# Agassiz

## 2020 Concrete Canoe Technical Proposal

Northern Arizona University

February 17, 2020

Dear Committee on National Concrete Canoe Competitions,

Attached to this letter is the Technical Proposal from the 2019-2020 Northern Arizona University Concrete Canoe Team. This document is the response to the Request for Proposal for the standardized concrete canoe design. The attached Technical Proposal displays the developed design from the Northern Arizona University Team. This design offers a simple, yet innovative approach that is executed accurately.
The design and construction of the canoe has been performed in full compliance with the specifications outlined in the Request for Proposal. The team acknowledge that the entire team has reviewed the Material Technical Data Sheets and Safety Data Sheets. The team acknowledges receipt of the Request for Information Summary. The team's entry complies with the responses provided in the Request for Information Summary. The anticipated registered participants are qualifying student members and National Student Members of the American Society of Civil Engineers and meet all eligibility requirements. The registered participants are as follows:

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Please contact the Project Manager, Kristen Rasmussen, if there are any questions or comments.

Sincerely,
**Northern Arizona University 2019-2020 Concrete Canoe Team**


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The Northern Arizona University's Concrete Canoe team has brought a taste of Flagstaff, AZ with this year's proposed canoe *Agassiz*. Northern Arizona University (NAU) is located at 7,000-ft above sea level in the picturesque mountain town of Flagstaff, at the base of the 12,000-ft San Francisco Peaks. One of the five peaks is Agassiz. Northern Arizona University's (NAU) canoe, *Agassiz,* showcases a simplified hull design to maximize construction techniques and provide a high-quality product. The team is focused on displaying a well-built canoe to ensure that American Society of Civil Engineers (ASCE) is provided with the best possible canoe. Table 1 below states the critical dimensions for the canoe; construction drawings of the standardized design are provided in Section 5.0.

*Table 1: Canoe Prototype Dimensions*

| Canoe Prototype Dimensions | | |
|---|---|---|
| Length | 212.5 | inches |
| Width | 27.52 | inches |
| Depth | 14.2 | inches |
| Thickness | 0.5 | inches |
| Weight | 160 | pounds |

Other notable features include the recycling of past canoe's molds to create the bulkheads for the canoe, building a reusable pour table and a curing chamber so that future teams can utilize this equipment. This not only promotes sustainability within this team, but also will have a lasting impact on future teams. The structural analysis proved to be innovative by the utilization of Microsoft Excel™. Design variables were inserted into the analysis spreadsheet and then equations were used to determine needed quantities to justify *Agassiz's* structural capacities. This methodology was convenient for changing design variables without the need to re-analyze structural capacities, these values simply altered based on the linked cells in Microsoft Excel™. The most innovative feature of analysis was the ability to write formulas for stress and moments, which are correlated with incremental lengths along the canoe and generate outputs automatically placed onto a graph. While Microsoft Excel™ is not an analysis program, its functionality goes to show the power of simplicity and innovation through creativity. The goals for construction of this canoe was to provide a very efficient and simple setup to optimize the amount of time given within this project. The symmetry of the canoe's hull helped assist in a faster turnover rate for manufacturing the mold. The simplification of the hull allowed the manufacturer to cut the time in half when producing each cross-section. Since the hull is symmetrical, the manufacturer could then stack to cross-sections together (the same cross-section from each half of the canoe) and cut them together. This resulted in a decrease of manufacturing time by 50%. The goal for *Agassiz's* mix design was to create a more sustainable concrete mix that utilizes a lower cement to cementitious material ratio (c/cm) to achieve a lighter and stronger concrete mix, since cementitious are usually lighter than cement. Table 2 represents the percentage of each recycled material that makes up each concrete mix by volume. *Agassiz's* mix design promotes sustainability by using fly ash, silica fume, Aero-Aggregate (UL-FGA) and Poraver™ materials. This also decreased the amount of cement needed to make the concrete mix design, which resulted in an overall lighter canoe. Table 3 has the properties of the finalized concrete mixes. Both concrete mix designs are at least 70% by volume, composed of by-products or are made from recycled materials excluding Poraver™. The addition of a water proofing admixture helps to seal the canoe from within the concrete which provides an extra layer of protection against water seeping through the concrete.

*Table 2: Percentage of Recycled Material*

| Material | Interior Mix (White) | Exterior Mix (Blue) |
|---|---|---|
| Fly Ash | 4.4% | 4.0% |
| Silica Fume | 2.3% | 2.3% |
| UL-FGA | 28.3% | 28.1% |
| Poraver™ (All Sizes) | 36.6% | 36.2% |
| Total | 71.6% | 70.6% |

*Table 3: Concrete Properties*

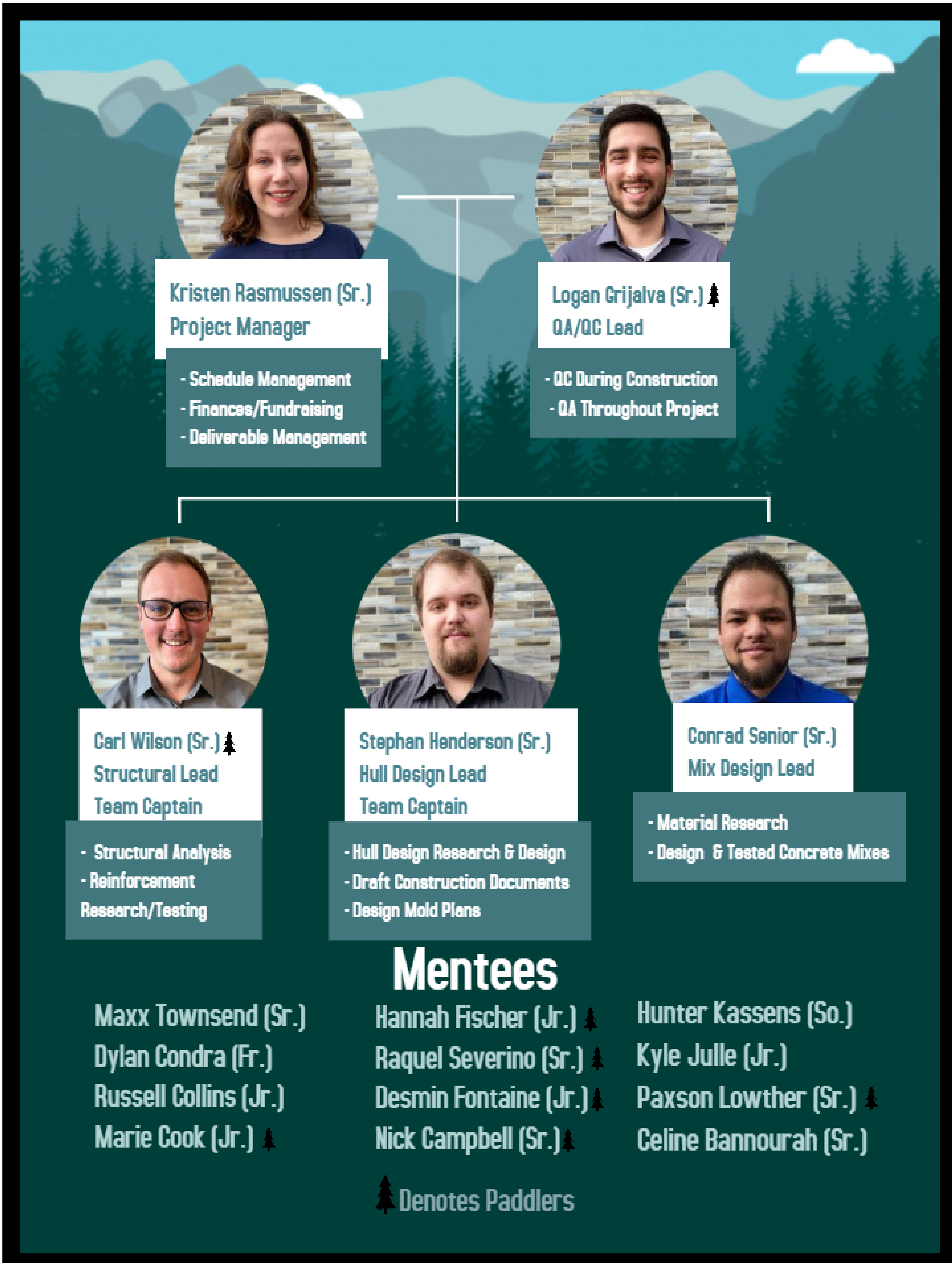
| Concrete Mix | Interior Mix (White) | Exterior Mix (Blue) |
|---|---|---|
| Wet Density | 56.1 $lb/ft^3$ | 55.8 $lb/ft^3$ |
| Dry Density (Oven dry) | 54 $lb/ft^3$ | 54 $lb/ft^3$ |
| Compressive Strength (7 day) | 1140 psi | 1230 psi |
| Compressive Strength (28 day) | 2110 psi | 2110 psi |
| Tensile Strength (28 day) | 180 psi | 180 psi |
| Composite Flexural Strength | 2080 psi | 2080 psi |
| Slump | ½ inch | ½ inch |
| Calculated Air Content | -4.6% | -5.7% |

### *2.1 ASCE Student Chapter Profile*

The Northern Arizona University ASCE Chapter mission statement is to increase a student's professional and personal network. It is also the responsibility of Civil Engineers to educate and inform the public of the Civil Engineering discipline. NAU ASCE accomplishes these objectives by getting students involved in sports throughout the year to put them into a team environment. This team environment helps members to develop a relationship with one another in the hopes of making friendships. Social events like tailgating, nacho nights, and hiking help students to take a break from a school routine and talk about interests they have and where they are from. These events help students to develop their personal and potential professional networks, make friends, and memories. General meetings and officer meetings for the club are held on a weekly basis. During general meetings, various companies come in and talk about current/ past projects they have worked on. Companies also talk about upcoming internships and full-time job opportunities. The goal for each meeting is to send the speakers back with a stack of student's resumes. To accomplish this goal some general meetings are used as a resume review with the Northern AZ Younger Member Group or the AZ Branch section. These opportunities give students the chance to speak to professionals one on one to receive helpful resume feedback. To help the community, NAU ASCE has adopted a street in Flagstaff to clean up which helps show the community that we care and want to help maintain the beauty of the mountains that over-look NAU. To help the community learn about Civil Engineering, NAU ASCE participates in Science Technology Engineering and Mathematics (STEM) nights that display a steel bridge and concrete canoe to inform the community about the process that we go through to make these projects. Kids can also enjoy reassembling the steel bridge by bolting the members together and sitting in the concrete canoe. NAU ASCE also helps NAU host second grade classroom tours, which tour the lab facilities of NAU. Second graders were shown the concrete cylinders and assisted other faculty with the Traffic, Soils, and Water Resources lab. In each of these labs, the second graders participated in hands on activities such as testing the plasticity index of soil or a demonstration of running the water pump into the flume. Being able to better NAU and the community of Flagstaff through student outreach via NAU ASCE is the overall mission we seek to accomplish.

### *2.2 Core Team Members*

The team is composed of five core team members; Logan Grijalva, Stephan Henderson, Kristen Rasmussen, Conrad Senior, and Carl Wilson. Logan Grijalva, the Quality Assurance and Quality Control Lead is responsible for quality control management during construction processes and mixing. His tasks also included ensuring all deliverables follow the 2020 NCCC Rules and Regulations and was responsible for creating the standard operating procedures for the construction of the canoe. Stephan Henderson, the Hull Design Lead is responsible for the hull design and research. He also designed and drafted the canoe mold, drafted final construction drawings, and head editor of reports and presentation. Kristen Rasmussen, the Project Manager, is in charge of project schedule maintenance, finances, deliverable management, and assisting in other tasks as needed. Conrad Senior, the Mix Design Lead is responsible for material research, designing and testing concrete mixes. He created the refined mix design based on testing. Carl Wilson, the Structural Lead, has conducted structural research and calculations to ensure that the loading applied to the canoe will not cause it to structurally fail. He is also responsible for reinforcement research and testing as well as assisting with the construction process. Carl will also contribute to the construction of the display, and is involved with training the paddlers and coordinating the races.


Kristen Rasmussen (Sr.)
Project Manager
- Schedule Management
- Finances/Fundraising
- Deliverable Management
Logan Grijalva (Sr.)
QA/QC Lead
- QC During Construction
- QA Throughout Project
Carl Wilson (Sr.)
Structural Lead
Team Captain
- Structural Analysis
- Reinforcement Research/Testing
Stephan Henderson (Sr.)
Hull Design Lead
Team Captain
- Hull Design Research & Design
- Draft Construction Documents
- Design Mold Plans
Conrad Senior (Sr.)
Mix Design Lead
- Material Research
- Design & Tested Concrete Mixes
Mentees
Maxx Townsend (Sr.)
Dylan Condra (Fr.)
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Marie Cook (Jr.)
Hannah Fischer (Jr.)
Raquel Severino (Sr.)
Desmin Fontaine (Jr.)
Nick Campbell (Sr.)
Hunter Kassens (So.)
Kyle Julle (Jr.)
Paxson Lowther (Sr.)
Celine Bannourah (Sr.)
Denotes Paddlers

*4.1 Hull Design*

The hull design utilizes a symmetrical design for ease of construction and to decrease the amount of time for mold production. The canoe team approached the project with a goal of developing a canoe shape that would speed up the construction of the mold. This also made it easy to finalize the shape of the canoe with multiple team members assisting in sanding and sealing the mold. As shown in Table 1 (1.0 Executive Summary, Page 1), the canoe is 212.5 inches long, which is equivalent to 17.71 ft. This shortened length allows for better maneuverability within the water when dealing with a tight turning radius. This shortened length also decreased the amount of material needed to construct the canoe, which decreased the weight, calculated at 160 lbs. A shorter canoe length does cause the canoe to sit lower into the water but still displaces the same amount of water as a longer canoe would. This would cause the canoe to be harder to maneuver around corners due to the force of buoyancy against the walls of the canoe. These negative effects are decreased with a shallow curve to the bottom of the canoe. Research has shown that a shallow curve allows for more stability will decreasing the amount the canoe will sit in the water [1]. The shallow curve will help displace more water than a shallow v design. Stability is a design criterion that was established by the team to allow everyone from experienced paddlers to beginners to be able to utilize the canoe. The projected freeboard of the canoe was 4.71 inches, which was selected to withstand turbulent waters. The structural elements considered was a basalt mesh reinforced gunwale. Since the canoe is narrow, the use of ribs would only decrease the amount of space available within the canoe. A reinforced cage was utilized to help transfer the structural loads throughout the canoe and to reduce torsional stress. The use of 3 ft bulkheads will help ensure that the canoe will pass the swamp test performed.

*4.2 Mix Design*

The goal for *Agassiz's* mix design was to create a concrete mix that weighed less than water and strong enough to withstand the weight of the paddlers during the races and transportation to conference. Utelite was chosen as the natural aggregate in the concrete mixture due to its lower specific gravity compared to pumice and lightweight sand. The team chose to use Utelite since it was provided to the team in various gradations. This aided in keeping the team on schedule because it was more efficient to test aggregate interlock strength since the material did not have to be crushed by the team. UL-FGA is a manufactured foamed glass aggregate, which was used to help reduce the weight of the concrete mixture and achieve the minimum 30% total aggregate volume required for each concrete mixture [2]. The UL-FGA had to be crushed using a Jaw Crusher to obtain the desired particle sizes between a #8-#200 sieve. The crushed material was wet sieved to clean the aggregate to obtain a better bond between the cementitious material and aggregate. Poraver™ was used to reduce the weight of the canoe and add strength due to its high crushing resistance [3]. The addition of fly ash and silica fume help to decrease the weight of the canoe while adding strength and improving the sustainability of the canoe. Fly ash decreases the amount of cement needed by replacing it with no significant reductions in compressive strength. Silica Fume helps to reduce the permeability of the concrete mixture by creating a glue that binds the cement particles together and filling in the void spaces in the cement [4]. Masterlife™ 300D also helps with waterproofing the concrete during the wet curing process, as the concrete begins to cure this admixture expands in the cracks when the concrete begins to shrink [5]. Masterfibers™ M100 will decrease the amount of cracking that occurs in the concrete by binding the concrete cracks and increasing the tensile strength of the concrete [6]. Table 7 and 8 lists all of the materials that will be used in the finalized concrete mixture. For the development of the mix design, the team made 21 different concrete mixtures to optimize the relationship between strength and weight. ASTM C31 was used to make concrete cylinders for testing the strength of each concrete mixture [7]. ASTM C39 and ASTM C496 was used to test each concrete mixture for compressive and tensile strength respectively [8]. Table 4 identifies the concrete mixtures that led to critical design decisions and provides the characteristics of the concrete that were tested. The initial concrete mixes were used to identify which c/cm ratio would give the best relationship between strength and weight. Various c/cm ratios were determined based on research of other concrete canoes that utilized silica fume and varying c/cm ratios. In Table 4, Mixes 4 through 7 show the different c/cm ratios that were tested. Mix 6, specifically, showed a 19% reduction in strength when compared to Mix 5. However, Mix 6 broke at 3020 psi which was an acceptable strength based off the reported structural calculations but was too heavy based on the goals set forth. Dues to this, a 55% c/cm ratio was selected for further concrete mix designs, which allowed strength to be added through the aggregates and silica fume without increasing the weight of the mix significantly. In Table 4, Mixes 9 through 11 showed how changing the amount of varying gradations of Utelite™ would change the strength of the concrete mix. Mix 9 was the strongest of those mixes at 2460 psi and weighed 77 lb/ft$^3$ which was still too heavy for the goal to make the mix lighter than water. To reduce the weight of the mix two different options were considered; reducing the cementitious material or Utelite™. Mixes 12 through 14 in Table 4 show the results of the compressive testing. Mix 14 was chosen as the finalized concrete mixture due to its higher compressive strength at 28 days compared to mixes 12 and 13. The increased strength comes from additional cementitious material being hydrated during the wet curing process. Throughout the mix design process slump, tests were performed as a measure of the workability. The slump had to be low enough to allow for the placement on the sloped wall of the canoe without sloughing off but still have a mix that allows for a pleasing aesthetic finish. The slump test was performed in accordance with ASTM C143 [9]. Figure 1 Illustrates and example of a slump test performed.


*Figure 1: Example of Slump Test Performed*

In the final mix iterations, dosages of water reducer were modified to limit the amount of water needed to achieve a desirable slump. The additional water added to the concrete mixture was tracked to the nearest gram to see how much extra water was needed per varying dosage. The results of this test are seen in Table 5. Mix 17 achieved a desirable slump of ½ inches, which would provide the best workability for hand placing technique. Mix 18 through 21 helped to determine the dosage of the powder pigment and whether to use white or gray cement. The dosage of the powdered pigment was based off the total weight of the cm material used in the concrete mixture. For Mixes 18 and 19 only 2% of the total weight was used to color the canoe which can be seen in Figure 1. Mixes 20 and 21, 5% of powder pigment color was used, which are seen in Figure 2. The team decided to use Mix 20 which gave the best contrast between the white concrete mixtures.

*Table 4: Summary of Concrete Mixtures*

| Mix Number | Characteristic of Interest | Compressive Strength @ 28 days (psi) | Wet Unit Weight (lb/ft$^3$) |
|---|---|---|---|
| Mix 4 | 12% c/cm | 600 | 70.4 |
| Mix 5 | 70% c/cm | 3970 | 73.7 |
| Mix 6 | 55% c/cm | 3020 | 73.1 |
| Mix 7 | 40% c/cm | 910 | 72.7 |
| Mix 9 | Well Graded Utelite™ | 2460 | 63.0 |
| Mix 10 | No Crushed Fines | 1720 | 62.9 |
| Mix 11 | Low #10 Mesh | 1700 | 63.3 |
| Mix 12 | 550 lbs of Low C/cm, No Crushed Fines | 1700 | 58.0 |
| Mix 13 | 550 lbs of C/cm, Well Graded Utelite™ | 1710 | 58.1 |
| Mix 14 | 600 lbs of C/cm Well Graded Utelite™ | 2110 | 58.4 |

*Table 5: Water Reducer Trials*

| Mix number | Amount of Water Reducer (fl. oz/cwt) | Additional Water (g/ft$^3$) |
|---|---|---|
| Mix 15 | 12 | 1300 |
| Mix 16 | 13 | 700 |
| Mix 17 | 14 | 290 |

*Table 6: Coloring Trials*

| Mix Number | Percent of Color added | Cement Color |
|---|---|---|
| Mix 18 | 2% | White |
| Mix 19 | 2% | Gray |
| Mix 20 | 5% | White |
| Mix 21 | 5% | Gray |

*Table 7: Material List*

| | |
|---|---|
| Cementitious Material | White Portland Cement Type I |
| | Portland Cement Type I/II/V |
| | Class F Fly Ash |
| | Silica Fume |
| Admixtures | MasterSet Delvo |
| | MasterGlenium 7500 |
| | Interstar Powder pigment |
| | Water Proofing Admixture |
| Fibers | MasterFiber M100 |

*Table 8: Aggregate Properties*

| Aggregates (Particle Size) | Specific Gravity | Absorption |
|---|---|---|
| Utelite™ Crushed Fines (#4-#100) | 1.62 | 17.6% |
| Utelite™ Fines (4-#100) | 1.62 | 17.6% |
| Utelite™ #10 Mesh (#8-#200) | 1.62 | 17.6% |
| Ultra-Lightweight Foamed Glass Aggregate (#8-#200) | 0.38 | 64% |
| Poraver™ (1.0-2.0 mm) | 0.4 | 19% |
| Poraver™ (.25-0.5mm) | 0.7 | 21% |
| Poraver™ (0.1-0.3mm) | 0.95 | 35% |

*Figure 2: Mix 18 and 19*

*Figure 3: Mix 20 and 21*

*4.3 Structural Design*

Structural analysis started with specifying goals to attain that would then be used in the mix design. These included the compressive strength and unit weight of the mix. The compressive strength of the mix needed to be relatively high in order to achieve a best-case tensile strength. Along with this, the team concluded that a unit weight less than water was desired for the mix to help with buoyancy and overall weight of the canoe. The analysis described below depicts numerical values showing how the goals listed above came to be.

The mesh reinforcement used in *Agassiz* was chosen for two main reasons. The first being that the team wanted to be innovative and environmentally conservative. The second being that the team wanted a mesh that would return large strain values at failure. The team had to decide between Basalt, Glass and Carbon fiber reinforcement. Although carbon fiber has a larger modulus of elasticity, it is a more brittle fiber compared to basalt. When it came to considering cost and innovation, the team took into account the abundance of basalt mesh the team had access to from prior concrete canoe teams. After decided the basalt mesh was a cheaper alternative, while still providing adequate strength properties, the team decided to use this material in *Agassiz.*

The structural analysis began by assuming a U-shaped concrete beam that has straight edges and 90-degree corners as seen in Figure 6. The team did not analyze a simply supported beam because that would entail reactions acting on the supports of the canoe. Instead, the team assumed the buoyancy force acting as the reaction along the entire length of the canoe as a distributed load. Due to the canoe experiencing a variety of loading, the buoyancy force changes proportionately to the canoe's depth in the water. The team used the unit weight of the mix and the cross-sectional area to determine the distributed self-weight of the canoe. This self-weight was 10.7 lb/ft, which made *Agassiz* just shy of 190 lbs under a continuous U-shaped beam analysis. Based off the unit weight and beam analysis, the team concluded that the physical weight of the canoe would be less than the value derived through structural analysis. This is because the U-shape analysis is a conservative approach. This self-weight distributed load and the paddler point loads gave *Agassiz* a resultant summation force of 990 lb acting in the negative y direction at the center of the canoe. Using Archimedes Principle, the team divided the unit weight of water into this resulting force to determine the volume the canoe will displace. Based on the 2, 200 lb paddlers, the self-weight of the canoe and the 5 foot long 80 lb/ft distributed load located at the center of the canoe, this volume came out to 15.9 $ft^3$. To determine the depth the canoe will rest in equilibrium underwater, the length and width dimension were divided into the displaced volume. This equilibrium depth was 9.49 inches giving the canoe a freeboard depth of 4.71 inches.

The team analyzed cross sections utilizing Microsoft Excel™. Section cuts were made longitudinally every 6 inches to determine the shear and moment acting on the canoe based on Figure 5. The team determined the maximum bending moment, acting at the middle of the canoe to be 284 lb*ft, see Figure 8. After this, flexural capacity was found based on geometric dimensions, concrete compressive strength, reinforcement properties and ACI 318-19 standards, which resulted in a flexural capacity of 935 lb*ft. This value represents the moment at which the concrete in the compression zone will crush and fracturing will begin, assuming tensioned controlled conditions [10]. Comparing the flexural capacity and the maximum bending moment, the canoe has a factor of safety of roughly 3. Next, the team determined the moment value at which the canoe will crack and found this to be 3350 lb*ft [10]. This large cracked moment strength is related to the relatively high tensile strength of *Agassiz's* mix. The difference in these moment capacities is based on the location of these cracks. At 935 lb*ft the first 0.6 in of the canoe will crack, this is the concrete in the compression zone. Cracking along the keel of the canoe will not occur until a 3350 lb*ft bending moment. This is because the cracked moment capacity is calculated from the depth to the tension face. Since *Agassiz* is experiencing a positive moment, the tension face in the keel.

Using the parallel axis theorem, the team calculated the Moment of Inertia for the cross section about the x-axis of the centroid. This calculation utilized the first and second area moments of inertia from the individual cross section members, and came out to 516 $in^4$. This high moment of inertia indicates that the canoe has a large resistance to bending. *Agassiz* then transformed the cross section to an equivalent area of concrete by using the modular ratio of the mesh reinforcement. This gave the canoe a higher, more accurate moment of inertia, which came out to 692 $in^4$. This increase in moment of inertia decreases the tensile and compressive stress acting on the canoe while increasing the cracked moment capacity.

The team then took the maximum moment applied in the middle of the canoe and determined the internal compressive and tensile stresses exerted on the cross section. The compressive stress on the cross section came out to 62.5 psi. Based on this, the team concluded that the compressive strength of the mix would be able to withstand this applied compressive stress considering the compressive strength of the mix is 2100 psi. This high compressive strength was needed to obtain a high tensile strength in the mix, this is because the ACI 318-19 code states that the tensile strength is dependent on ASTM pre-determined coefficients and the square root of the compressive strength [10]. The tensile strength of the mix came out to 183 psi. This ensured that the internal tensile stress of 23.4 psi would be of no concern, because this difference in tensile stress and tensile strength gave the canoe a factor of safety of 7.85.

The team then determined the modulus of rupture for the concrete mix. This value is critical because it represents when the canoe will crack [10]. Due to the high compressive strength of the mix, the modulus of rupture came out to 258 psi. This value was greater than the tensile stress experienced, which gave a factor of safety for the canoe of roughly 11.

After this, the team determined the shear stresses acting on the keel and gunwale was 2.97 psi and 1.06 psi respectively. These shear stresses were relatively low due to the large moment of inertia of the cross section where the load was analyzed. The shear value chosen for the keel came from the shear force diagram in Figure 7, while the shear for the gunwale came from the force of water as seen in Figure 6. These values differed because the shear experienced by the keel is due to the paddlers while the shear in the gunwale is due to the water pressure. Analysis continued with the determination of shear resistance in the concrete to be 68.7 psi [10]. Comparing the shear stress of 2.97 psi and 1.06 psi in the keel and gunwale respectively to the shear strength of the concrete, the shear factor of safety came out as just over 23. This large factor of safety is critical because direct shear can affect the canoe due to the thin wall thickness.

These factors of safety are necessary because the assumptions made are not directly representing the actual geometry of the canoe. Since the assumed crossed section is based on a constant U-shape geometry, the moment of inertia will be lower due to the curved geometry, raising the internal stresses and ultimately lowering strength capacities. This assumed geometry was the most accurate way to analyze the canoe without utilizing computer software.

*4.4 Construction Process*

The form used for mold construction was a 1.5 density EPS foam block that was cut using a CNC machine. The 1.5 density foam was chosen because it was optimal for shaping and rigidity once the concrete mix was applied. A female mold was chosen for this project to account for shrinkage in the concrete. This will allow the concrete to shrink into itself with no obstructions. This will eliminate possible cracking of the canoe during the curing process. A female mold also retains the water that was in the concrete to help fully hydrate the cement. The foam mold was cut into 64 pieces and had to be glued together then sanded down to match the shape of the hull. A liquidized rubber was then used to act as a barrier between the mold and the release agents. The foam gave the team the most control over the shape of the canoe compared to a wood frame with respect to the project schedule. The EPS Foam pieces were placed onto the constructed pour table to make construction easier. The pour table also allowed for a tight fit of the foam pieces so that the shape of the canoe is an accurate representation of the designed shape. Throughout the concrete testing the team discovered the fibers were difficult to evenly distribute throughout the mix when using the drum mixers. It was then decided that the final concrete mixture would be placed in the drum to combine cementitious material, aggregates and admixtures. Then the mixture would be placed in a 5-gallon bucket and a concrete mixing drill with a paddle blade would be used to mix in the fibers for even distribution throughout the mix. To minimize the construction process the team decided on a simple layering scheme; two layers of concrete and three layers of basalt mesh. For aesthetic purposes the layer on the outside of the canoe will be colored blue and the layer on the inside of the canoe will be white. The day before construction the dry materials of the concrete mixture were batched out to make the construction process more efficient on the day of construction. On the day of construction, the mix design team began mixing the first concrete mixture, the blue mix, while the construction team prepared the mold with the release agent. After testing five different release agents that are discussed in the QA/QC practices the team decided upon petroleum jelly to help release *Agassiz* from the EPS foam mold. The petroleum jelly was a better option because it allowed for an easier release of the canoe and is safer to use since the team won't be exposed to any chemical release agent. Once the mix was prepared and the mold was ready the concrete placement began. The concrete placement begins on the belly of the canoe and is pulled up onto the sides of the canoe. The first layer is placed, then the Quality Control Manager checked the thickness of the concrete along the bottom and sides of the canoe. Once the proper ¼" thickness of the first layer is placed, the basalt mesh reinforcement was laid into the canoe. While this happens the white concrete for the second layer is mixed, then the placement of the white concrete began utilizing the same process as the first concrete mix. The thickness is then checked at ¼ inches using painting sticks marked at ¼ inches. Paint sticks allowed for an accurate thickness check by not being able to penetrate the mold when inserted. The gunwales of the canoe are finished with a flat top for aesthetics. When the placement of concrete is complete the curing chamber is set up around the concrete canoe and the humidifiers are put into the chamber. The curing chamber was constructed using a PVC pipe frame and plastic sheeting. The PVC pipes were attached directly to the pour table and the plastic sheeting was wrapped around the table and taped to keep the humidity from escaping. The canoe will wet cure in the humidifying chamber for 14 days and will then be removed from the mold and place in a humid room for 7 days. The humidity of the room will be decreased as the 7 days progresses and finally dry cured for 7 days. The utilization of a female mold and an extremely slippery release agent, the concrete will be allowed to shrink in on itself during the curing process, with no force inside the cavity of the canoe to restrict this shrinkage. To remove *Agassiz* from the foam mold the team will remove the female mold in sections by sliding the mold to the end of the pour table and cutting the mold with the use of a hot knife. The transportation stand will be used to support the canoe as it is released from the mold. *Agassiz* will then be wet sanded to create an aesthetically pleasing finish on both the outside and inside of the canoe. The first layer of sealant will be placed and will be left to dry to allow the stickers to be applied on the side, denoting the university name and canoe name. The application of the second coat of sealant will then finish the construction of *Agassiz.*

*4.5 Scope, Schedule, and Fee*

The project management scheme the team has chosen to utilize follows the same hierarchy as the organizational chart as seen on page 3. The Project Manager and QA/QC Lead work together to monitor the overall progress of the project and the three technical leads; Structural Lead, Hull Design Lead, and Mix Design Lead. The Project Manager collaborates with the three technical leads to determine the tasks necessary to complete the project and the financial needs to obtain the necessary materials. The QA/QC Lead ensured that the time given to each task was sufficient and the methods were accurate. Figure 3 below depicts the distribution of hours within the design and construction of *Agassiz.*

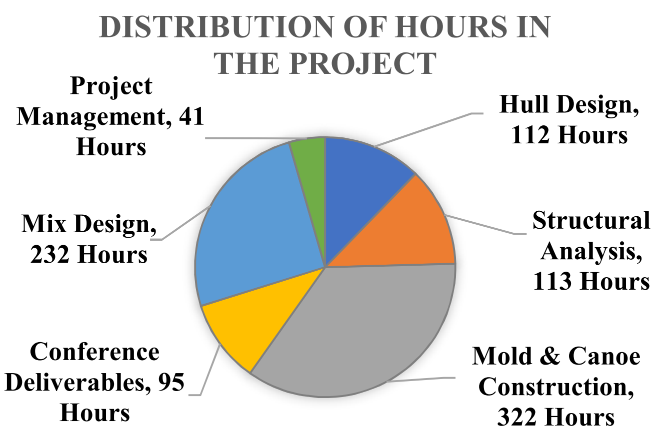



*Figure 4: Graphical Representation of the Distribution of Hours*

To develop the scope required to cover all aspects of this project the team worked together to ensure all areas were adequately thought out. To account for the risk that comes with working with concrete and creating a new concrete mix the team decided to build 5 weeks of float into the schedule to allow for any unforeseen challenges the project could face. This allowed the team to prevent falling behind schedule. A half-sized "practice canoe" was constructed using the same standard operating and concrete mix procedures to ensure that the final canoe was built with optimum quality. The Project Manager and QA/QC Lead worked with each technical lead to determine what materials would be necessary to complete their scope tasks and what the anticipated costs of those materials were. These anticipated costs were used to create the project budget. The cost of this project is illustrated on the next page in Table 9. The anticipated milestones were Mix Design, Hull Design, Construction and Competition. The team chose these four milestones because they were the most critical in the completion of *Agassiz.* These milestones were also chosen because they directly correlated with the critical path shown on the schedule. The critical path activities that the team has identified are Mix Design, Construction, and Conference Deliverables. They were determined by analyzing the schedule that the team created and identifying which tasks were critical to completion to stay on schedule. The major hurdle that the team identified at the beginning of the project was the mix design. This process is time consuming because of the relatively long curing time needed for each mix. In order to test the strength of the mix the team had to wait at least 7 days, or longer to determine the ultimate strength. This meant that the Mix Design Lead had to work strategically and make calculated decisions when altering mixes to ensure there was enough time and material to create a final mix that was both lightweight and strong. There was also a potential hurdle in material procurement for the materials used in the concrete mixture. This is because if the team decided on a final mix design and was unable to acquire enough of the necessary material to build the full canoe, either the mix would have to be changed and tested again or the construction day would have to be pushed back. If the construction of the canoe were to be pushed back, too far it would not be able to fully cure before finishing aspects of the scope began.

*Table 9: Itemized Fee Summary Sheet*

| Detailed Cost Estimate | | | | | |
|---|---|---|---|---|---|
| | Classification | Quantity | UM | Rate ($/UM) | Cost |
| Labor Costs | | | | | |
| | Principal Design Engineer | 41 | HR | 50 | $ 2,050.00 |
| | Design Manager | 236 | HR | 45 | $ 10,620.00 |
| | Project Construction Manager | 39 | HR | 40 | $ 1,560.00 |
| | Construction Superintendent | 37 | HR | 40 | $ 1,480.00 |
| | Project Design Engineer | 141 | HR | 35 | $ 4,935.00 |
| | Quality Manager | 70 | HR | 35 | $ 2,450.00 |
| | Graduate Field Engineer (EIT) | 68 | HR | 25 | $ 1,700.00 |
| | Technician/Drafter | 10 | HR | 20 | $ 200.00 |
| | Laborer/Technician | 269 | HR | 25 | $ 6,725.00 |
| | Clerk/Office Admin | 4 | HR | 15 | $ 60.00 |
| Sub-Total | | 915 | | | $ 31,780.00 |
| Direct Labor Cost | Includes Direct Labor Costs, Indirect Employee Costs & Profit Multipliers | | | | $ 105,001.12 |
| Shipping Cost | | | | | |
| | Enclosed Trailer Transport | 1 | LS | 1811.77 | $ 1,811.77 |
| Sub-Total | | | | | $ 1,811.77 |
| Expenses | | | | | |
| | White Type I Cement | 50.37 | lb | 0.03 | $ 1.51 |
| | Fly Ash Class F | 26.67 | lb | 0.02 | $ 0.53 |
| | Waterproofing Admixture | 1.008 | lb | 7.16 | $ 7.22 |
| | Densified Silica Fume | 13.334 | lb | 0.44 | $ 5.87 |
| | Poraver (All Sizes) | 51.852 | lb | 0.05 | $ 2.59 |
| | UL-FGA | 28.121 | lb | 0.05 | $ 1.41 |
| | Utelite (All Sizes) | 13.332 | lb | 0.05 | $ 0.67 |
| | Master Fiber M 100 | 0.074 | lb | 0.93 | $ 0.07 |
| | MasterSet Delvo (Retarder) | 0.35 | gal | 5.5 | $ 1.93 |
| | MasterGlenium 7500 (Reducer) | 0.441 | gal | 8.35 | $ 3.68 |
| | MasterLife SRA 20 (Shrinkage Reducer) | 0.268 | gal | 6.16 | $ 1.65 |
| | Interstar Blue Color | 2.74 | Lb | 5.00 | $ 13.70 |
| | Mold | 1 | LS | 1200 | $ 1,200.00 |
| | Non-Carbonated Water | 5.7 | Gal | 0.03 | $ 0.17 |
| | Foam for Flotation | 3.5 | CF | 25.00 | $ 87.50 |
| | Sealant | 55.62 | SF | 0.5 | $ 27.81 |
| | Basalt | 74.52 | SF | 1.6 | $ 119.23 |
| Sub-Total | | | | | $ 1,475.53 |
| Expenses | | | | | $ 1,623.09 |
| Total | | | | | $ 108,435.97 |

*4.6 Health & Safety*

Northern Arizona University's College of Engineering holds the safety of their students as their main priority when working with possible hazardous material and or tools that could harm the user. This year's concrete canoe team developed a safety binder with a compiled list of materials and tools that could affect the team's health or safety. A list of contacts is provided in the binder in case an incident were to occur, so that the team knew who to contact to handle any situation whether it be exposure to a hazardous chemical or a medical emergency. Faculty and team captains held scheduled meetings to ensure that each revision would identify all hazards associated with this project and how to address them reviewed this binder.

During material testing all equipment and tools that were to be used, as outlined in the safety binder, were inspected to ensure all guards were in place and, if applicable, all power cords had no frays or damage. All required personal protective equipment was identified and acquired before the testing started. The team designated one individual to be the safety lead during testing. This individual was responsible for ensuring all protective wear was utilized correctly throughout the duration of the testing process.

The safety implementation during construction day was crucial due to the increased amount of people present. To start the day the team held a safety meeting to ensure all members had a clear understanding of expected safety practices. Both the mix design team and the construction team were educated on the dangers of concrete burns and were provided with personal protective equipment to prevent it from happening. The exposure to the admixtures in the concrete were also considered and personal protective equipment such as gloves and masks were used to minimize these hazards. The mix design team was shown the proper way to operate the drum mixer and concrete mixing drill.

*4.7 Quality Control and Quality Assurance*

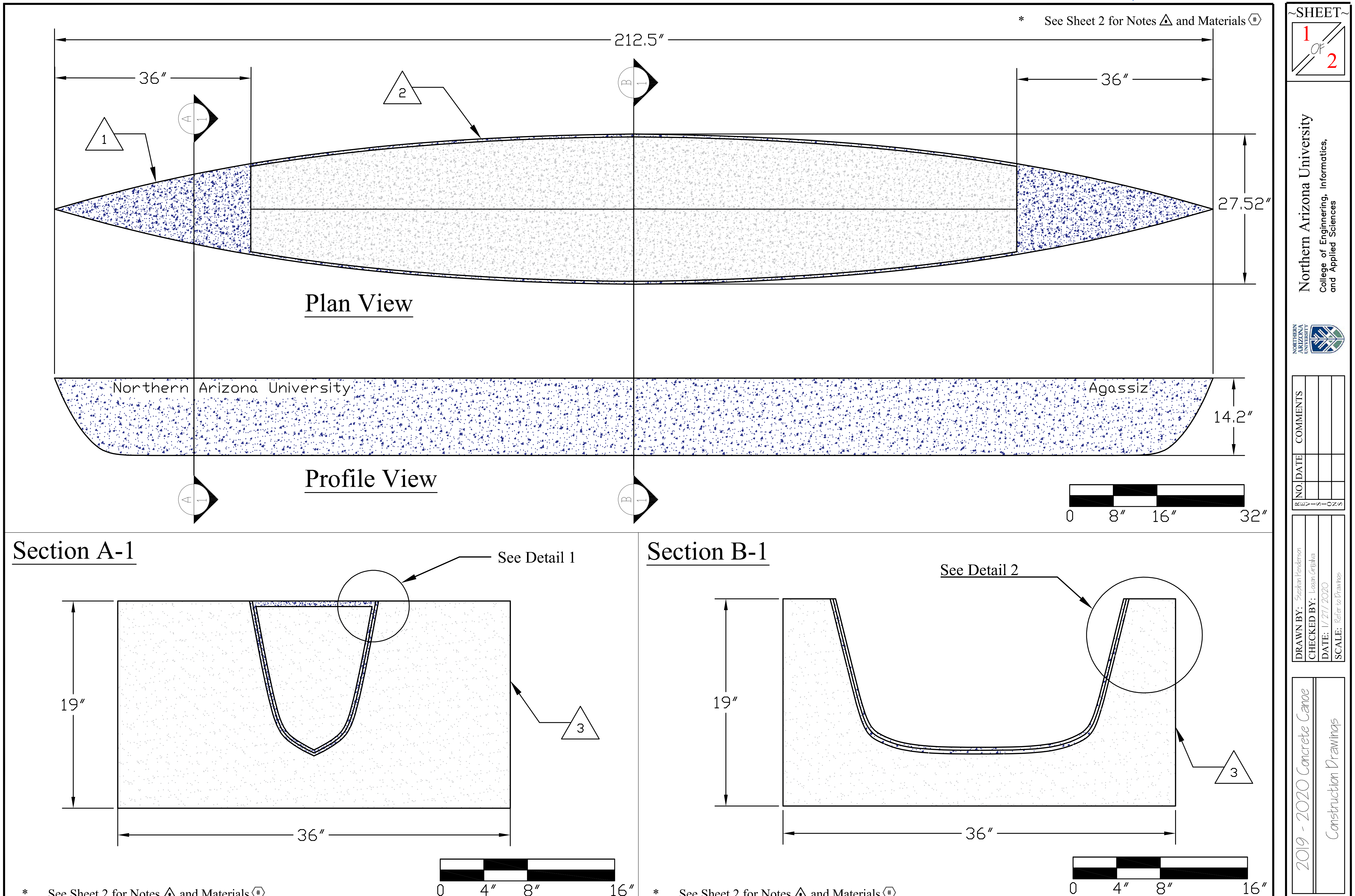
The focus for *Agassiz* was to create a lighter and faster canoe by reducing the weight of the canoe. To accomplish this goal the team had to set in place certain QA/QC procedures to ensure that a consistent thickness was met, especially in the bottom of the canoe where it is more difficult to gauge the depth. The team chose to create a half size canoe for testing material placement and canoe removal from the foam mold. The foam mold was coated in a liquid rubber to protect it from any release agents that may be used in the removal process. The canoe was divided into five different sections to test the different releasing agents that would be applied, and to see how well the canoe releases from the foam mold. The releasing agents that the team decided to test was a liquid release agent, petroleum jelly, cooking spray, water displacing mixture, and a water-based lubricant. To gage the thickness of material placement across the hull of the canoe, the team utilized paint sticks, which provided measurement that, were easy to read. The paint stick was pushed into the sides and bottom of the canoe making sure that each layer of concrete (excluding the reinforcement mesh) was a ¼ inches thick. In addition to creating a construction process that would run smoothly, the team had to verify that the concrete mix design and hull design complied with the NCCC rules and regulations. In doing so, a spreadsheet was created to narrow down acceptable material and design parameters. Google Documents was a prime resource used for the team to keep track of the various technical data and material data sheets allowing each team member access to the project documents for reference throughout the duration of the project. The team held weekly meetings to report progress and keep the team on schedule. These weekly meetings helped ensure that the rules and regulations were being followed and allowed for more review of the deliverables to ensure optimal quality.

*4.8 Sustainability*

The team addressed sustainability of the concrete mixture by utilizing UL-FGA, fly ash, and silica fume. This was accomplished by creating a concrete mixture that was, by volume, 70% by-products or manufactured aggregates. The UL-FGA is a recycled aggregate comprised of 100% recycled glass bottles. Fly ash and silica fume are both by-products with cementitious properties which are lighter than cement but keeps the concrete mixture strong. Being able to incorporate such a high volume of recycled and by-product materials into the concrete mixture helps to prevent this material from just ending up in the landfill. These materials are already being generated, if they can be used to create a sustainable building material it will aid in the effort to reduce the carbon footprint by reducing the cement manufacturing. They also come at a decreased cost to create, so an increased usage of it will save money by decreasing the amount of cement required in concrete. This also keeps these materials from contaminating the soil and water that our society depends on.

Another focus to improve the sustainability of the project was to create reusable elements for the construction process. This year's team constructed a pour table and a curing chamber that is durable enough for future teams to use. This will allow next year's team to re-use these construction elements and reduce the material needed each year to construct the canoe.

Recycling is the last focus that the team has used to reduce the impact on the environment. This year the team will use recycled mold material to construct the end caps of *Agassiz*. The molds from previous years were created using EPS foam blocks. Instead of buying new foam components this year, the old mold was stored and will be shaped for the endcaps. This will give the material a secondary use and reduce the overall impact. This will improve the economic sustainability of NAU's concrete canoe teams. If materials can be utilized continuously, it will save the team money that could be put towards material research. The team's involvement in learning initiatives such as STEM nights and engineering department tours promotes the continuation of the engineering discipline and inspires the next generation.


* See Sheet 2 for Notes and Materials
212.5″
36″
36″
27.52″
1
2
A 1
B 1
Plan View
Northern Arizona University
Agassiz
14.2″
Profile View
0 8″ 16″ 32″
Section A-1
See Detail 1
19″
36″
3
0 4″ 8″ 16″
* See Sheet 2 for Notes and Materials
Section B-1
See Detail 2
19″
36″
3
0 4″ 8″ 16″
* See Sheet 2 for Notes and Materials
~SHEET~
1 OF 2
Northern Arizona University
College of Engineering, Informatics, and Applied Sciences
REVISIONS
NO.
DATE
COMMENTS
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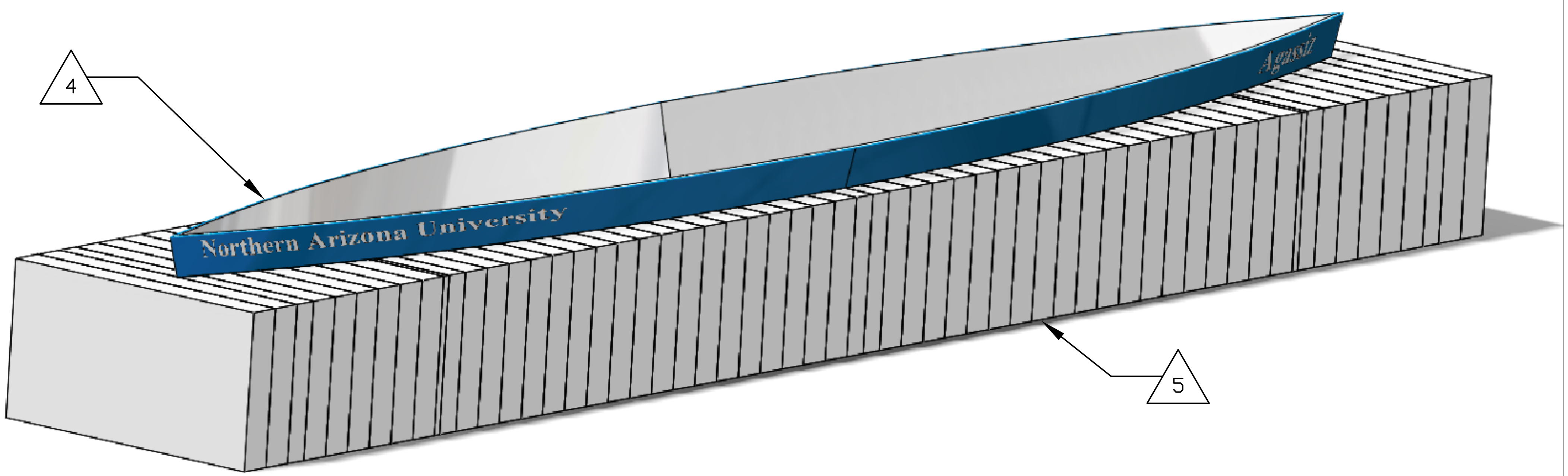
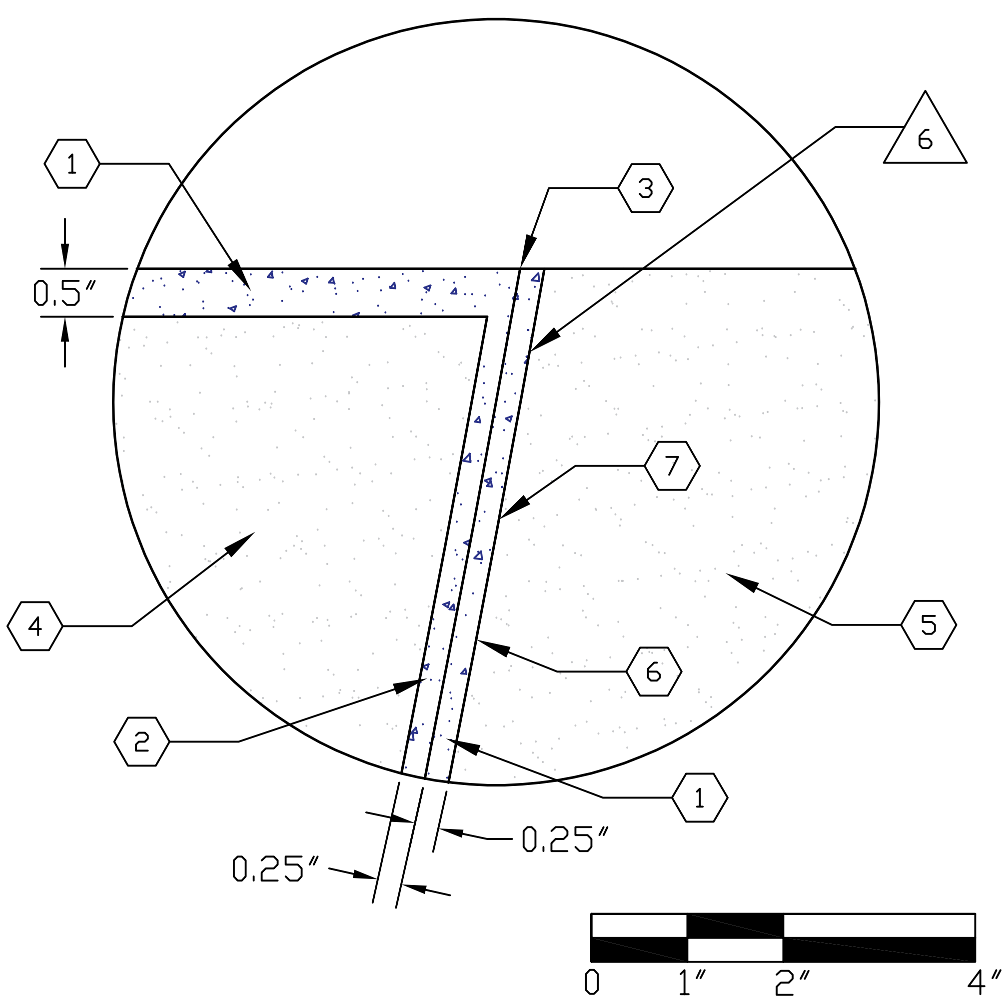
CHECKED BY:
DATE: 1/27/2020
SCALE: Refer to Drawing
2019 - 2020 Concrete Canoe
Construction Drawings

## Isometric View

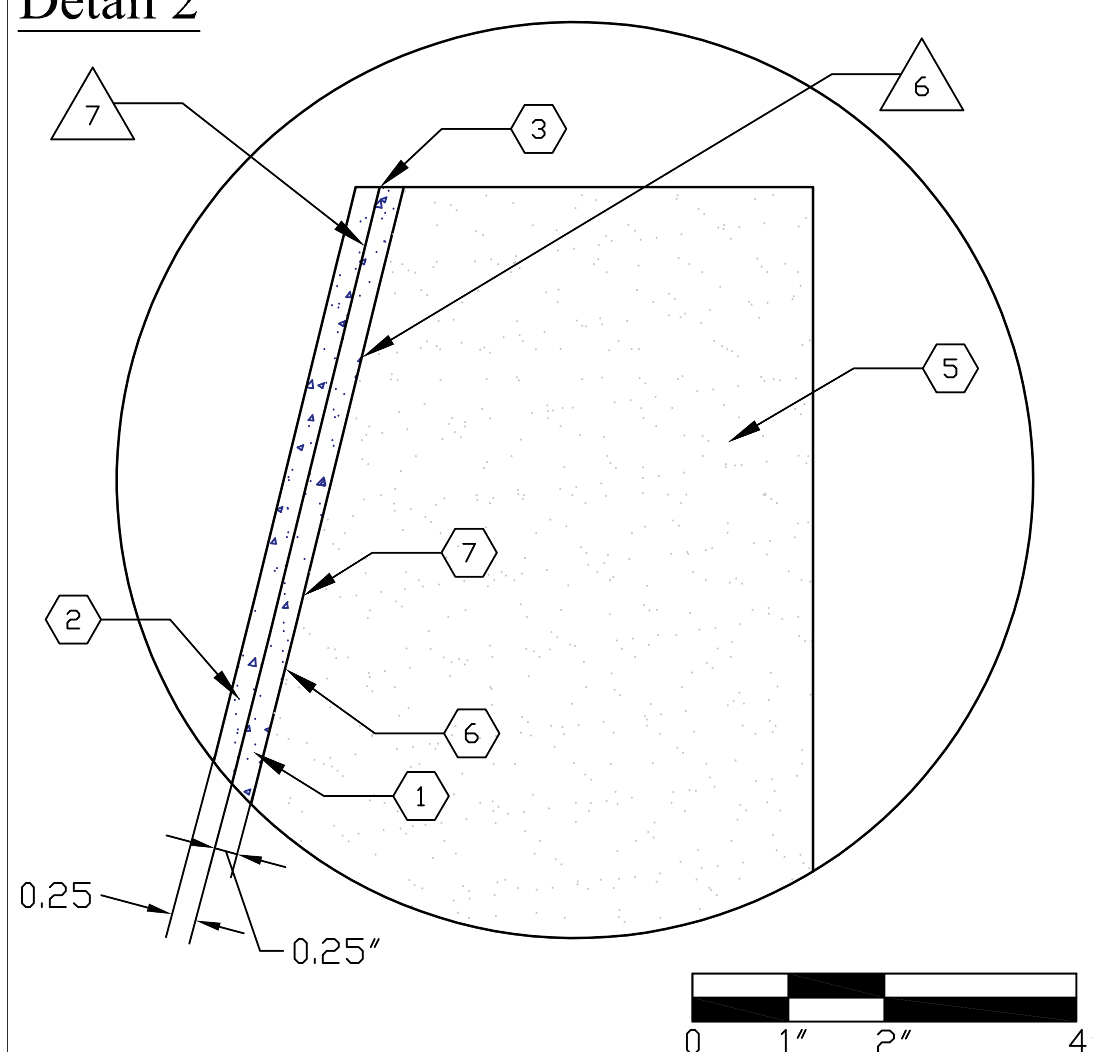



Not to Scale

## Detail 1




## Detail 2




## Notes

1) Section A-1 is typ. for first 36 inches of canoe on both the bow and stern.
2) Section B-2 is typ. for interior of canoe between the Bulkheads.
3) Mold is displayed for section cuts to display construction practices.
4) Canoe has been lifted from the mold to demonstrate the difference in the mold and the canoe.
5) Mold is split up into 4" sections for constructability purposes and to retain the designed shape
6) Liquid Rubber is applied to the mold for protection, and then the release is applied.
7) A retarder admixture has been added to the concrete for a slower set time. This will decrease the possibility of delaminating between the layers

## Bill of Materials

1) Concrete Mix (Stated within the report), Blue
2) Concrete Mix (Stated within the report), White
3) Basalt Mesh
4) Expanded Polystyrene (EPS) High Density Foam for Bulkheads
5) EPS High Density Foam Mold
6) Liquid Rubber
7) Petroleum Based Gel (used as release agent)

~SHEET~ 2 OF 2

Northern Arizona University
College of Engineering, Informatics, and Applied Sciences

| REVISIONS | NO. | DATE | COMMENTS |
|---|---|---|---|
| | | | |

DRAWN BY: Stephan Henderson
CHECKED BY: Logan Grijalva
DATE: 1/27/2020
SCALE: Refer to Drawings

2019 - 2020 Concrete Canoe
Isometric View / Details 1 & 2

| ID | Task Mode | WBS | Task Name | Duration | Start | Finish |
|---|---|---|---|---|---|---|
| 1 | | **1** | **Mix Design** | **93 days** | **Mon 9/9/19** | **Sat 1/18/20** |
| 2 | | 1.1 | Material Research | 25 days | Mon 9/9/19 | Fri 10/4/19 |
| 3 | | 1.2 | Material Acquisition | 60 days | Mon 9/9/19 | Sun 11/10/19 |
| 4 | | 1.3 | Initial Mix Design | 30 days | Mon 9/9/19 | Wed 10/9/19 |
| 5 | | 1.4 | Testing | 50 days | Mon 9/9/19 | Wed 10/30/19 |
| 6 | | 1.5 | Redesign | 20 days | Wed 10/30/19 | Wed 11/20/19 |
| 7 | | 1.6 | Final Mix | 20 days | Sat 11/23/19 | Sat 1/18/20 |
| 8 | | **2** | **Hull Design** | **28 days** | **Thu 10/10/19** | **Thu 11/7/19** |
| 9 | | 2.1 | Canoe Development | 10 days | Thu 10/10/19 | Sun 10/20/19 |
| 10 | | 2.2 | Mold Development | 3 days | Sun 10/20/19 | Wed 10/23/19 |
| 11 | | 2.3 | Mold Distributer | 15 days | Wed 10/23/19 | Thu 11/7/19 |
| 12 | | **3** | **Structural** | **25 days** | **Sun 10/20/19** | **Fri 11/15/19** |
| 13 | | 3.1 | Calculations | 15 days | Sun 10/20/19 | Mon 11/4/19 |
| 14 | | 3.2 | Aquiring Mesh/ Post-tension | 3 days | Tue 11/5/19 | Thu 11/7/19 |
| 15 | | 3.3 | Testing | 7 days | Fri 11/8/19 | Fri 11/15/19 |
| 16 | | **4** | **Construction** | **49 days** | **Fri 10/25/19** | **Sun 1/19/20** |
| 17 | | 4.1 | Stand | 20 days | Fri 10/25/19 | Fri 11/15/19 |
| 18 | | 4.2 | Pour Table | 12 days | Fri 11/15/19 | Wed 12/4/19 |
| 19 | | 4.3 | Post Tensioning Equipment | 1 day | Fri 11/15/19 | Sat 11/16/19 |
| 20 | | 4.4 | Mold Preparation | 7 days | Fri 11/8/19 | Fri 11/15/19 |
| 21 | | 4.5 | Cure Chamber | 2 days | Fri 11/15/19 | Sun 11/17/19 |
| 22 | | 4.6 | Practice Pour | 1 day | Sat 1/18/20 | Sun 1/19/20 |
| 23 | | **5** | **Final Pour** | **45 days** | **Sun 2/9/20** | **Sat 4/4/20** |
| 24 | | 5.1 | Mixing and Placing | 1 day | Sun 2/9/20 | Mon 2/10/20 |
| 25 | | 5.2 | Wet Curing | 14 days | Mon 2/10/20 | Mon 2/24/20 |
| 26 | | 5.3 | Dry Curing | 14 days | Mon 2/24/20 | Tue 3/10/20 |
| 27 | | 5.4 | Removal | 1 day | Tue 3/10/20 | Wed 3/11/20 |
| 28 | | 5.5 | Post Tensioning | 1 day | Wed 3/11/20 | Thu 3/12/20 |
| 29 | | 5.6 | Aesthetic | 14 days | Thu 3/12/20 | Sat 4/4/20 |
| 30 | | **6** | **Conference** | **117 days** | **Tue 10/22/19** | **Sat 4/4/20** |
| 31 | | 6.1 | Preliminary Schedule | 10 days | Tue 10/22/19 | Fri 11/1/19 |
| 32 | | 6.2 | Prequalification Form | 10 days | Tue 10/22/19 | Fri 11/1/19 |
| 33 | | 6.3 | ASCE Student Chapter Annual Reports/Dues Deadline | 14 days | Sat 1/18/20 | Sat 2/1/20 |
| 34 | | 6.4 | Technical Proposal and MTDS Addendum Deadline | 15 days | Sat 2/1/20 | Mon 2/17/20 |
| 35 | | 6.5 | Presentation | 18 days | Sun 3/8/20 | Sat 4/4/20 |
| 36 | | 6.6 | Report | 18 days | Sun 3/8/20 | Sat 4/4/20 |
| 37 | | 6.7 | Races/Rowing | 20 days | Mon 2/10/20 | Sun 3/1/20 |
| 38 | | 6.8 | Display/Decoration | 8 days | Thu 3/12/20 | Sun 3/29/20 |
| 39 | | **7** | **National Deliverables** | **41 days** | **Sun 5/3/20** | **Mon 6/15/20** |
| 40 | | 7.1 | Technical Proposal and MTDS Addendum Deadline | 15 days | Sun 5/3/20 | Tue 5/19/20 |
| 41 | | 7.2 | 2020 ASCE National Concrete Canoe Competition, hosted by University of Wisconsin-Madison | 2 days | Sat 6/13/20 | Mon 6/15/20 |
| 42 | | **8** | **Project Management** | **156 days** | **Mon 9/9/19** | **Wed 4/1/20** |
| 43 | | 8.1 | Scheduling | 156 days | Mon 9/9/19 | Wed 4/1/20 |
| 44 | | 8.2 | Meetings | 156 days | Mon 9/9/19 | Wed 4/1/20 |
| 45 | | 8.3 | Fundrasing | 90 days | Mon 9/9/19 | Wed 1/15/20 |

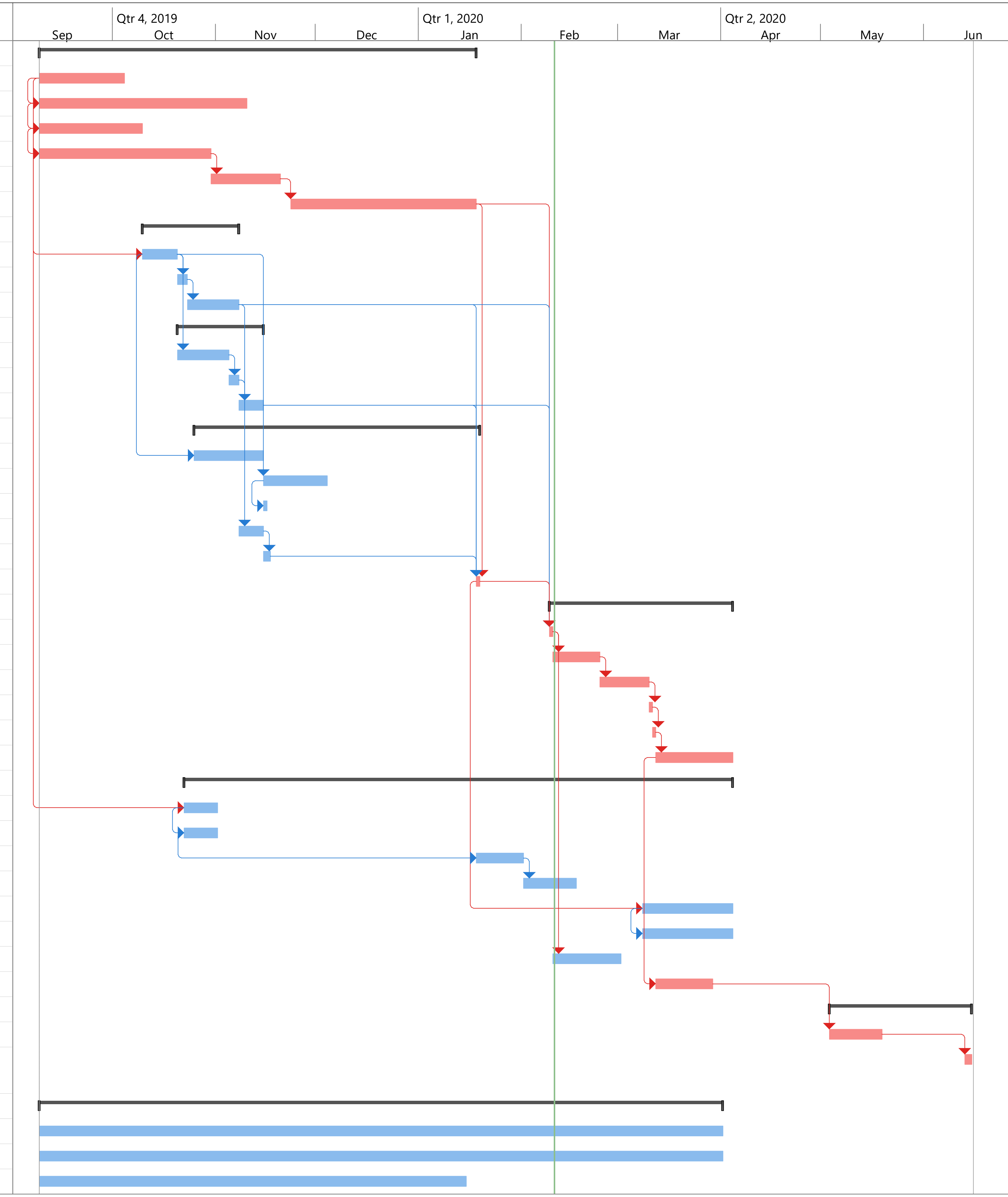


*Table 10: Mix Proportions (Color Varies)*

| Cementitious Materials | | | | |
|---|---|---|---|---|
| Component | Specific Gravity | Volume cubic $ft^3$ | Amount of CM | |
| Cement | 3.15 | 1.73 $ft^3$ | 340 $lb/yd^3$ | Total cm (includes c) 610 lb/yd |
| Class F Flyash | 2.3 | 1.25 $ft^3$ | 180 $lb/yd^3$ | |
| Silica Fume | 2.2 | 0.66 $ft^3$ | 90 $lb/yd^3$ | C/CM 56% |

| Fibers | | | | |
|---|---|---|---|---|
| Component | Specific Gravity | Volume | Amount of Fibers | |
| MasterFiber M 100 | 0.91 | 0.009 $ft^3$ | 0.5 $lb/yd^3$ | Total Amount of Fibers 0.5 $lb/yd^3$ |

| Aggregates | | | | | | | |
|---|---|---|---|---|---|---|---|
| Aggregates | Expanded Glass or Cenosphere | Abs (%) | SG OD | SG SSD | Base Quantity, W: $W_{od}$ ($lb/yd^3$) | Base Quantity, W: $W_{ssd}$ ($lb/yd^3$) | Volume $V_{agg}$, SSD ($ft^3$) |
| Utelite Crushed Fines | No | 17.6 | 1.62 | 1.90 | 30 | 35.28 | 0.297 |
| Utelite Fines | No | 17.6 | 1.62 | 1.90 | 30 | 35.28 | 0.297 |
| Utelite #10 Mesh | No | 17.6 | 1.62 | 1.90 | 30 | 35.28 | 0.297 |
| UL-FGA | No | 64 | 0.38 | 0.62 | 190 | 311.6 | 8.013 |
| Poraver™ (1-2 mm) | Yes | 19 | 0.4 | 0.48 | 160 | 190.4 | 6.410 |
| Poraver™ (0.5-0.25 mm) | Yes | 21 | 0.7 | 0.85 | 120 | 145.2 | 2.747 |
| Poraver™ (0.3-0.1 mm) | Yes | 35 | 0.95 | 1.28 | 70 | 94.5 | 1.181 |

| Liquid Admixtures | | | | |
|---|---|---|---|---|
| Admixture | lb/US gal | Dosage (fl. oz/cwt) | % Solids | Amount of Water in Admixture |
| MasterSet Delvo | 9.93 | 5 | 14 | 6.77 |
| MasterGlenium 7500 | 9.06 | 14 | 26 | |
| MasterLife SRA 35 | 7.59 | 5 | 80 | |

| Solids (Dyes, Powered Admixtures, and Mineral Fillers) | | | | |
|---|---|---|---|---|
| Component | Specific Gravity | Volume ($ft^3$) | Amount ($lb/yd^3$) | |
| Waterproofing Admixture | 2.1 | 0.052 | 6.8 $lb/yd^3$ | Total Solids 6.8 lbs |

| Water | | | |
|---|---|---|---|
| | w/c Ratio (%) | Amount ($lb/yd^3$) | Volume |
| Water | - | 327.95 | 5.26 $ft^3$ |
| Total Freee Water from all Aggregates | 0.96 | 80.46 | |
| Total Water From All Admixtures | w/cm Ratio (%) | 6.77 | |
| Batch Water | 0.53 | 240.72 | |

| Densities, Air content, Ratios, and Slump | | | | | | |
|---|---|---|---|---|---|---|
| Values for a Cubic yard | Cm | Fibers | Aggregate SSd | Solids, Total | Water | Total |
| Mass (lb) | 601.80 | 0.500 | 630 | 6.8 | 328 | 1567 |
| Absolute Volume ($ft^3$) | 3.587 | 0.009 | 19.24 | 0.052 | 5.3 | 28.1 |
| Theoretical Density ($lb/ft^3$) | 55.8 | | Air Content, Air, (%) | | -5.77 | |
| Measured Density ($lb/ft^3$) | 59.02 | | Air Content, Air, (%) | | -4.24 | |
| Total Aggregate Ratio (%) | 71.3 | | Slump (in) | | 0.5 | |
| EG +C Ratio (%) | 53.7 | | | | | |

## Cementitious Material

### Cement (White)

$W_{OD} = 340\ lbs$

$$V_{OD} = \frac{180}{3.15 * 62.4} = 1.73\ ft^3$$

### Fly Ash

$W_{OD} = 180\ lbs$

$$V_{OD} = \frac{1.25}{2.3 * 62.4} = 1.254\ ft^3$$

### Silica Fume

$W_{OD} = 90\ lbs$

$$V_{OD} = \frac{90}{2.2 * 62.4} = 0.656\ ft^3$$

## Aggregates

### Poraver™ 1-2

$W_{OD} = 160\ lb$

$$V_{OD} = \frac{160}{0.4 * 62.4} = 6.41\ ft^3$$

$$Abs = \frac{190.4 - 160}{160} x100\% = 19\%$$

$$MC_{total=} \frac{160.8-160}{160} x100\% = 0.5\%$$

$$MC_{free} = 0.5\% - 19\% = -18.5\%$$

$$W_{SSD} = \left(1 + \frac{19}{100}\right) * 160 = 190.4\ lbs$$

$$w_{free} = 160 * \frac{-18.5}{100} = -29.6\ lbs$$

$$W_{stk} = 190.4 - 29.6 = 160.8 lbs$$

### Poraver™ 0.25-0.5

$W_{OD} = 120\ lbs$

$$V_{OD} = \frac{120}{0.7 * 62.4} = 2.75\ ft^3$$

$$Abs = \frac{145.2 - 120}{120} * 100\% = 21\%$$

$$MC_{total} = \frac{120.6 - 120}{120} * 100\% = 0.5\%$$

$$MC_{free} = 0.5\% - 21\% = -20.5\%$$

$$W_{SSD} = \left(1 + \frac{21}{100}\right) * 120 = 145.2\ lbs$$

$$w_{free} = 120 * \left(\frac{-20.5}{100}\right) = -24.6\ lbs$$

$$w_{stk} = 145.2 - 24.6 = 120.6\ lbs$$

### Poraver™ 0.1-0.3

$W_{OD} = 70\ lbs$

$$V_{OD} = \frac{70}{0.95 * 62.4} = 1.18\ ft^3$$

$$Abs = \frac{94.5 - 70}{70} * 100\% = 35\%$$

$$MC_{total} = \frac{70.35 - 70}{70} * 100\% = 0.5\%$$

$$MC_{free} = 0.5\% - 35\% = -34.5\%$$

$$W_{SSD} = \left(1 + \frac{35}{100}\right) * 70 = 94.5\ lbs$$

$$w_{free} = 70 * \left(\frac{-34.5}{100}\right) = -24.15\ lbs$$

$$w_{stk} = 94.5 - 24.15 = 70.35\ lbs$$

UL-FGA (#8-#200)

$W_{OD} = 190\ lbs$

$$V_{OD} = \frac{190}{0.38 * 62.4} = 8.01\ ft^3$$

$$Abs = \frac{311.6 - 190}{190} * 100\% = 64\%$$

$$MC_{total} = \frac{237.5 - 190}{190} * 100\% = 25\%$$

$$MC_{free} = 25\% - 64\% = -39\%$$

$$W_{SSD} = \left(1 + \frac{64}{100}\right) * 190 = 311.6\ lbs$$

$$w_{free} = 190 * \left(\frac{-39}{100}\right) = -74.1\ lbs$$

$$w_{stk} = 311.6 - 74.1 = 237.5\ lbs$$

Utelite[TM] Fines

$W_{OD} = 30\ lbs$

$$V_{OD} = \frac{30}{1.62 * 62.4} = 0.297\ ft^3$$

$$Abs = \frac{35.28 - 30}{30} * 100\% = 17.6\%$$

$$MC_{total} = \frac{32.57 - 30}{30} * 100\% = 8.55\%$$

$$MC_{free} = 8.55\% - 17.6\% = -9.05\%$$

$$W_{SSD} = \left(1 + \frac{17.6}{100}\right) * 30 = 35.28\ lbs$$

$$w_{free} = 30 * \left(\frac{9.05}{100}\right) = -2.72\ lbs$$

$$w_{stk} = 35.28 - 2.72 = 32.56\ lbs$$

Utelite[TM] Crushed Fines

$W_{OD} = 30\ lbs$

$$V_{OD} = \frac{30}{1.62 * 62.4} = 0.297\ ft^3$$

$$Abs = \frac{35.28 - 30}{30} * 100\% = 17.6\%$$

$$MC_{total} = \frac{34.54 - 30}{30} * 100\% = 15.14\%$$

$$MC_{free} = 15.14 - 17.6 = -2.46\%$$

$$W_{SSD} = \left(1 + \frac{17.6}{100}\right) * 30 = 35.28\ lbs$$

$$w_{free} = 30 * \left(\frac{-2.46}{100}\right) = -0.738\ lbs$$

$$w_{stk} = 35.28 - 0.738 = 34.54\ lbs$$

Utelite[TM] #10 Mesh

$W_{OD} = 30\ lbs$

$$V_{OD} = \frac{30}{1.62 * 62.4} = 0.297\ ft^3$$

$$Abs = \frac{35.28 - 30}{30} * 100\% = 17.6\%$$

$$MC_{total} = \frac{34.62 - 30}{30} * 100\% = 15.4\%$$

$$MC_{free} = 15.4 - 17.6\% = -2.2\%$$

$$W_{SSD} = \left(1 + \frac{17.6}{100}\right) * 30 = 35.28\ lbs$$

$$w_{free} = 30 * \left(\frac{-2.2}{100}\right) = -0.66\ lbs$$

$$w_{stk} = 35.28 - 0.66 = 34.62\ lbs$$

## Admixtures

Water Reducer

$$w_{admx} = 14 * 5.95 * 74\% * \frac{1\ gal}{128\ fl.oz} * \frac{9.05\ lbs}{gal}$$
$$= 4.36\ lbs$$

$$S = 14 * 5.95 * 26\% * \frac{1gal}{128fl.oz} * \frac{9.05\ lbs}{gal}$$
$$= 1.53\ lbs$$

Retarder

$$w_{admx} = 5 * 5.95 * 86\% * \frac{1}{128} * \frac{9.93\ lbs}{gal} =$$
1.98 lbs

$$S = 5 * 5.95 * 14\% * \frac{1gal}{128fl.oz} * \frac{9.93\ lbs}{1\ gal}$$
$$= 0.32\ lbs$$

Shrinkage Reducer

$$w_{admix} = 5 * 5.95 * 20\% * \frac{1}{128} * \frac{7.59\ lbs}{gal}$$
$$= 0.35\ lbs$$

$$S = 5 * 5.95 * 80\% * \frac{1\ gal}{128\ fl.oz} * \frac{7.59\ lbs}{gal}$$
$$= 1.41 lbs$$

Color Powder

$S = 37.01\ lbs$

$$V = \frac{37.01}{1.2 * 62.4} = 0.494\ ft^3$$

Water Proofing Admixture

$S = 6.80\ lbs$

$$V = \frac{6.8}{2.10 * 62.4} = 0.052\ ft^3$$

## Water

Free Water from Aggregates= $-156.57 lbs$
Water from Admixtures= $6.77 lbs$
Water for Cement Hydration= $323.3\ lbs$

## Concrete Analysis

$$\sum Masses = Mass\ of\ Total\ Concrete$$
$$= 1622\ lbs$$

$$\sum Volume = Total\ Volume\ of\ Concrete$$
$$= 28.84\ ft^3$$

$$Yield = \frac{28.87}{27} = 1.07$$

$$D = 55.0\ lb/ft^3$$

$$Wet\ Unit\ Weight = \frac{1615\ lbs}{28.76\ ft^3} = 56.2 \frac{lbs}{ft^3}$$

$$Air\ Content = \frac{56.2 - 55.0}{56.2} * 100\% = 0.218\%$$

$$\frac{w}{c}\ ratio = 0.96$$

$$\frac{w}{cm} ratios = 0.53$$

Total Aggregate Volume Percentage =
$\frac{19.24}{28.76} = 67\% > 30\%$ Complaint

Expanded Glass and Cenoshperes Volume =
$\frac{350}{630} = 56\% < 70\%$ Complaint

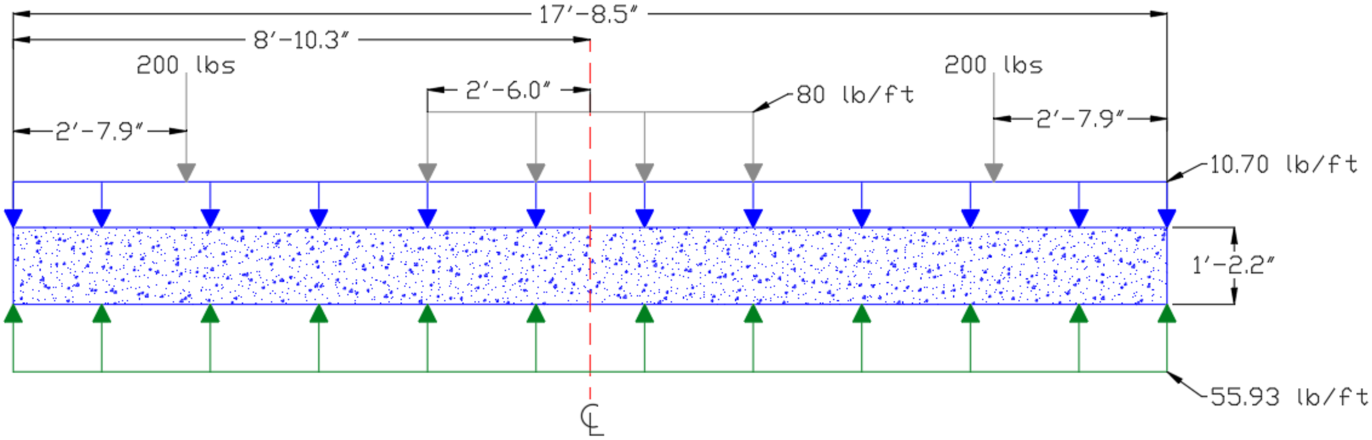



*Figure 5: Elevation Free Body Diagram*

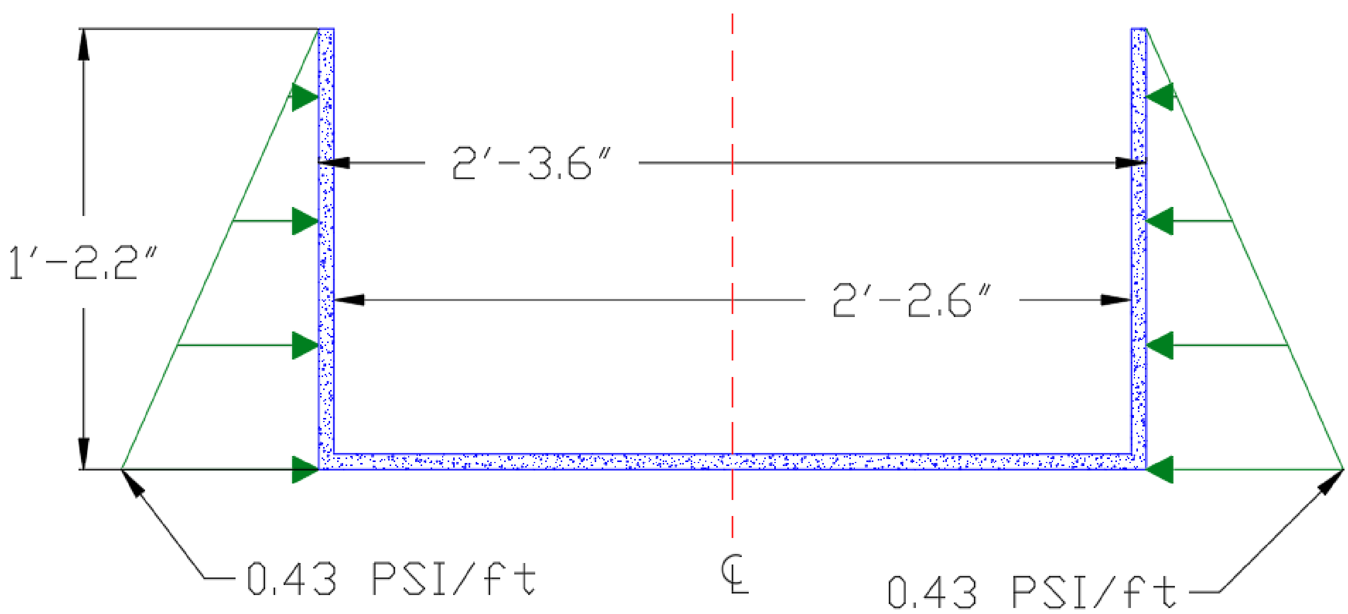



*Figure 6: Cross Sectional Free Body Diagram*

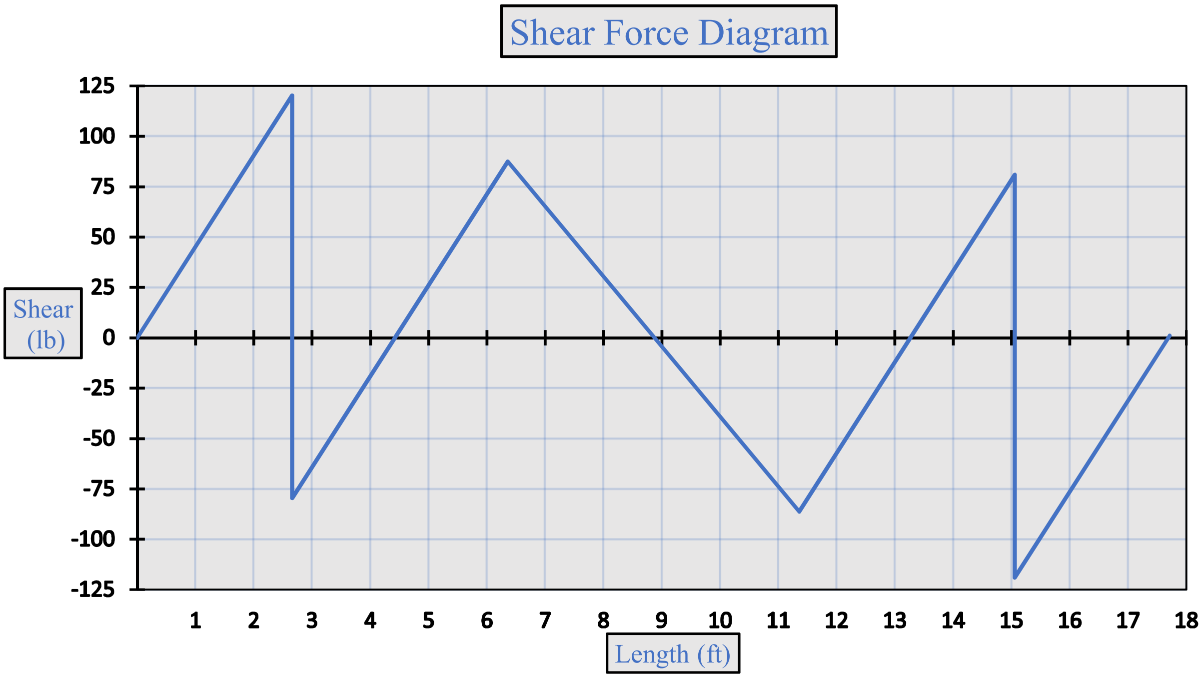



*Figure 7: Shear Force Diagram*

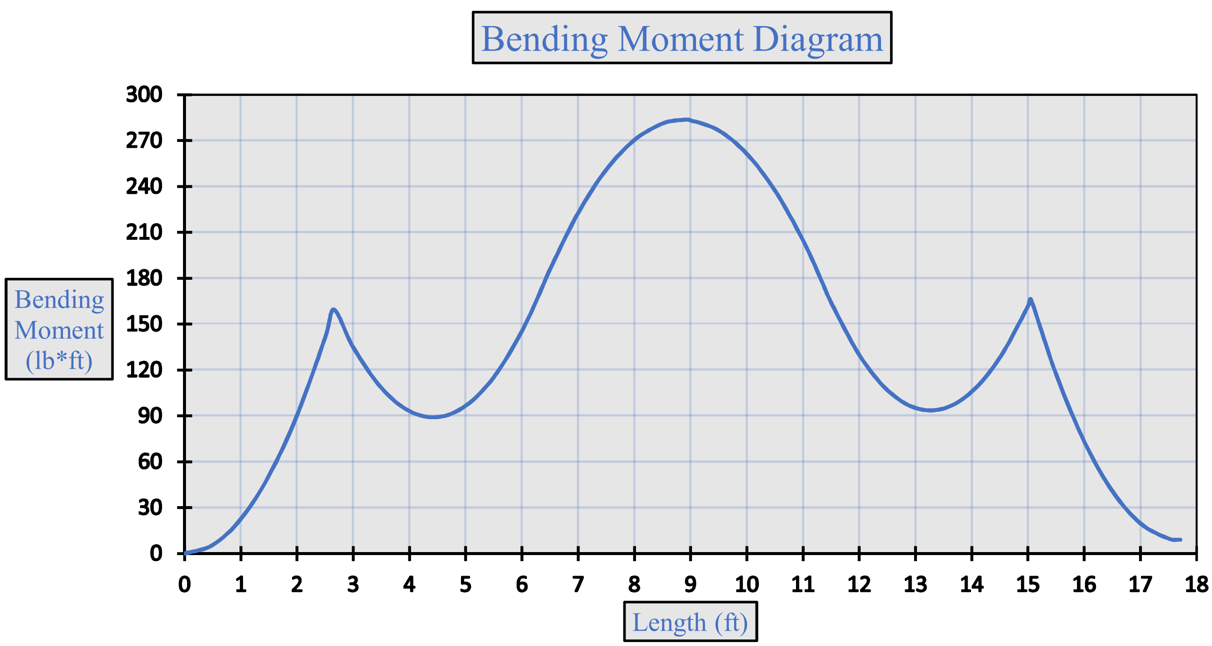



*Figure 8: Bending Moment Diagram*

***Self-Weight of Canoe: ($W_D$)***

$$W_D = A_X(ft^2) * \gamma_M(\frac{lb}{ft^3})$$

$$W_D = [0.191 * 56](\frac{lb}{ft})$$

$$w_D = 10.7\left(\frac{lb}{ft}\right) = 189.50(lb)$$

***Volume Displacement: ($V_D$)***

$$V_D = \frac{\Sigma F_Y(lb)}{\gamma_W(\frac{lb}{ft^3})}$$

$$V_D = \left[\frac{(200*2)+(80*5)+(10.70*17.71)}{62.40}\right](ft^3)$$

$$V_D = 15.86\ (ft^3)$$

***Equilibrium Depth: ($D_E$)***

$$D_E = H(ft) - \frac{V_D(ft^3)}{L(ft) * W(ft)}$$

$$D_E = \left[1.18 - \left(\frac{15.86}{17.71 * 2.30}\right)\right](ft)$$

$$D_E = 0.791(ft) = 9.49(in)$$

***Buoyancy Force: ($F_B$)***

$$F_B = \rho(\frac{slug}{ft^3}) * g(\frac{ft}{s^2}) * V_D(ft^3)$$

$$F_B = [1.94 * 32.2 * 15.86](lb)$$

$$F_B = 990.58(lb) = 55.93(\frac{lb}{ft})$$

***Max Moment: ($M_{MAX}$)***

$$M_{MAX} = -\left(\left(W_D\left(\frac{lb}{ft}\right) * L^2(ft^2)\right) * \frac{1}{8}\right) - \left(\left(U_L\left(\frac{lb}{ft}\right) * L_{U_L}{}^2(ft^2)\right) * \frac{1}{8}\right) - \left(PL(lb) * 35\% * L(ft)\right) + \left(\left(F_B\left(\frac{lb}{ft}\right) * L^2(ft^2)\right) * \frac{1}{8}\right)$$

$$M_{MAX} = -\left[\left((10.7 * 17.71^2) * \frac{1}{8}\right) - \left((80 * 5^2) * \frac{1}{8}\right) - (200 * 0.35 * 17.71) + \left((55.93 * 17.71^2) * \frac{1}{8}\right)\right](lb * ft)$$

$$M_{MAX} = 283.57(lb * ft)$$

***Flexural Capacity: ($\phi M_n$) [ACI–21.2.2]***

$$M_n = C_c(lbs) * \left(d(in) - \left(\frac{\beta_1 * c(in)}{2}\right)\right)$$

$$c = \left[\frac{0.003}{\left(\frac{0.0667 + 0.003}{13.95}\right)}\right](in)$$

$$c = 0.6(in)$$

$$C_c = [0.85 * f_c{}'(psi) * \beta_1 * c(in) * b_w(in)]$$

$$C_c = (0.85 * 2100 * 0.85 * 0.60 * 1)(lb)$$

$$C_c = 910.35(lb)$$

$$M_n = \left[910.35 * \left(13.95 - \left(\frac{0.85 * 0.5}{2}\right)\right)\right](lb * in)$$

$$M_n = 12467.24(lb * in) = 1038.94(lb * ft)$$

*Assume Tension Controlled* $\phi M_n = 935.04(lb * ft)$

***Cracked Flexural Capacity: ($M_{CR}$) [ACI-24.2.3.5]***

$$M_{CR} = \frac{f_r(\text{psi}) * I_g(\text{in}^4)}{y_t(\text{in})}$$

$$M_{CR} = \left[\frac{7.5 * 0.75 * \left(\sqrt{2100}\right) * 561.13}{3.6}\right](\text{lb} * \text{in})$$

$$M_{CR} = 40178.45(\text{lb} * \text{in}) = 3348.20(\text{lb} * \text{ft})$$

***Centroid (Neutral Axis): ($\bar{Y}$)***

$$\bar{Y}_X = \frac{A_i(\text{in}^2) * Y_i(\text{in})}{A_i(\text{in}^2)}$$

$$\bar{Y}_X = \left[\frac{\left(\left(2*(0.5*14.2)*\frac{14.2}{2}\right)+\left((0.5*27.6)*\frac{0.5}{2}\right)\right)}{\left((2*(0.5*14.2))+(0.5*27.6)\right)}\right](\text{in})$$

$$\bar{Y}_X = 3.85(\text{in}) = 0.32(\text{ft})$$

***Moment of Inertia: ($I_X$)***

$$I_X = \Sigma\left[I_i(\text{in}^4) + A_i {d_i}^2(\text{in}^4)\right]$$

$$I_X = \left[2\left(\left(\frac{0.5*14.2^3}{12}\right) + \left(0.5 * 14.2 * \left(\frac{14.2}{2} - 3.85\right)^2\right)\right) + \left(\left(\frac{(27.6-(2*0.5))*0.5^3}{12}\right) + \left(\left((27.6 - (2 * 0.5)) * 0.5\right) + \left(\left(3.85 - \frac{0.5}{2}\right)^2\right)\right)\right)\right](\text{in}^4)$$

$$I_X = 561.13(\text{in}^4)$$

***Compressive Stress: ($\sigma_C$)***

$$\sigma_C = \frac{M_{MAX}(\text{lb} * \text{in}) * (H - Y)(\text{in})}{I(\text{in}^4)}$$

$$\sigma_C = \left[\frac{(283.57 * 12) * \left((1.18 * 12) - 3.85\right)}{561.13}\right](\text{psi})$$

$$\sigma_C = 62.52(\text{psi})$$

***Tensile Stress: ($\sigma_T$)***

$$\sigma_T = \frac{M_{MAX}(\text{lb} * \text{in}) * Y(\text{in})}{I(\text{in}^4)}$$

$$\sigma_T = \left[\frac{(283.57 * 12) * 3.85}{561.13}\right](\text{psi})$$

$$\sigma_T = 23.35(\text{psi})$$

***Shear Stress - Keel: ($\tau_k$) [ACI-14.5.5.1]***

$$\tau_k = \frac{V(\text{lb}) * Q(\text{in}^3)}{I(\text{in}^4) * b(\text{in})}$$

$$\tau_k = \left[\frac{120.34*\left(0.5*(17.71*12)*\left((3.85-\left(\frac{0.5}{2}\right))\right)\right)}{561.13*27.6}\right](\text{psi})$$

$$\tau_k = 2.97(\text{psi})$$

***Shear Stress – Gunwale: ($\tau_g$) [ACI-14.5.5.1]***

$$\tau_g = \frac{V(\text{lb}) * Q(\text{in}^3)}{I(\text{in}^4) * b(\text{in})}$$

$$\tau_g = \left[\frac{\left(0.43*\frac{1}{3}*1.18*(17.71*12*14.2)\right)*\left(0.5*14.2*\left(13.3-\left(\frac{0.5}{2}\right)\right)\right)}{3138.0*14.2}\right](\text{psi})$$

$$\tau_g = 1.06(\text{psi})$$

$$*I_y = 3138(\text{in}^4) \;\&\; \bar{Y}_Y = 13.3(\text{in})*$$

| | |
|---|---|
| ***Shear Strength: ($V_c$)***<br>***[ACI-22.5.5]*** | $V_c = 2 * \lambda * \left(\sqrt{f'_c(psi)}\right)$<br>$V_c = \left[2 * 0.75 * \left(\sqrt{2100}\right)\right](psi)$<br>$V_c = 68.74(psi)$ |
| ***Modulus of Rupture: ( $f_r$)***<br>***[ACI-19.2.3.1]*** | $f_r = 7.5 * \lambda * \sqrt{f_c'(psi)}$<br>$f_r = \left[7.5 * 0.75 * \sqrt{2100}\right](psi)$<br>$f_r = 257.77(psi)$ |
| ***Direct Tensile Strength:***<br>***($f_t$)***<br>***[ACI-20.2.1.3]*** | $f_t = 4 * \sqrt{f_c'(psi)}$<br>$f_t = \left[4 * \sqrt{2100}\,\right]$ (psi)<br>$f_t = 183.3(psi)$ |

## Hull Thickness

Total Thickness of Canoe Thickness = 0.5 inches
Reinforcement (Basalt Mesh) Thickness = 0.04 inches
Layers of Reinforcement = 3

*Total Reinforcement Thickness*

Total Thickness of Reinforcement=Reinforcement Thickness∗Layers of Reinforcement

*Composite Thickness Ratio*

Composite Thickness=Total Thickness of Reinforcement/Total Thickness of Canoe

Composite Thickness Ratio = 24% < 50% = Compliant

## Percent Open Area Calculation

Variables:
$t_1$= Thickness of reinforcement along sample length
$t_2$= Thickness of reinforcement along sample width
$d_1$= Spacing of reinforcing (center-to-center) along sample width + $\left(2 * \frac{t_1}{2}\right)$
$d_2$= Thickness of reinforcing (center-to-center) along sample width + $\left(2 + \frac{t_2}{2}\right)$
$n_1$= Number of apertures along sample length
$n_2$= Number of Apertures along sample width
$Area_{aperture}$= Area of single aperture

*Open Area Calculation*

$$\sum Area_{open} = n_1 * n_2 * Area_{apeture}$$

*Total Area Equation*

$$Area_{total} = Length_{sample} * Width_{sample}$$

*Percent Open Area Equation*

$$POA = \frac{\sum Area_{Open}}{Area_{Total}} * 100$$

*Table 11: Results of Percent Open Area Calculation*

| Variable | Quantity |
|---|---|
| $d_1$ (mm) | 30.1 |
| $d_2$ (mm) | 30.6 |
| $t_1$ (mm) | 5.6 |
| $t_2$ (mm) | 3.9 |
| $n_1$ | 6 |
| $n_2$ | 6 |
| Length (mm) | 180.6 |
| Width (mm) | 183.6 |
| $\sum Area_{Open}$ (mm) | 22500 |
| $Area_{Total}$ (mm) | 33158.16 |
| POA>40% | 67.9% |

*References*

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[3] Poraver, Poraver Expanded Glass Technical Data Sheet, June, 2016.

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## Pre-Qualification Form (Page 1 of 4)

__Northern Arizona University___
*(school name)*

We acknowledge that we have read the 2020 ASCE National Concrete Canoe Competition Request for Proposal and understand the following (*initialed by team project manager and ASCE Faculty Advisor*):

| | | |
|---|---|---|
| The requirements of all teams to qualify as a participant in the Conference and National Competitions as outlined in Section 2.0 and Attachment 1. | KR | ML |
| The requirements for teams to qualify as a potential Wildcard team including scoring in the top 1/3 of all Annual Reports, submitting a Statement of Interest, and finish within the top 1/2 of our Conference Concrete Canoe Competition (Attachment 1) | KR | ML |
| The eligibility requirements of registered participants (Section 2.0 and Attachment 1) | KR | ML |
| The deadline for the submission of *Preliminary Project Delivery Schedule* and *Pre-Qualification Form* (uploaded to ASCE server) is November 1, 2019; 11:59 p.m. Eastern | KR | ML |
| The last day to submit *ASCE Student Chapter Annual Reports* to be eligible for qualifying (so that they may be graded) is February 1, 2020 | KR | ML |
| The last day to submit *Request for Information* (RFI) to the CNCCC is January 15, 2020 | KR | ML |
| Teams are responsible for all information provided in this *Request for Proposal*, any subsequent RFP addendums, and general questions and answers posted to the ASCE Concrete Canoe Facebook Page, from the date of the release of the information. | KR | ML |
| The submission date of *Technical Proposal* and *MTDS Addendum* for Conference Competition (hard copies to Host School and uploading of electronic copies to ASCE server) is Monday, February 17, 2020. | KR | ML |
| The submission date of *Technical Proposal* and *MTDS Addendum* for National Competition (hard copies to ASCE and uploading of uploading of electronic copies to ASCE server) is May 19, 2020; 5:00 p.m. Eastern. | KR | ML |

Kristen Rasmussen — 10/28/19
*Project Manager (print name)* — *(date)*

Kristen Rasmussen
*(signature)*

MARK LAMER — 10/28/19
*ASCE Student Chapter Faculty Advisor (print name)* — *(date)*

[signature]
*(signature)*

*Figure 9: Page 1 of Prequalification Form*

## Pre-Qualification Form (Page 2 of 4)

Northern Arizona University
*(school name)*

***In 150 words or less, provide a high-level overview of the team's Health & Safety (H&S) Program. If there is currently not one in place, what does the team envision their H&S program will entail?***

The Health and Safety program that the team has implemented consists of hazard prevention and training. All members of the team have completed the university's chemical handling and safety training. The team has also compiled information regarding the chemicals that will be used and hazards that the team could encounter. The safety data sheet for each chemical and hazardous substance will be on hand during any work with the materials. This sheet provided instructions for safe use and first aid instructions, and disposal information. The potential hazards the team could be exposed to have been identified along with the proper steps to take to mitigate the risk of these hazards occurring.

***In 150 words or less, provide a high-level overview of the team's current QA/QC Program. If there is currently not one in place, what does the team envision their QA/QC program will entail?***

The QA/QC program that the team has in place for this project is the construction of a half size model of the canoe mold. The purpose of this half size model will be to practice acquiring a constant thickness, by controlling the thickness of our canoe, the team can mitigate the overall canoe weight to make it as light as possible and practice creating enough concrete mix in a timely manner.

***Has the team reviewed the Department and/or University safety policies regarding material research, material lab testing, construction, or other applicable areas for the project?***

The team has completed university training concerning safety and chemical handling and safety. A safety and health plan have been established with the lab manager to ensure all rules are understood being followed.

***The anticipated canoe name and overall theme is –*** *(please provide a brief description of the theme. The intent is to allow ASCE to follow up to determine if there may be copyright or trademark issues to contend with, as well as to provide insight)*

The name of this year's canoe is Agassiz. This year's theme is inspired by Mt. Agassiz located in Flagstaff, Arizona. The overall theme will consist of capturing the picturesque views that Mt. Agassiz provides the Flagstaff community.

***Has this theme been discussed with the team's Faculty Advisor about potential Trademark or Copywrite issues?***

The theme has been discussed with the Faculty Advisor and no potential Trademark or Copywrite issues are foreseen.

***The core project team is made up of 5 number of people.***

*Figure 10: Page 2 of Prequalification Form*

***Provide an estimated project budget for the year (including materials, transportation, etc.). Base this on real costs (not costs provided in the Detailed Cost Assessment). List and approximate (percentage (%) of overall) anticipated financial sources for the upcoming year (University, material donations, sponsors, monetary donations, etc.)***

## Financial Sources

| Financial Source | Percentage |
|---|---|
| University | 60% |
| Material Donations | 20% |
| Sponsors | 20% |

*Table 1: Financial Source Distribution*

*Figure 11: Page 3 of Prequalification Form*

Project Budget

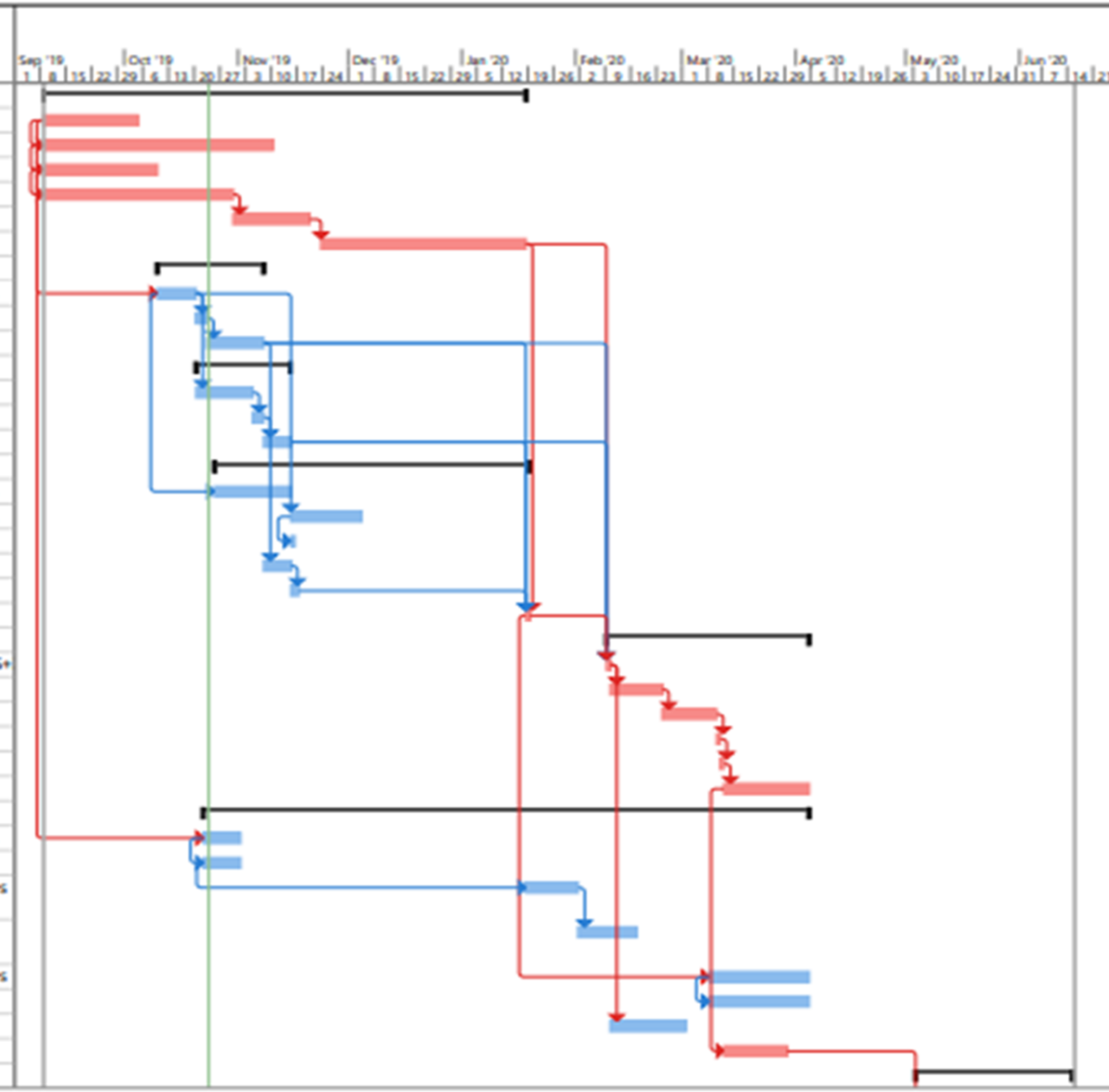
## 2019-2020 Concrete Canoe Budget

EXPENSES

| *Item* | *Amount* |
|---|---|
| **Canoe** | $1,470.00 |
| **Finishing** | $120.00 |
| Sealant | $70.00 |
| Sanding Material | $50.00 |
| **Materials** | $950.00 |
| Aggregate | $700.00 |
| Admixtures | $250.00 |
| **Structural Components** | $400.00 |
| Basalt Mesh | $100.00 |
| Post Tensioning | $300.00 |
| **Mold** | **$1,900.00** |
| Purchasing of Mold | $1,800.00 |
| Construction of Mold | $100.00 |
| **Transportation** | $1,100.00 |
| Transportation cart | $100.00 |
| Trip Cost | $1,000.00 |
| **Total** | $4,470.00 |

*Figure 12: Page 4 of Prequalification Form*

| ID | WBS | Task Name | Duration | Start | Finish | Predecessors |
|---|---|---|---|---|---|---|
| 1 | 1 | **Mix Design** | **93 days** | **Mon 9/9/19** | **Sat 1/18/20** | |
| 2 | 1.1 | Material Research | 25 days | Mon 9/9/19 | Fri 10/4/19 | |
| 3 | 1.2 | Material Acquisition | 60 days | Mon 9/9/19 | Sun 11/10/19 | 2SS |
| 4 | 1.3 | Initial Mix Design | 30 days | Mon 9/9/19 | Wed 10/9/19 | 3SS |
| 5 | 1.4 | Testing | 50 days | Mon 9/9/19 | Wed 10/30/19 | 4SS |
| 6 | 1.5 | Redesign | 20 days | Wed 10/30/19 | Wed 11/20/19 | 5 |
| 7 | 1.6 | Final Mix | 20 days | Sat 11/23/19 | Sat 1/18/20 | 6FS+3 days |
| 8 | 2 | **Hull Design** | **28 days** | **Thu 10/10/19** | **Thu 11/7/19** | |
| 9 | 2.1 | Canoe Development | 10 days | Thu 10/10/19 | Sun 10/20/19 | 4SS+30 days |
| 10 | 2.2 | Mold Development | 3 days | Sun 10/20/19 | Wed 10/23/19 | 9 |
| 11 | 2.3 | Mold Distributer | 15 days | Wed 10/23/19 | Thu 11/7/19 | 10 |
| 12 | 3 | **Structural** | **25 days** | **Sun 10/20/19** | **Fri 11/15/19** | |
| 13 | 3.1 | Calculations | 15 days | Sun 10/20/19 | Mon 11/4/19 | 9 |
| 14 | 3.2 | Aquiring Mesh/ Post-tension | 3 days | Tue 11/5/19 | Thu 11/7/19 | 13 |
| 15 | 3.3 | Testing | 7 days | Fri 11/8/19 | Fri 11/15/19 | 14 |
| 16 | 4 | **Construction** | **49 days** | **Fri 10/25/19** | **Sun 1/19/20** | |
| 17 | 4.1 | Stand | 20 days | Fri 10/25/19 | Fri 11/15/19 | 9SS+15 days |
| 18 | 4.2 | Pour Table | 12 days | Fri 11/15/19 | Wed 12/4/19 | 9FS+25 days |
| 19 | 4.3 | Post Tensioning Equipment | 1 day | Fri 11/15/19 | Sat 11/16/19 | 18SS |
| 20 | 4.4 | Mold Preparation | 7 days | Fri 11/8/19 | Fri 11/15/19 | 11 |
| 21 | 4.5 | Cure Chamber | 2 days | Fri 11/15/19 | Sun 11/17/19 | 20 |
| 22 | 4.6 | Practice Pour | 1 day | Sat 1/18/20 | Sun 1/19/20 | 7,11,15,21 |
| 23 | 5 | **Final Pour** | **45 days** | **Sun 2/9/20** | **Sat 4/4/20** | |
| 24 | 5.1 | Mixing and Placing | 1 day | Sun 2/9/20 | Mon 2/10/20 | 7,11,15,22FS+ |
| 25 | 5.2 | Wet Curing | 14 days | Mon 2/10/20 | Mon 2/24/20 | 24 |
| 26 | 5.3 | Dry Curing | 14 days | Mon 2/24/20 | Tue 3/10/20 | 25 |
| 27 | 5.4 | Removal | 1 day | Tue 3/10/20 | Wed 3/11/20 | 26 |
| 28 | 5.5 | Post Tensioning | 1 day | Wed 3/11/20 | Thu 3/12/20 | 27 |
| 29 | 5.6 | Aesthetic | 14 days | Thu 3/12/20 | Sat 4/4/20 | 28 |
| 30 | 6 | **Conference** | **117 days** | **Tue 10/22/19** | **Sat 4/4/20** | |
| 31 | 6.1 | Preliminary Schedule | 10 days | Tue 10/22/19 | Fri 11/1/19 | 2SS+42 days |
| 32 | 6.2 | Prequalification Form | 10 days | Tue 10/22/19 | Fri 11/1/19 | 31SS |
| 33 | 6.3 | ASCE Student Chapter Annual Reports/Dues Deadline | 14 days | Sat 1/18/20 | Sat 2/1/20 | 32SS+51 days |
| 34 | 6.4 | Technical Proposal and MTDS Addendum Deadline | 15 days | Sat 2/1/20 | Mon 2/17/20 | 33 |
| 35 | 6.5 | Presentation | 18 days | Sun 3/8/20 | Sat 4/4/20 | 22SS+48 days |
| 36 | 6.6 | Report | 18 days | Sun 3/8/20 | Sat 4/4/20 | 35SS |
| 37 | 6.7 | Races/Rowing | 20 days | Mon 2/10/20 | Sun 3/1/20 | 24 |
| 38 | 6.8 | Display/Decoration | 8 days | Thu 3/12/20 | Sun 3/29/20 | 29SS |
| 39 | 7 | **National Deliverables** | **41 days** | **Sun 5/3/20** | **Mon 6/15/20** | |




Page 1

*Figure 13: Page 1 of Initial Project Schedule*

| ID | WBS | Task Name | Duration | Start | Finish | Predecessors |
|---|---|---|---|---|---|---|
| 40 | 7.1 | Technical Proposal and MTDS Addendum Deadline | 15 days | Sun 5/3/20 | Tue 5/19/20 | 38FS+34 days |
| 41 | 7.2 | 2020 ASCE National Concrete Canoe Competition, hosted by University of Wisconsin-Madison | 2 days | Sat 6/13/20 | Mon 6/15/20 | 40FS+24 days |
| 42 | **8** | **Project Management** | **156 days** | **Mon 9/9/19** | **Wed 4/1/20** | |
| 43 | 8.1 | Scheduling | 156 days | Mon 9/9/19 | Wed 4/1/20 | |
| 44 | 8.2 | Meetings | 156 days | Mon 9/9/19 | Wed 4/1/20 | |
| 45 | 8.3 | Fundrasing | 90 days | Mon 9/9/19 | Wed 1/15/20 | |

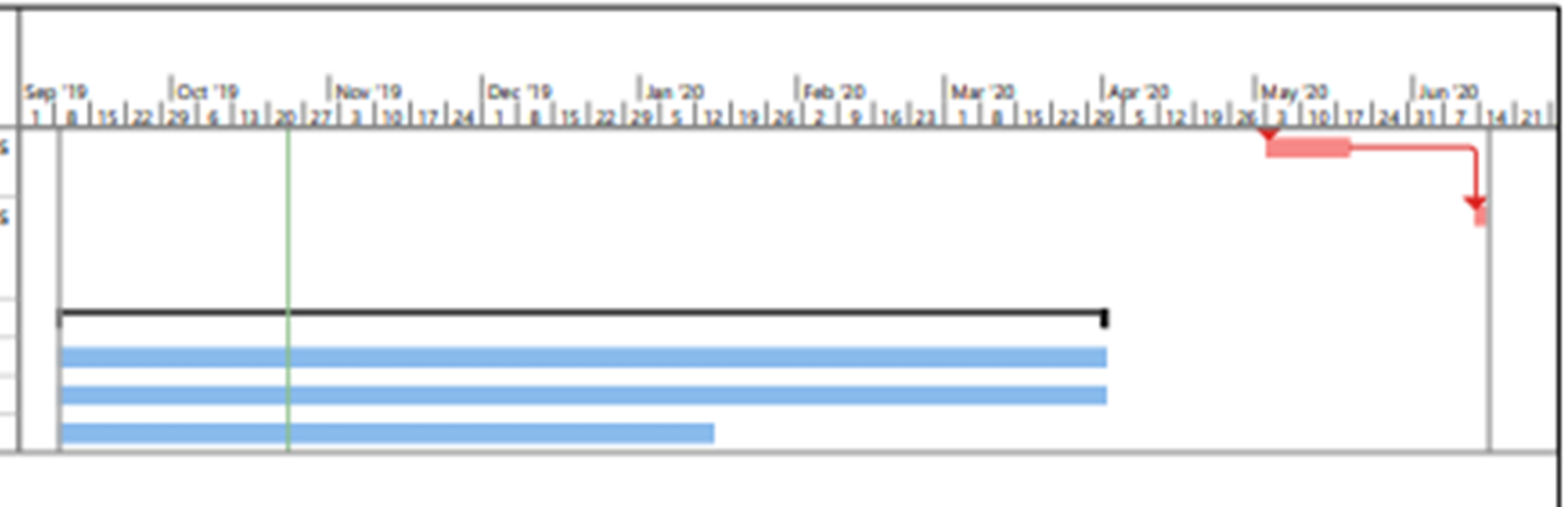



*Figure 14: Page 2 of the Initial Schedule*

## RFP Addendum Acknowledgment Form

Northern Arizona University
*(school name)*

We acknowledge that we have received and acknowledge the following Addendums to the 2020 ASCE National Concrete Canoe Competition Request for Proposal (*initialed by team project manager* and *ASCE Faculty Advisor*):

**Addendum No. 1: Presentation Q&A**

This Addendum provides the Technical Presentation score card and a list of questions that the judges can use during the 10-minute Judge's question & answer period. In addition, a scorecard was provided.

Per Section 8.0 of the Request for Proposals (RFP), the presentation is limited to 3 minutes and will be cutoff at precisely 3 minutes by a signal. Also, per Section 8.0 of the RFP, the technical presentation "...should focus on the primary aspects of the design, construction, and technical capabilities. Briefly summarize the major aspects of the project, with the intent of demonstrating why your team, design, and prototype should be selected by the panel of judges for the standardized design (recall this is a hypothetical scenario to provide an end goal for the RFP and the competition)." ML KR

**Addendum No. 2: Durability & Repairs**

This Addendum provides information regarding how the durability of the canoe prototype is to be assessed, allowable repairs and materials, and forms including *Damage / Accident Report*, *Repair Procedure Report*, and *Reconstruction Request*. ML KR

**Addendum No. 3: Detailed Cost Assessment**

This Addendum provided a list of material costs for a variety of cementitious materials, pozzolans, admixtures, fibers, aggregates, and other constituents that were not presented in *Attachment 4: Detailed Cost Assessment* of the Request for Proposal. Teams were also advised that if they have products that were not given a specific price for, they should use their best judgement to use a price for a similar material in their Material Cost Estimate. ML KR

Kristen Rasmussen 2/11/20
*Project Manager (print name)* *(date)*

Kristen Rasmussen
*(signature)*

MARK LAMER 02/11/20
*ASCE Student Chapter Faculty Advisor (print name)* *(date)*

*(signature)*

*Figure 15: RFP Addendum Acknowledgment Form*