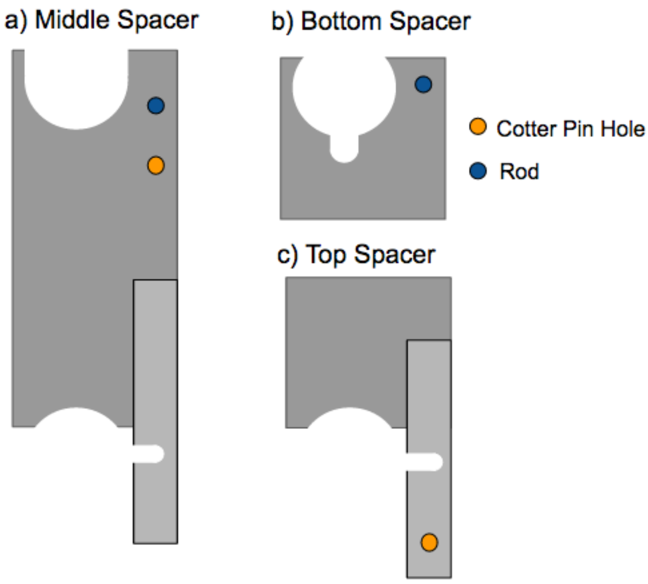

Figure 13: Schematic of the (a) middle, (b) bottom, and (c) top spacers with the location of the holes for the cotter pins.

Once inserted, the cotter pins performed as expected for all except the top spacer. As shown below in Figure 14, the top spacer was still able to rotate slightly, even with the cotter pin in place.

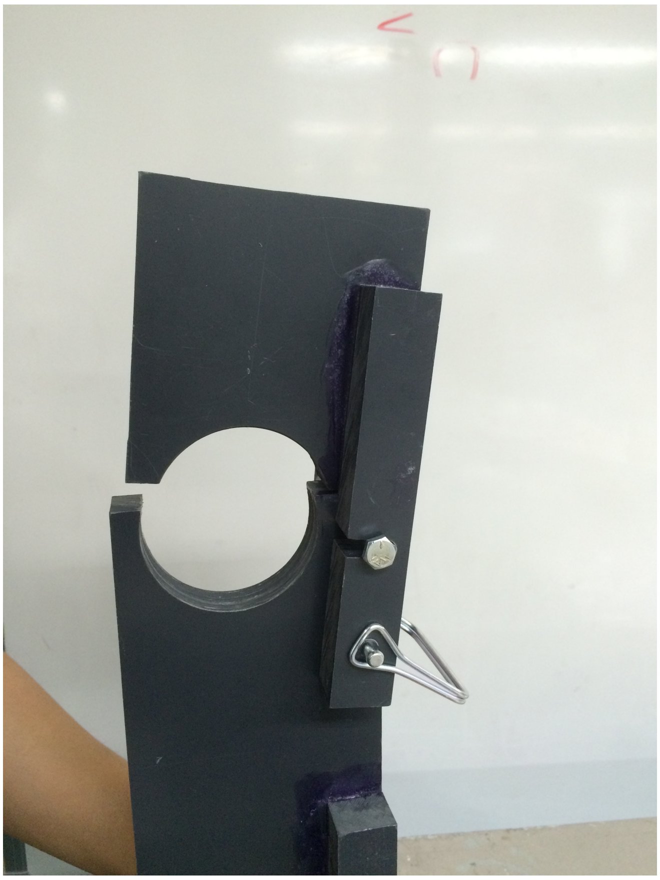

Figure 14: A close-up of the top spacer illustrating the degree of rotation exhibited even with a cotter pin installed.

Final Spacer Design Analysis

The cotter pin attachment was initially meant to serve as the means for preventing rotation for the top spacer only. However, further evaluation led to the conclusion that the cotter pin should be included in all of the spacers for additional security. This will serve to fix the bottom spacer to the filter floor without needing to extend the body of the bottom spacer to the floor. While having the bottom spacer rest on the floor is optimal for stability purposes, ease of installation will be sacrificed, which was ultimately deemed the unfavorable option. Additionally, due to the stainless steel loops installed on the filter floor, the bottom spacer will have to include an additional hole with which the stainless steel loop can be attached. This hole is shown in Figure 12 above.

As shown in Figure 14 above, the cotter pin attachment did not prevent rotation of the spacers, which was a major concern for the spacer system. This degree of rotation was deemed to be problematic by the engineers in Honduras who were concerned that the instability of the spacers could cause dislodging of the modules. The team hypothesized that the rotation was a result of the slot in the latches providing space for the top spacer to rotate. The engineers advised the team to determine a method to minimize any rotation by the spacers.

Furthermore, the engineers in Honduras have advised the team that the front-to-back width of the spacer is too wide to fit in between the branches of the module. One way to remedy this is to use thinner PVC sheets for the latches.

Modified Final Spacer Design

Even though the cotter pin was meant to eliminate rotation of the spacers, the top spacer allowed some degree of movement. The slot in the latches, which was determined to be the point of rotation, was replaced by a hole. The hole/cotter pin system eliminates any tendency for rotation.

The modified final spacer design illustrates the new locations of cotter pins on all of the spacers as well as the replacement of the slot in the latches of the top spacer. Consequently, the removal of the rod in the middle spacer closest to the top spacer eliminates the necessity of the top spacer to be rotated during spacer assembly. The other spacers must be rotated into place to accommodate for the filter module. Since a module will not be installed above the top spacer, the top spacer can be simply lowered into place.

This design still needs to be tested to determine if it solves the problem of the top spacer rotation.

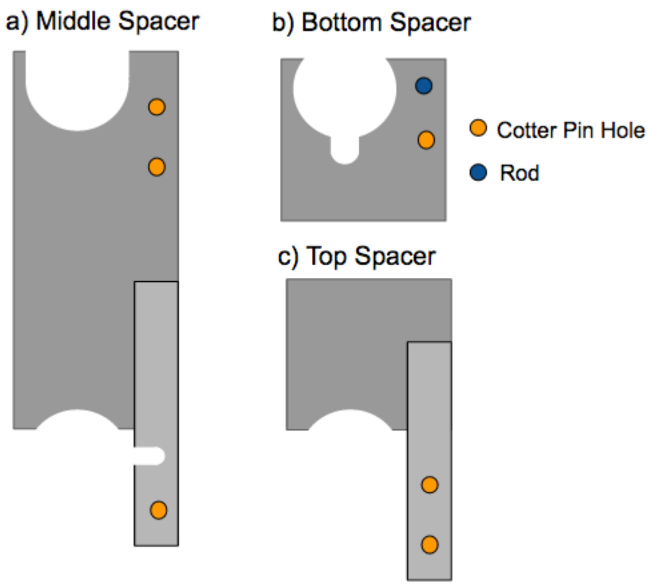

Figure 15: Final design schematic of the (a) middle, (b) bottom, and (c) top spacers with the location of the holes for the cotter pins.

Movable Platform

The movable platform was designed first, to offer a safe and convenient place for operators to stand on when installing the modules in the tank, and second, to prevent the modules from deforming from the force of the operator's weight.

This platform was meant to be collapsible so that operators can easily move the platform to the next location of installation. The platform is two separate planks attached in the middle by a hinge to sustain its collapsible nature. On one of the planks, angle brackets were installed on either side so that once the platform is extended, the platform is stable.

Iteration 1

Initial Platform Design

The first design for a platform system is depicted below in Figures 16 and 17 below depicting the view when extended and when collapsed, respectively. The purpose of the platform is to provide a more secure apparatus for operators to stand on while installing modules.

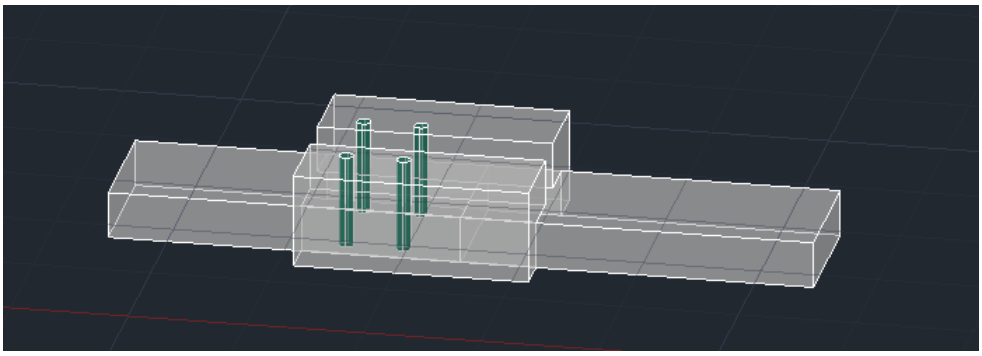

Figure 16: The initial design for a platform when extended created in AutoCAD. Shown above is a system of two boards connected together by a hinge. To increase the stability of the extended boards, two angle brackets, which extend over both boards, are firmly installed with screws to prohibit movement.

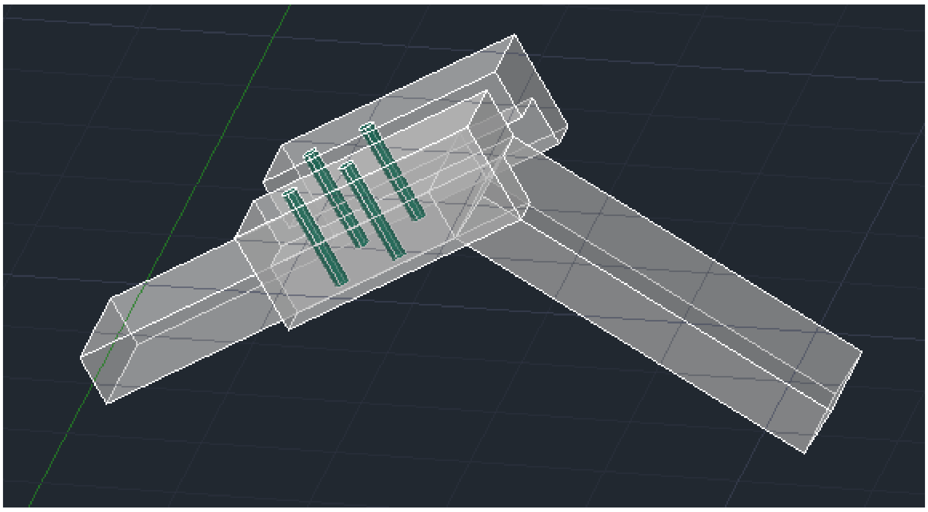

Figure 17: The initial design for a platform when semi-collapsed created in AutoCAD. Shown above is the same platform, just oriented to depict how the platform will look when folded.

This design was proposed by the director of the AguaClara program, Professor Weber-Shirk. The team took this design and began to determine the design constraints.

Design Constraints:

- The platform should be oriented parallel to the trunk line so that the operator can walk along the platform to fully install and secure the module.
- The platform should be offset from the center of the trunk line to allow for ease of tightening the flexible rubber fitting.

Initial Platform Fabrication

The movable platform consist of two boards which were connected by hinges (0.119 inch thickness). The prototype now is 70 cm long for each board (for a total platform length of 1.40 m), with a thickness of 5 cm and width of 20 cm (based on people's length of feet). To reinforce the safety of the platform, one of the boards had two angle brackets with four screws that prevents the boards from collapsing when operators walked on it. The operators would extend the platform into slots along the filter wall to provide a resting surface for the platform. These slots would be constructed during the initial construction of the filter as rectangular channels. For AguaClara plants that will be constructed, the channels will be made during the construction of the filters. As the concrete for the filter is being poured, contractors will create channels that run almost the entire length of the filter. The channels are oriented parallel to the trunk line and located just above the position of every other module. These channels will allow for the platform to be easily moved to make the assembly process easier. Once the platform is properly inserted, the operator then will receive the module and assist it into the flexible rubber fitting and walk to the other end of the module to push the module completely into the fitting. The configuration of the channels was under discussion with the engineers in Honduras given that waterproofing the channel in the filter is the current challenge in construction. After further consideration, the channels were designed to be rectangular in geometry and tall enough to ease the process of waterproofing the channel. The rectangular channels will be 5 cm in depth and 11 cm in height. The drawing 18 below displays the side view of the tank with channels in it.

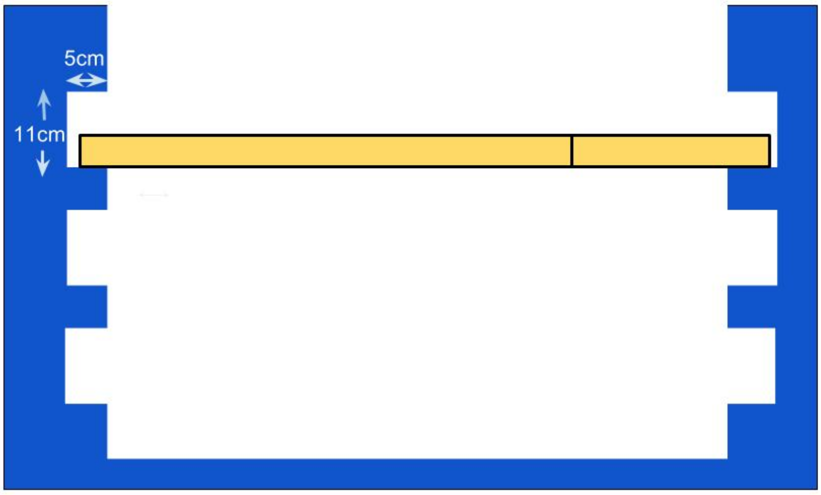

Figure 18: The side view of the tank with channels which will support the platform in Las Vegas, Honduras.

Figure 19 below shows the construction of the channels for the AguaClara plant constructed in Las Vegas, Honduras. The dimensions of the channels were determined to be a depth of 5 cm (into the wall of the filter) and a height of 11 cm. This height allows for the contractors to apply waterproofing sealant onto the concrete channel. The width of the channels were originally planned to be the width of the filter, however, after further consideration this was determined to be unnecessary. Instead, there are 25 cm gaps on either side of the channel. Channels were constructed right above the location of the third and fifth modules, as well as 15 cm above the top-most module. A channel was not constructed above the first (botttom-most) module, since operators can simply stand on the filter floor during installation.

Figure 19: The rectangular channels with the depth of 5 cm and the height of 11 cm which will support the platform in Las Vegas, Honduras.

The team conducted a stress test on the the platform (20 cm x 70 cm each x $\frac{3}{4}$ inch) on a scale in the lab, as depicted in Figure 20 below.

Figure 20: The initial fabrication of the full scale movable platform. This picture was taken directly before stress testing.

Initial Platform Fabrication Analysis

Initial analysis has led to the conclusion that a platform design connecting two wooden boards by a hinge and providing stability with two angle brackets will most likely work. Operators can stand on the module for short periods of time as they move the platform to a preferred position in the filter. The force exerted by the operators weight will not contribute to the overall instability of the modules due a momentary strain.

The team conducted a stress test and determined that the platform could withstand forces of under 160 lbs applied in the center. The failure was displayed by the cracks in one board, which occurred along the placement of the holes as shown in Figure 21 below. According to the suggestion of the engineers in Honduras, the board should be capable of handling weights of 300 lbs to ensure that operators can comfortably and safely assemble filter modules without risk of the platform collapsing. The stress test demonstrated the weakness of the wooden boards used.

Figure 21: The full scale platform was broken when the team conducted stress testing on the scale. The highest observed force before failure occurred at 160 lbs.

Iteration 2

Modified Platform Design

After further evaluation of the initial platform design, the team determined a potentially easier fabrication procedure for the platform. Instead of designing a movable platform, the team thought it would be preferred to use a wooden plank as the platform and simply install stainless steel rungs into the filter wall for the platform to rest on.

Modified Platform Design Analysis

The team ultimately decided against this idea after they talked with the AguaClara engineers in Honduras, Jonathan Christensen and Walker Grimshaw. The engineers advised the OStaRS team that the stainless steel rungs would interfere with installation of modules. Additionally, these rungs had the potential of deforming due to the weight of the operator, which would lead to instability of the concrete filter walls. The AguaClara engineers instructed the team to return to the initial design and begin thinking about the necessary constraints of this system.

Iteration 3

Final Platform Design

Based on the failure of the original platform design consisting of two wooden boards, a hinge, and two angle brackets, the team instituted the realized design amendments. First, a higher quality of wood was obtained to increase the potential load capacity of the platform. This wood was Douglas Fir lumber with dimensions 2 in by 10 in by 8 ft. Moreover, since the wood was thicker than the previous design, wider angle brackets were sought. From the analysis of the previous platform, angle brackets that extended the entire length of the platform were thought to increase the overall stability and performance of the platform. However, since the wood platform is thicker, the wood itself is strong enough to support the maximum load capacity of 300 lbs. For this reason, the angle bracket will not have to extend the entire length of the platform.

This load capacity could also be increased by offsetting the hinge location from the center of the platform to one side of the platform. Since the previous failure occurred at the center where the hinges were attached, the idea was proposed to offset the hinge to preserve the original strength of one contiguous wood board. The idea behind this is that the strongest platform would be one without any cuts. The exact location of the length of the two boards has yet to be determined. Additionally, the feasibility of a slot depth of 5 cm for a 1.40 m long platform will need to be tested.

Final Platform Fabrication

Fabrication of the wooden platform was completed similar to the previous platform. The 8 ft (approximately 2.5 m) long wood board was cut to a length of 1.40 m to serve as a prototype for a platform in a 1.3 m filter. The lengths for the two wooden boards were determined arbitrarily. The team decided that the shorter board should be a minimum of 20 cm long to hold the required weight. Once the board was cut to create two boards of 24 cm and 1.16 m length, the team hinged the boards together and attached a wider angle bracket to cover the hinged portion of the platform. The purpose of the brackets is to prevent any tendency of the platform to collapse. The weakest point of the platform is at the location of the hinge, so if the bracket is placed to distribute the load from the location of the hinge attachment, the platform should be able to carry its designed load capacity. The brackets were cut to a length of 64 cm and installed 9 cm from the end of the shorter board of the platform. Figure 22 below shows the exact configuration of the final platform design.

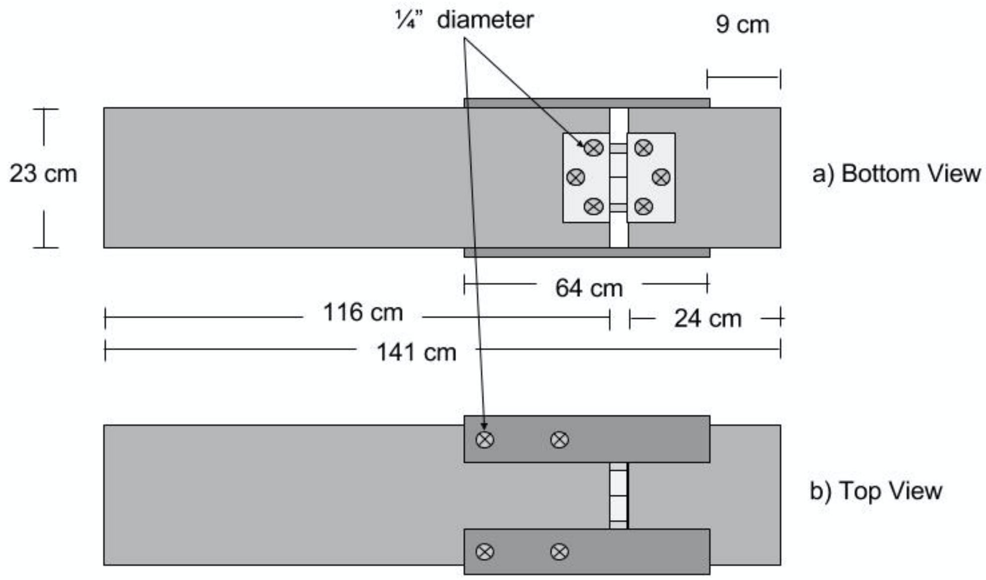

Figure 22: A detailed schematic including dimensions for the final design of the movable platform.

Final Platform Analysis

Once fabrication was completed, the next step was to stress test this platform design to determine whether or not it could withstand the design capacity of 300 lbs. The team conducted stress testing by placing one end of the platform on the scale and supporting the other end with cinder blocks. The team recruited a few participants to stand on the platform since the team was confident that the platform would be able to surpass its load requirement. Three participants stood on the platform, with a combined weight of over 350 lbs. There were no signs of failure in the form of deformation or crack formation during or after the test. The stress test was ultimately concluded a success since the platform performed better than expected.

While the platform exceeded standards in terms of load capacity, there is room for improvement in terms of fabricating a platform that can be immediately used in AguaClara treatment plants. In terms of the fabrication process, the platform was very simply assembled. However, this platform was quite heavy and could lead to difficulty in inserting into the filter slot for a sole operator.

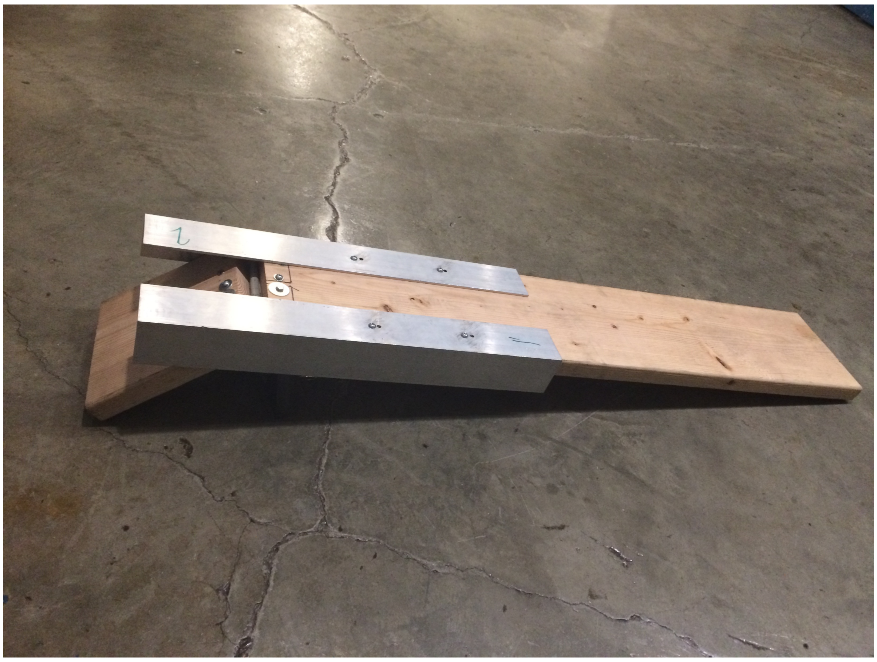

Figure 23: The finalized platform design shown after stress testing. The platform is slightly bent to show the flexibility of the design.

Holder

The holder system or trunk line support system is designed to support the dead end (the end not secured with the Fernco fitting) of the trunk line. The trunk lines in San Matias are supported adequately, and are the model for trunk line supports in future AguaClara plants. This support system consists of stainless steel brackets that extend out of the filter wall on either side of the trunk line. Once the filter module is installed, PVC clamps surround the trunk line and are clamped to the stainless steel brackets. This system effectively prevents any vertical movement during filter operation, but does not stop the horizontal movement. Since the trunk line is attached via Fernco fitting which is not a very tight connection and since the trunk line does not extend the entire filter length, while the filter is running, the trunk lines tend to shift slightly out of the Fernco fitting. Therefore, the primary goal in terms of the holder system is to figure out how to fill the gap between the trunk line and the filter wall to stop any horizontal shifting.

Iteration 1

Initial Holder Design

The engineers in Honduras suggested placing a PVC plate to fill the gap between trunk line and the filter wall to limit the movement. This PVC plate will be clamped in the stainless steel brackets. If this is deemed the best solution, no changes will have to be implemented to the existing system. The feasibility of this idea will be investigated after further consideration and experimentation.

Conclusions

From the lengthy brainstorm and design process, the team learned the number of parameters that must be considered before moving forward in construction. While brainstorming possible designs for spacers, the team neglected to consider that there would be a module between spacers. This led to the inability of the spacers to work as designed. Keeping this in mind, the team made some modifications on the latch to make the spacers function. After the fabrication of the PVC spacers, the team determined the proper shop techniques necessary to create a functional spacer. Slight oversights have led to improper fabrication of the PVC spacers. In the future, the team will know to utilize the proper tools to create an accurate model. Additionally, in regards to the platform, the team determined that simple solutions can provide necessary results. The final platform design, which used a higher grade of thick wood, can easily be implemented in AguaClara water treatment plants with constructed channels to provide operators with a sturdy surface to stand on while installing filter modules.

Based on consultations with AguaClara engineers in Honduras, the design of the spacer and the platform are feasible and will be installed in Las Vegas, Honduras in a few months. The new installation method of the spacer removes the need for hose clamps, which can become difficult to maneuver when full of sand. Instead, the new system utilizes zero tools for installation and only one extra piece to secure the spacers (cotter pin), making this a more preferred option to keep modules in place. For the platform, the new design provides a safe place for operators to stand on when installing modules so that they can assemble the modules with ease.

Future Work

The team will send the Mathcad and AutoCAD of the designs in few days to the engineers in Honduras to assist them with fabrication in the Las Vegas treatment plant. Some complications with filter assembly still remain unsolved. First of all, the hose clamps used to hold the whole system together and inhibit the branches from moving off the trunk line are tedious to assemble. Multiple hose clamps are needed to wrap around one module. Additionally, hose clamps become difficult to assemble and disassemble with the addition of sand. Furthermore, the designed platform is undesirably bulky, therefore, it is not convenient for operators to easily manipulate. A platform constructed with a lighter material will ease the process of filter assembly. Finally, the spacer assembly process can be simplified and made cheaper by making cotter pins instead of purchasing them.

Future teams should work on finalizing design specifications to accelerate the process of creating AutoCAD drawings, testing the new spacer with cotter pins in the top spacer instead of the rod/slot system, fabricating the platform with a lighter wood, and creating a comprehensive assembly manual for contractors.

Semester Schedule

Task Map

OStaRS

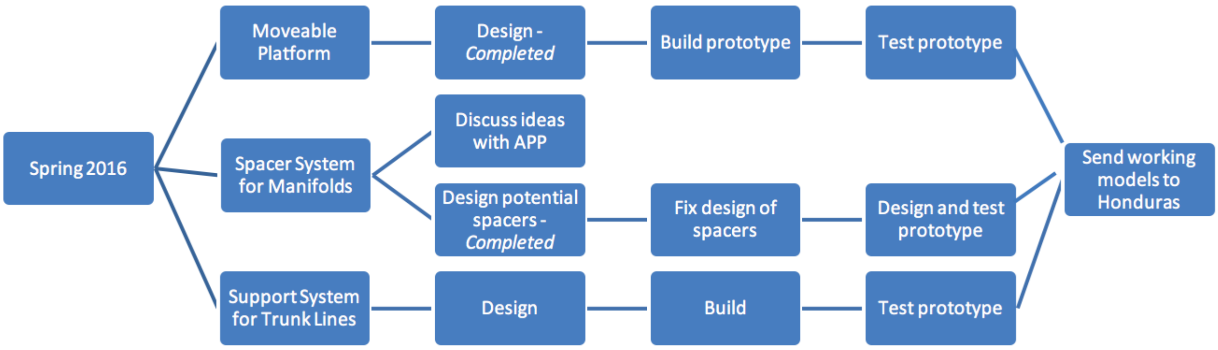

Figure 24: OStaRS Subteam Detailed Task Map

Task List

1. **February 12:** Completed Detailed Task List and Update Wiki Page (individual and team)

2. **February 19:** Completed Literature Review.

3. **February 24:** Completed sketches for spacer system and movable platform.

4. **February 26:** Completed drawing the designs in AutoCAD. Completed Research Report 1.

5. **March 4:** Presented designs to Monroe and AguaClara engineers. Selected design to construct and purchase construction materials.

6. **March 11:** Completed Research Report 2.

7. **March 14:** Completed presentation for symposium.

8. **March 18:** Completed midterm peer evaluation. Updated Individual Contribution Page.

9. **March 25:** Finished fabrication of spacers and platform.

10. **April 8:** Completed testing and evaluation of constructed spacers and movable platform. Completed Research Report 3.

11. **April 15:** Presented findings and model to Monroe and AguaClara engineers. Applied any feedback received.

12. **April 22:** Completed Research Report 4.
13. **April 29:** Complete spacer sand test.
14. **May 6:** Create fabrication manuals for spacer and platform
15. **May 11:** Complete Final Report draft. Clean up lab spaces.
16. **May 18:** Complete Final Report and peer evaluations. Update individual wiki page and team page
17. **May 20:** Upload Final Presentation and Final Report on team wiki page.

Report Proofreader: Mengqi Jiang