University of Michigan
2022 Technical Proposal

Stallion

Date: February 12th, 2022

To: Committee on Concrete Canoe Competitions

Subject: Response to RFP – 2022 Technical Proposal, STALLION

Dear Committee on Concrete Canoe Competitions,

The Michigan Concrete Canoe Team declares that the proposed hull design, concrete mixture design, reinforcement scheme, and construction of the prototype canoe have been performed in full compliance with the specifications outlined in the *Request for Proposal* (RFP). The team has reviewed all Material Technical Data Sheets (MTDS) and Safety Data Sheets (SDS) for the included and experimental materials. *The Request for Information* (RFI) Summary has been reviewed by the team, and the team's submissions comply with all requirements from the responses provided in said summary. The below list of anticipated registered participants and their associated ASCE Society Member ID Numbers contains only those who are both Society Student Members of ASCE and qualified student members who meet all eligibility requirements.

University of Michigan

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Executive Summary

The University of Michigan has long valued research as a path to exploration and discovery and earned its 10-year consecutive title as the Nation's #1 Public Research Institution by understanding that there is no better way to learn than hands-on experimentation [1]. The College of Engineering embodied these values in 1929 when it established Camp Davis in Wyoming so that students could take field geology classes and learn how to survey land [2]. This invokes an image of cowboys traveling west into the unknown with a desire to understand the world around them that the Michigan Concrete Canoe Team (MCCT) embraces as its 2022 theme. MCCT contributes to the experimental culture of the University by enabling students to test new processes, design their own concrete, and have a practical and tactile approach to learning. This year, MCCT embodies the spirit of cowboys exploring the West as new test methods and construction techniques were pioneered to present *STALLION*, MCCT's 2022 entry into ASCE's Concrete Canoe Competition. The specifications for *STALLION* are shown below in **Table 1**.

MCCT competes in ASCE's North Central conference and demonstrates its adherence to the University's tenets with this year's submission. The past four years have been the most successful in the team's recorded history. In 2018, *MAJESTY* placed first at the North Central conference. In 2019, *TERRA* placed second. While MCCT was unable to compete with *KEPLER* in 2020 due to the COVID-19 pandemic, many improvements were made that have been maintained up to this year. In 2021, *ROWMAINE*, while not a physical prototype, placed first at the North Central conference and went on to place sixth at Nationals. MCCT has earned these successes through dedicated members striving for technical excellence.

Over 60% of current MCCT team members joined the team this year, and the cohort was excited to break new ground for the team. COVID-19 required a team structure independent of any one person. MCCT team members contracted COVID-19, dealt with supply chain issues, and rescheduled Casting Day. However, the team was adaptive and resilient: making more concrete than in any previous year, beginning several new tests, and improving the curing process.

MCCT's Hull Design subteam built off the knowledge gained from hydrodynamic testing in the 2021 season and chose to narrow the shape of the canoe, decreasing stability to increase speed. The Mix Design subteam vastly improved the way mixes were tested and information recorded, helping the team to survey and understand a previously unfamiliar landscape. The final mix design used an increase in the water reducer dosage to increase

Table 1. Canoe Specifications

<table>
<tr><th colspan="6">STALLION</th></tr>
<tr><td colspan="2">Weight</td><td>191 lb</td><td colspan="2">Compressive Strength (28 day)</td><td>880 psi</td></tr>
<tr><td colspan="2">Length</td><td>248 in</td><td colspan="2">Split Tensile Strength (28 day)</td><td>260 psi</td></tr>
<tr><td colspan="2">Width</td><td>26 in</td><td colspan="2">Flexural Strength (28 day)</td><td>220 psi</td></tr>
<tr><td colspan="2">Depth</td><td>12 in</td><td colspan="2">Pressure Air Content</td><td>18.8 %</td></tr>
<tr><td colspan="2">Average Hull Thickness</td><td>0.8 in</td><td colspan="2">Slump</td><td>0.25 in</td></tr>
<tr><td rowspan="2">Structural Concrete Unit Weight</td><td>Wet</td><td>67.5 lbs/ft^3</td><td rowspan="2">Finishing Concrete Unit Weight</td><td>Wet</td><td>88.9 lbs/ft^3</td></tr>
<tr><td>Dry</td><td>60 lbs/ft^3</td><td>Dry</td><td>75 lbs/ft^3</td></tr>
</table>

workability while maintaining strength. MCCT did physical air content and flexural strength tests for the first time this year, allowing the comparison of experimental numbers to calculated ones. MCCT is in the process of doing an Air Void test, a test first used in 2020, performing a Rapid Chloride Permeability Test (RCPT), and Scanning Electron Microscopy (SEM) on concrete mixes for the first time.

The team ventured into new territories by rebuilding the past curing process for the Enhanced Focus Area (EFA) report. This unprecedented experiment was able to improve concrete strength, but also brought unintended challenges in the finishing process. Investments in capital goods such as a pressure air meter, concrete curing blanket, and cone bottom tank for K20 have allowed the team to increase technical rigor and safety. Embracing and learning from both the victories and trials of pioneering, MCCT submits its 2022 canoe design, *STALLION* as a response to the 2022 RFP.

Project Delivery Team

ASCE Student Chapter Profile

The ASCE Student Chapter at the University of Michigan organizes academic, social, and professional events for its members and the wider Civil and Environmental Engineering (CEE) community. The chapter is comprised of eight student officers and holds weekly executive board meetings to discuss current and future events.

The first event of the year organized and hosted by the University's student chapter was the annual Civil and Environmental Engineering Career Fair, which was held virtually this year. This career fair is unique to the department in that all the companies that are invited to the fair are searching for civil and/or environmental engineers. This event helps students in the department find internships, full time jobs, and brings professionalism to campus. The ASCE Student Chapter at Michigan also hosts a Speaker Series. The Speaker Series luncheons occur every Friday. They have been a staple within the department for several years and attract a group of 20-40 undergraduate and graduate students from all civil and environmental engineering concentrations. Due to COVID-19, the series was conducted in a hybrid format this year. Speakers utilized Zoom to present while CEE students were able to attend in-person to watch the presentation and enjoy a provided lunch. The series also provides an opportunity for companies to recruit, introduce themselves to students, and create a presence on campus. The presentations themselves are a mix of technical engineering information and engaging networking. The chapter endeavors to create a relaxed environment where students can ask questions and learn.

Lastly, the ASCE Student Chapter at the University of Michigan hosts social events. It is very important to get to know one's peers and make connections with faculty, and the student chapter helps build these relationships by hosting social events. This fall, the chapter hosted a coffee truck that gave out free coffee to CEE students and faculty. The chapter also planned a study event for finals week where breakfast and coffee were provided to the CEE department. A weekend in Chicago is currently being planned, where alumni will take students on site tours around the city. This is a great opportunity for networking with alumni, faculty, and other students.

Collaborations between the chapter and MCCT have contributed to the ongoing success of both groups. This relationship ensures that MCCT has the support necessary for continual improvement and excellence at the annual ASCE competition.

Key Team Members

Captain, *Deborah Reisner*: The Captain creates a project plan and budget for the year and monitors the team's progress. This position facilitates general meetings and keeps subteams informed to make sure they are on track with deadlines. Additionally, the Captain helps any subteam when questions arise and prepares the team for competition.

Secretary, *Jenna Bonello*: The Secretary ensures all members are involved and informed by recapping meetings, scheduling events, and keeping team member information up to date.

Treasurer, *Stacey Zeng*: The Treasurer directs the team's finances. This includes registering for competition and managing the cost of materials for the mix design. This position also coordinates all team fundraising.

Hull & Structural Design Lead, *Luke VanAuken*: The Hull and Structural Design lead utilizes modeling and analysis software to determine the hull of the canoe and tests scaled designs. Additionally, the lead creates and analyzes load cases, reports shear and bending moments, and ensures the structural integrity of the canoe.

Mix Design Lead, *Eli Richards*: The Mix Design lead formulates and tests concrete mixes in order to determine the final design. This position keeps a record of each mix to track density and strength.

Mix Design Assistant, *Erdem Ozdemir*: The Mix Design assistant works closely with the Mix Design lead to plan and run subteam meetings to improve efficiency. The intention is that the assistant will become next year's Mix Design lead.

Construction Lead, *Gina Kittleson*: The Construction lead drafts designs for the technical display, canoe stands, and other large aesthetic elements such as the cross section.

Aesthetics Lead, *Lily Gandhi*: The Aesthetics lead designs the overall look of the canoe. The team votes on a theme and the Aesthetics lead develops this theme throughout all display elements.

Technical Submissions Lead, *Emma Anielak*: The Technical Submissions lead makes sure that the team's competition technical submissions are complete and cohesive.

Finishing Lead, *Connor Arrigan*: The Finishing lead completes the final look of the canoe. This position prepares the mold, smoothes the canoe during casting, and organizes sanding of the canoe after it has cured.

Quality Control/Assurance, *Xanthe Thomas*: The Quality Control/Assurance lead plans and performs test procedures for sample concrete, Casting Day concrete, and the canoe itself to check that these items meet MCCT's quality standards.

Paddling Lead, *Jamie Blatnikoff*: The Paddling lead recruits the paddling subteam and organizes team workouts. This position also reserves the Marine Hydrodynamics Laboratory and plans outdoor events to practice paddling.

Safety Officer, *Xanthe Thomas*: The Safety Officer learns all the requirements for the team to use a workspace at the Wilson Student Team Project Center on campus and keeps team members informed of these requirements. This position attends weekly safety meetings to make sure that the student project space is utilized safely.

Public Relations, *Leah Riutta*: The Public Relations lead increases awareness of the team on campus and plans outreach events to recruit new members. This includes managing the team's social media as well as planning social events for the team.

Webmaster, *Jamie Blatnikoff*: The Webmaster updates the team's website with current information and team member bios.

Organizational Chart

Faculty Advisor
Will Hansen

Team Captains: 🌵

Deborah Reisner
Captain (Sr.)🌵

Eli Richards
Mix Design (Sr.)🌵

Luke VanAuken
Hull Design (Jr.)

Emma Anielak
Tech. Submissions (Sr.)

Connor Arrigan
Finishing (Sr.)

Erdem Ozdemir
Mix Assistant (Jr.)

Gina Kittleson
Construction (Soph.)

Lily Gandhi
Aesthetics (Soph.)

Xanthe Thomas
Quality Control/Assurance
and Saftey Lead(Jr.)

Jamie Blatnikoff
Paddling/ Webmaster (Jr.)

Jenna Bonello
Secretary (Soph.)

Leah Riutta
Public Relations (Jr.)

Stacey Zeng
Treasurer (Soph.)

Kate Ceccacci
Claire Smith
Cindy Wheaton
Libby Chambers
Jonah Berman
Nicholas Said
Koby Khoo
Ian Rosenberg
Gillian James

Ben Routhier
Gigi Nassir
Konnor Walter
Luke Snudden
Vivian Kim
Nicholas Said
Karina Otten
Jenny Chong
Griffin de las Heras

Technical Approach

Hull Configuration

This year the MCCT Hull Design subteam focused on revising last year's canoe, *ROWMAINE*, using newly introduced software and fundamental principles of naval architecture. Specific objectives for *STALLION* included decreasing resistance to increase speed by creating a narrower canoe and fully introducing new subteam members to a plethora of techniques and methods of creating canoe designs for future competitions. Due to the success of previous year's models, MCCT was able to efficiently identify necessary alterations and utilize the remaining time of the season to familiarize new members with the process of designing a canoe.

The Hull Design subteam developed and tested three different canoe hull shapes in the Marine Hydrodynamics Laboratory (MHL) as part of the 2021 EFA Report since a canoe did not need to be built for competition [3]. Hydrodynamic calculations were performed which showed the magnitude of both wave and frictional resistance that the canoe would experience when racing. The results of the MHL testing led the Hull Design subteam to conclude that MCCT's 2020 canoe, *KEPLER,* had the stability and frictional properties that were desired for what the team was focusing on when compared to new designs. This test and evaluation process resulted in a greater understanding of the hydrodynamic properties of MCCT's canoe. Based on feedback from paddlers in *KEPLER*, MCCT determined that they had an excess amount of stability, which in turn could be decreased to maximize *STALLION*'s velocity when moving through the water.

The stability of the canoe is dependent on all three of the canoe's parameters: length, beam, and height. When looking at these three parameters, the Hull Design Subteam hypothesized that altering the beam alone would result in the improved canoe design that was desired. Using Rhinoceros 6.0 (Rhino), MCCT was able to create five different models to evaluate the effectiveness of decreasing the beam [4]. These models had 5% decrements in the beam, and when comparing each of them in the hydrostatic software, PolyCAD 10.4, the subteam found that a 10% decrease in beam length would produce a canoe with viable stability and better max speed [5]. This means the team changed the maximum width of the canoe from 29-inches to 26-inches. These alterations and their accompanying results are shown in **Table 2** which compares the overall beam length to the attributed heeling angle and transverse metacentric height (GMT).

The heeling angle and the GMT are a clear and concise way to estimate stability, and they effectively show the leniency of the canoe to tilting while paddling. The Hull Design subteam wanted to ensure that the overall shape and performance of the canoe stayed relatively the same; parameters such as block coefficients and prismatic coefficients were compared, making sure these values didn't drop significantly. Additionally, in **Table 2** it can be seen that the block coefficient stayed relatively the same, but the heeling angle increased by 1.5 degrees. The GMT decreased by about 2-inches, which was expected when narrowing the canoe. To compensate for this decrease in stability, MCCT has been holding paddling practices in the Marine Hydrodynamics Laboratory to train both experienced and inexperienced paddlers.

Table 2. Beam Decrements and Their Respective Canoe Parameters

	Beam Length (inches)	Heeling Angle	GMT (inches)	Block Coefficient (C_b)	Prismatic Coefficient (C_p)
Original - 0%	29.0	23.5°	8.2	0.44	0.59
5%	27.5	24.0°	7.1	0.44	0.58
***STALLION* - 10%**	26.0	25.0°	6.2	0.44	0.59
15%	24.6	26.5°	5.3	0.44	0.58
20%	23.1	27.5°	4.5	0.44	0.59

With the tight time constraints that accompany the construction phase of building the canoe, the team had limited time for new hull configurations. In reaction to this early deadline, the Hull Design subteam researched new ways to create an adaptable model for future years, including adding additional control points for easier adjustments and adding more layers for easier access to certain parameters. As seen in **Figure 1**, the team successfully added additional control points to the canoe's hull, the red spline being *KEPLER*'s model and the black spline being *STALLION*'s improved design. More control points near the gunwales improves beam iteration efficiency since it is easier to manipulate the stations of the Rhino model when modifying the hull design.

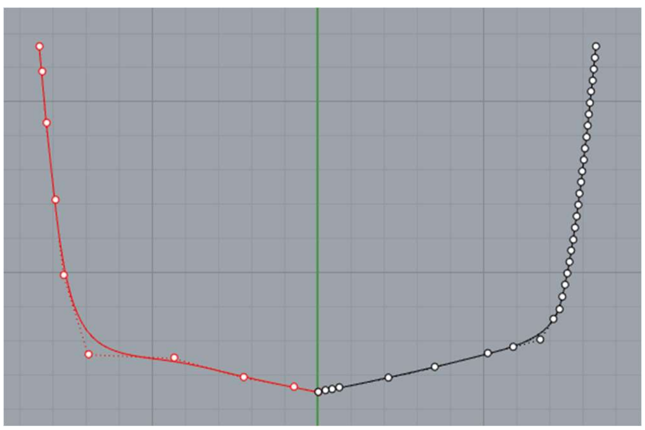


Figure 1. Cross-sectional Cut of KEPLER (Red) vs STALLION (Black) in Rhinoceros 6.0 Showing Improved Control Points

The team's various 3D canoe models were adjusted this way so altering the canoe's parameters would be easier for future members of the subteam. Additionally, the team focused on making transition documents and step-by-step tutorials for canoe builds, hydrostatic modeling, and Excel-based structural calculations. Since most members join the MCCT Hull Design subteam with little previous naval design experience, the team wants to make the transition into the Hull-Design subteam as smooth as possible to optimize the short time frame that accompanies the modeling process. With these new processes and methods of canoe design, MCCT will have a more precise design basis for many years to come.

Structural Analysis

This year, the Structural Analysis subteam was combined with the Hull Design subteam to provide a greater understanding of canoe properties and the design process to new members. MCCT developed four different loading cases to determine the bending moments and shear stress values of the canoe. The four cases consisted of Male Tandem, Female Tandem, four-person Coed, and placing the canoe on stands outside of the water. In the case of the stands, the bending moment was calculated with the stands at 6.25 ft and 14.4 ft from the bow, a more applicable case than the simply supported load cases considered in **Appendix C**. The paddlers were considered as point loads and were positioned at 20% and 80% of the canoe's length for tandem cases, and 20%, 40%, 60%, and 80% of the canoe's length for the coed case. To get an average weight for paddlers, MCCT conducted a survey of all team members who planned on paddling at competition and found the mean weight for both male and female cases. The team calculated bending moment and shear stress diagrams for each individual case using fourth order polynomial equilibrium equations in Microsoft Excel [6]. Based on the calculations listed in **Appendix C**, it was found that the female tandem case resulted in the maximum bending moment of the canoe with a magnitude of 538-pound foot. A graph of each of the four case's respective bending moments is shown in **Figure 2**.

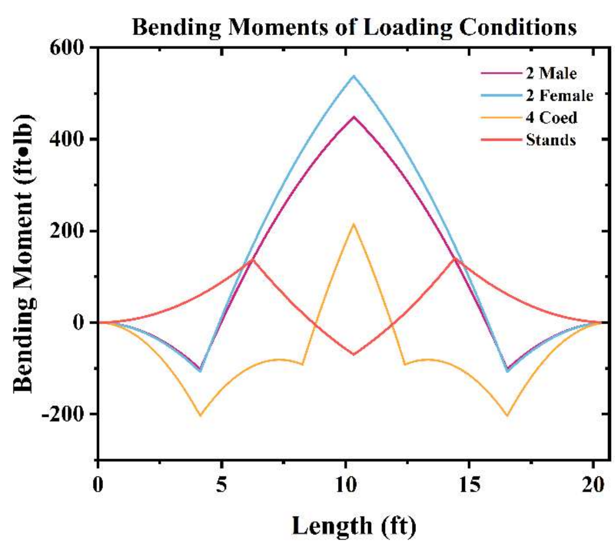


Figure 2. Bending Moments of Various Loading Conditions Along Canoe Length

The mix chosen by the Mix Design subteam contained a maximum yield tension of 256-psi, which was nearly two times as strong as *ROWMAINE*'s yield tension of 132-psi. This resulted in a safety factor of 3.3, an increase from *ROWMAINE*'s safety factor, indicating that the Mix Design subteam met their goal of making a stronger concrete.

Materials Selection and Testing Protocol

The two primary goals of the Mix Design subteam were to design a lightweight concrete stronger than *ROWMAINE*'s mix and to facilitate the transfer of knowledge of processes to younger team members. Designing a stronger mix proved to be an achievable goal because of the new natural aggregate volume percentage requirements in the RFP; however, making low density concrete was a challenge. Due to a miscommunication of material compliance to the ASTM C330 classification, only seven of the 16 test mixes the Mix Design subteam made followed RFP requirements.

In designing the mix for *STALLION*, few adjustments were made to past years cementitious materials ratios as a strong base in this area was established from prior experimentation and testing. Instead, the focus was on adjusting the aggregate makeup due to requirements of the RFP. As in previous mix designs, the pozzolan VCAS 160 was used as a lightweight substitute for a large portion of Portland Cement because it has a lower specific gravity, is a recycled material, and has lower CO_2 emissions [7]. Class C Fly Ash, another pozzolan, was used for very similar reasons [8]. This material is a byproduct of coal fired power plants and by using it, a pre-existing material is utilized rather than let it go to waste. The cementitious materials also continued to include Komponent, a type K cement, in the same proportion as in previous years to prevent shrinkage cracking [9][10]. One change made in the cementitious materials was that the Mix Design subteam returned to using GGBFS 100 instead of GGBFS 120. In 2020, *KEPLER* switched to using GGBFS 120 to improve the workability of the mix in the absence of latex [10]. This year's team would have elected to do the same, however, suppliers were unable to provide GGBFS 120, so the subteam was forced to fall back on the previous material. The Mix Design subteam did, however, take steps to improve the workability through other materials, specifically admixtures. For the pigmented finishing mix, known as slurry, GGBFS 120 was replaced with Portland Cement to create a stronger and less dusty concrete. GGBFS 120 was used for *KEPLER* because it is white and can be pigmented with vivid colors, but *STALLION*'s finishing pigments are dark colors which are compatible with the duller Portland Cement.

With respect to aggregates, drastic adjustments to the proportions present in the mix were needed to comply with new volume requirements in the RFP. The final aggregate properties are shown below in **Table 3**. An early decision made to prioritize the strength of the concrete was to no longer use CityMix, which was used in *ROWMAINE* as a replacement for glass cenospheres [11]. CityMix significantly reduced the strength of the concrete, and this year the subteam decided to completely exclude it since a limited quantity of non-ASTM C330 compliant aggregates were allowed. As in previous years, three different sizes of Poraver were used to improve the gradation of mixes. Until November, the Mix Design subteam was designing mixes believing that Poraver was ASTM C330 compliant because the supplier had informed the team as such [12]. When it came to the team's attention that Poraver did not meet the slump and gradation requirements of ASTM C330, the proportion of Poraver was decreased to meet RFP requirements [13].

The ASTM C330 compliant aggregates were Buildex, which the subteam began using in *ROWMAINE*, and Norlite, which the subteam began using in *KEPLER*. Both are lightweight expanded shales, but Buildex has a larger particle size and is lighter than Norlite [14]. Having these two differently sized natural aggregates contributed to the overall gradation of the aggregate selection.

Table 3. Aggregate Properties

Aggregate	Composition	Specific Gravity	Absorption (%)	Particle Size (mm)
Poraver 1-2	Glass Microsphere	0.40	19	1.0 - 2.0
Poraver 0.5-1		0.50	18	0.50 - 1.0
Poraver 0.25-0.5		0.70	21	0.25 - 0.50
SG 300	Cenosphere	0.72	1	0.01-0.30
K20		0.20	1	0.03-0.09
Buildex	Expanded Shale	1.20	12	3.18-6.35
Norlite	Ceramic Shale	1.55	7	0-4.76

Two other aggregates were used that are not ASTM C330 compliant. These were SG 300 and K20, both of which are very fine aggregates and mineral fillers that contribute to the smaller particle range of the gradation. A smoother gradation minimizes the total volume of voids between aggregates, improving the workability of the mix [15]. They are also lightweight, which was critical to keeping the density of the concrete low [16][17].

We continued to implement internal curing by iterating on the process begun with *KEPLER* for all test mixes and the canoe itself [10]. This was accomplished by soaking the natural aggregates, Buildex and Norlite, so that during the curing process they would release water which aids in the hydration reaction and increases the strength of the mix. Internal curing can also prevent early shrinkage. To ensure consistency, a measured amount of water was added to the aggregates such that they were completely submerged, the aggregates were allowed to soak for a minimum of 24 hours, and then the remaining water was poured through a sieve so that aggregates were not lost. To control the true quantity of water that goes into the mix, the weight of the water removed from the bucket is subtracted from the original weight of water that was added, then the weight of water remaining in the aggregates is subtracted from the total water designed to be added to the mix.

The mix used two admixtures: an air entrainer and a high range water reducer, or superplasticizer. The proportion of air entrainer that was used in previous years was maintained, however the subteam decided to experiment with increasing the amount of water reducer. In *KEPLER*, the team elected to double the amount of water reducer in order to improve the workability of the mix in the absence of latex [10]. Studies have shown that overdosing a superplasticizer increases workability without decreasing strength at the low Fly Ash contents that the mix uses [18]. This year, the team tested two mixes, identical except for the proportion of water reducer, and determined that doubling the water reducer in the mix was beneficial for the workability of the mix, using this new doubled proportion in the final design. *STALLION* continues to employ the same dosage of Polyvinyl Alcohol (PVA) fibers in its mix as in previous years to prevent shrinkage cracking [19]. These fibers are equally divided by dosage between ¼-in, ⅓-in, and ½-in lengths [20][21][22].

This year, the team performed tensile and compressive tests at 7, 14, and 28-days on the Casting Day concrete, resulting in a robust curve of strength over time. This curve can be seen in **Figure 3**. In the testing regimen, the team decided to implement a system for disqualifying poorly made cylinders. When a cylinder is weaker than the average strength of the cylinders cured for a shorter time, it is discounted as a poorly made cylinder. One 28-day cylinder fell into this category.

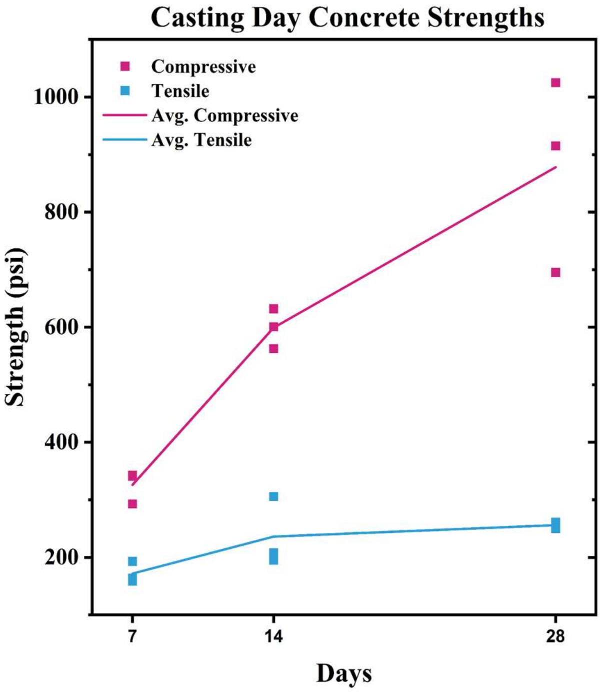


Figure 3. 7, 14, 28 Day Compressive and Flexural Strengths of Casting Day Concrete

The team made flexural beams for the first time. Traditionally, flexural strength was calculated based on **Equation 1.**

$$f_r = 7.5 * \sqrt{f_c} \quad \textbf{(1)}$$

$$f_r = flexural\ strength$$
$$f_c = compressive\ strength$$

This new test allowed the comparison of this calculation of 220-psi to an experimental value, which averaged 50-psi. The large discrepancy between these values, likely due to the dependance of results on sample preparation and testing condition, and the large amount of concrete these tests require, explains why the team has traditionally not done flexural tests and will likely not continue them in the future [23]. Conversely, the air content tests, also performed for the first time this year, were extremely accurate. The comparison of calculated and experimental values for both flexural strength and air content are shown in **Table 4**.

Transfer of knowledge was an important goal because of the 17 regular Mix Design team members, only four had previous experience, and only two had been on the team during a year when the team casted a physical canoe. As a result, much of the Mix Design meetings were spent teaching new members about concrete and the methods used to design and test mixes, as well as incorporating new strategies and tests. The subteam was able to prepare future generations for upcoming seasons and made the process of transferring knowledge easier for the next iteration of the Executive Board.

Table 4. Comparison of Experimental and Calculated Results for Flexural Strength and Air Content

Flexural Strength (28 day)	Experimental	50 psi
Flexural Strength (28 day)	Calculated	220 psi
Pressure Air Content	Experimental	18.8 %
Gravimetric Air Content	Calculated	18.6%

MCCT's Casting Day concrete had an average density less than that of water but a large standard deviation of almost 5-lb/ft^3. Some cylinders did not float because they were packed poorly resulting in large voids. This large range in standard deviation is mostly due to an increase in test specimens; the final density value was calculated by averaging 21 cylinders, while in past years six cylinders were averaged. This increase in data is ultimately an improvement, making conclusions more robust by better estimating the possible variation in mixes.

The Mix Design subteam was successful in its goals for the 2022 season. A mix with an average density of 60-lb/ft^3 and improved workability was selected as the final mix. The compressive strength of the concrete improved by 150-psi from 2021 and new members learned the important processes of the team, ensuring a strong foundation to work from for years to come.

Proposed Construction Process

Form Material Selection

MCCT used Expanded Polystyrene (EPS) as the material for the male mold, as was done in 2020 [10]. This material was selected for its compatibility with the outside vendor's machinery and because it can be sourced from repurposed scraps of foam from the vendor's projects. The mold is fabricated by the vendor in three parts so the scrap foam may be utilized and MCCT can transport it easily.

Form Construction & Preparation

The mold was secured together with dowel rods on top of an even work surface. A layer of automotive body filler, which remedies any pitting of the foam mold that may hinder final smoothness and de-molding, was applied to the entirety of the canoe mold. This layer was intentionally thinner than in 2020 as MCCT members noticed excessive automotive body filler degrades the EPS and requires more sanding of the mold to achieve a smooth finish. So the mold could be easily removed after concrete was placed, multiple coats of Chem-Trend® water-based release agent were applied to the mold. This was chosen over oil-based alternatives because a water-based agent is more sustainable. The release agent was applied to the canoe mold with a pneumatic paint sprayer in a HEPA-filtered paint booth. The mold was then marked to indicate where sections of cut mesh were to be placed. Separate mesh pieces were used to prevent pockets of air in the concrete caused by stiffness in the mesh.

Method of Mixing Concrete

As in previous years, the Mix Design subteam measured the cementitious materials, aggregates, and fibers into separate labeled batches prior to Casting Day. This provided correct amounts of each component in consecutive batches of concrete. This practice yielded a more consistent mixture throughout the canoe and improves Casting Day efficiency.

The K20 was added first to the Hobart D300 mixer because it prevented loss of material into the air when mixed. The cementitious materials and non-natural aggregates were added second. The natural aggregates were added third since they were pre-soaked, and the cementitious materials should remain dry for as long as possible. The air entrainer was added next, and then mixing began. About 75% of the total water and all fibers were added quickly within 30-seconds. The water reducer was added directly after the water and fibers. Finally, the rest of the water was added to the mixture.

Placing Concrete

MCCT has continued to see positive results in the canoe's construction using the "Chasing Method" for placing the concrete. This method involves the construction of the canoe at different stages along the length of the canoe, allowing more people to work at once and reducing the risk of cold joints. The placing of the concrete was divided into three stages: the placing of the first ⅜-inch layer of concrete, the incorporation of the fiberglass mesh into the concrete, and the placing of the second ⅜-inch layer of concrete. Moving from the bow to the stern, the first layer of concrete was placed moving from the keel line to the gunwales until the layer was of appropriate thickness in the first chasing section. When the chasing section reached the desired length, it was checked for thickness compliance, and when met, concrete placement continued to the next chasing section. When a section of the first layer of concrete was wide enough, a 2-ft section of mesh was placed and incorporated by rubbing small amounts of concrete over the mesh. The first layer of concrete continued to be laid on the rest of the mold while the mesh of the first chasing section was being incorporated. This process was repeated down the length of the canoe while overlapping each piece of mesh by two-inches, until the mesh was fully incorporated into the first layer of concrete on the canoe. Once the mesh was fully incorporated in a chasing section, the second layer of concrete could be laid, checking to maintain a total thickness of ¾-inch. This process continued until the entire mold was covered in all three layers. The bow of the canoe was sculpted to create a more pointed shape to cut through the water, and the stern was sculpted into a rounded shape to create smooth streamlines.

Curing

This year the curing process of the canoe was altered after experimentally testing several different curing methods as outlined in the EFA. The new curing method involved covering the canoe in damp burlap, plastic, and an insulating concrete curing blanket. The burlap was sprayed with water at least once every three-days. The new method kept free water maintained on the entire surface area for the duration of the curing process as required by ASTM C192, in an attempt to prevent cracking due to cyclic drying and rewetting of the concrete [24]. This curing process took place over 28-days starting on December 11, 2021 in a paint booth with fans set to heat the room if it dropped below a critical temperature of 60-degrees Fahrenheit. Internal curing was facilitated by pre-soaking the natural aggregates, Buildex and Norlite, for 24-hours, which limited the risk of shrinkage and improved concrete workability [25].

Mold Removal and Finishing

After curing was complete and before the canoe was de-molded, the exterior of the canoe was sanded. The canoe was kept on the mold to stabilize the gunwales and prevent cracking during sanding. The mold was then removed from the inside of the canoe. This was done by flipping the canoe and resting it on old, female mold pieces to support it. Mold removal was more challenging than in past years, taking multiple days and damaging the mold so that it could not be reused. Mold removal has historically been a simple process, but improvements to the curing process detailed in the EFA may have caused the removal issues.

The Finishing Lead organized sanding sessions to sand the exterior and interior of the canoe. Sanding was done in a closed tent with proper ventilation and respirators. The Finishing subteam started sanding with an 80-grit paper and worked up to a 320-grit paper. After final sanding, slurry was applied and allowed to dry completely, then two coats of SILRES BS 6920 sealer were applied to the entirety of the vessel [26].

Aesthetics

MCCT's theme revolves around the well-known Western aesthetic: the frontier of the historical wild west and imagery of deserts, cacti, saloons, and cowboys. This theme, as shown in the informational display and structural stands for the competition, was also incorporated into the design of the canoe using slurry. The Aesthetics subteam continued to use the stencils to place slurry as it yielded sharp lines and clear results. The slurry was used to create a horseshoe trail across *STALLION* to tie the canoe's design into the rest of the display and cactus patterns repairing hairline cracks. The aesthetic elements on the inside of the canoe were intentionally placed to avoid where paddlers will sit during tandem races to be durable during racing.

The Construction and Aesthetics subteams also revised the design of the structural stands for competition. In previous years, the canoe has been supported by two V-shaped braces along the keel line. To spread out the force distribution on the canoe, new supports hold the canoe with straps across the entire width (**Figure 4**) placed outside of the repaired cracks. This increased the amount of compressive force on the canoe without introducing any additional tensile forces. MCCT is confident that this design fully supports the canoe with more redundancies while it is being displayed.

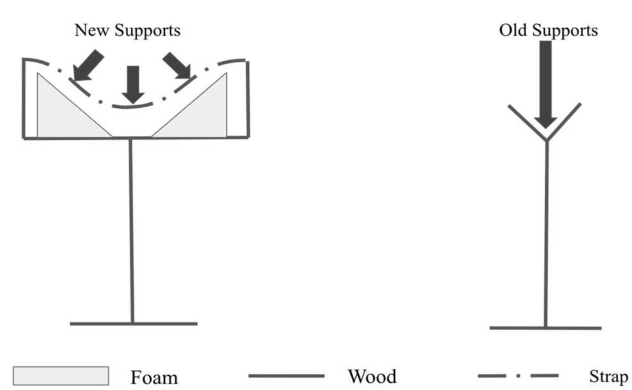


Figure 4. Canoe Structural Supports Diagram

Scope, Schedule, and Fee

To be awarded a design contract by the CCCC, MCCT considered how to arrange the budget, schedule, project scope, and risk management to fulfill the requirements of the RFP and guide the team to producing a quality canoe.

Critical path items in the team's project schedule in order of occurrence included recruiting, the release of the RFP, choosing a theme, choosing a Hull Design, Nov. 5th competition Deliverables, choosing a Mix Design, Casting Day, weighing the canoe, the Technical Proposal due date, flotation testing, and Regional Competition. The schedule was arranged such that internal deadlines were before the deadlines required by the competition or physical constraints of the design process. MCCT experienced disruptions to the schedule due to supply chain and material procurement issues. This resulted in postponing Casting Day one week later than was originally scheduled. While Casting Day is a critical path activity, this delay did not impact consecutive critical path activities because it was purposely scheduled earlier than necessary. The delay could have not been more than one week, otherwise many facilities and MCCT members would be unavailable. Because of this built-in flexibility for risk management, MCCT intends to use the same schedule structure in the future. More emphasis will be placed on acquiring materials proactively, requesting average lead time information from suppliers, and tracking material inventory.

Since MCCT did not build a canoe last year and an in-person competition was not held, the 2022 team budget was the largest in team history. MCCT primarily invested these funds in capital goods, such as a pressure air meter, K20 storage tank, and concrete curing blanket to prepare the team for future years. Although one-time-costs increased, the canoe materials cost, $696.54, decreased by 15% in comparison to 2021 [11]. Investments this year gave MCCT the tools, infrastructure, and testing necessary to offer a competitive proposal for a high-quality canoe. Norlite, Buildex, GGBFS 100, Komponent, and Fly Ash are all materials that are donated from the suppliers to MCCT. Other materials did not need to be purchased as the team had bought or received them from sponsors in previous years. Overall, 20% of the canoe material costs were not expenses this year.

Quality Control and Quality Assurance

Mix Testing Quality Assurance

This year, MCCT performed a much larger variety of tests on wet and cured concrete mixes. In the past, the team did not take physical air content measurements, and only used theoretical gravimetric calculations. The team attempted two methods of experimental air content testing to determine which would yield more accurate results for the lightweight concrete: the volumetric air meter and the pressure air meter [27][28]. The volumetric air meter was best suited to the specifications of the team's concrete based on aggregate size; however, agitation with the alcohol solution separated the aggregates by density and resulted in lighter weight aggregates rising out of the air meter, which prevented accurate measurement. Subsequently, the team tested and purchased a pressure air meter, show in **Figure 5**. This type of air meter was chosen because of its This type of air meter was chosen because of its ability to keep the mixture homogeneous. MCCT taught members how to calibrate the air meter and properly

Figure 5. Pressure Air Meter

perform an air test according to ASTM C231 standards to be able to obtain a physical measurement during the mixing process [28].

The team also focused on more thorough testing of cured concrete. The team sought to improve the consistency of test results by ensuring the cylinder-making processes followed ASTM C31 standards. Instead of doing three equal lifts for 8-in cylinders, MCCT adjusted the process to follow the industry standard of two equal lifts [29]. The team also changed the curing times of test cylinders to one 7-day cure and two 14-day cures for each design mix to be able to better identify invalid strength tests.

Casting Day Quality Assurance

Several quality assurance devices were prepared and utilized on casting day. Firstly, ⅜-inch thick, flexible foam tape, generally used for window insulation, was used to indicate the desired thickness of each layer of concrete. The Quality Control and Assurance (QA/QC) Lead placed the tape along the canoe mold in one-foot intervals as a guide for uniform concrete thickness during placement. Secondly, the QA/QC Lead painted ⅜-in colored stripes on construction nails. The nails were intermittently stuck into the concrete throughout Casting Day to confirm that layers were the correct thickness after they had been placed. Finally, to guide the keel line, a string was attached to dowels that were placed through the mold on each end of the canoe and strung taught from bow to stern as seen in **Figure 6**.

Figure 6. Mesh Being Incorporated into the First Layer of Concrete with the QA/QC Devices of Foam Tape and Keel Line String (Credit to Brenda Ahearn)

Quality Control

MCCT will conduct a flotation test to confirm buoyancy of the canoe and use an air void test to confirm air content of a cured concrete cylinder prior to product delivery. Since the standard deviation of the final mix includes concrete that does not float, the team will first conduct a floatation test on the canoe and then make the critical decision on whether foam bulkheads should be added. These quality control measures will demonstrate that the design and implementation strategy deliver a viable final product that meets the design specifications.

Non-Construction Quality Control and Assurance

The team added a Technical Submissions Lead in 2021 who is responsible for reviewing technical documents and ensuring RFP requirements are being met. This position was kept this year to monitor the quality of reports and delegate responsibilities for project deliverables.

Sustainability

MCCT used Fly Ash and GGBFS 100 as more sustainable alternatives for Portland Cement in the concrete design. The team continued to use a water-based release agent instead of oil-based release agent and a mold made of scrap pieces of EPS foam. While the challenges with mold removal meant that large pieces of the mold could not be reused, enough was salvaged to use for the full-scale model cross-section and some scrap foam was donated to art students.

Using the same Lifecycle Analysis methodology used in the 2021 EFA, the CO_2 emissions of the gate-to-grave production process of one metric ton of *STALLION*'s concrete was calculated to be 1,316-lbs of CO_2 [3]. This is an increase from *ROWMAINE* and *KEPLER*, but still less than *TERRA*. The increase in emissions is largely due to an increase in water reducer to improve workability, the reintroduction of K20, and an increase in natural aggregate proportion to comply with the RFP. **Figure 7** shows the trend of materials processing over the last four years.

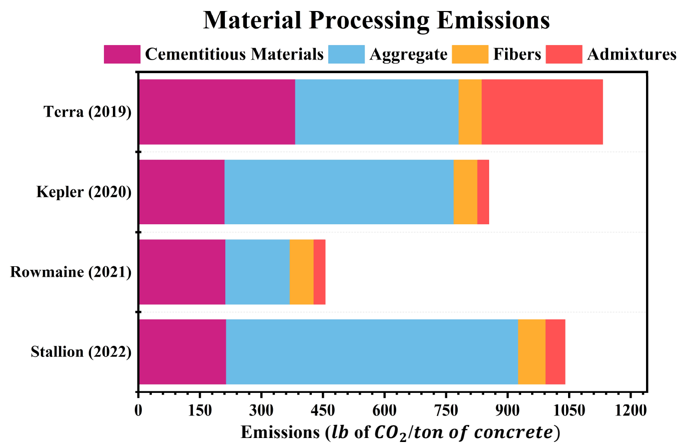


Figure 7. Materials Processing Emissions of 1 Metric Ton of Concrete for the past 4 years of Mix Design

MCCT began to experiment with safer ways of handling concrete wash water, given that the team works in a communal space with other student project teams that is not specifically designed for handling concrete. Concrete wash water can be damaging to municipal water infrastructure and the surrounding environment [30]. Instead of rinsing mixing tools from concrete in a sink, they were rinsed in a separate container of water. The intention is that in the spring this water can be poured into a concrete washout container, dried, and the remains safely thrown away or recycled locally. If a local recycler can be found that will accept this concrete, this program could be expanded in future years to include all of the team's scrap concrete.

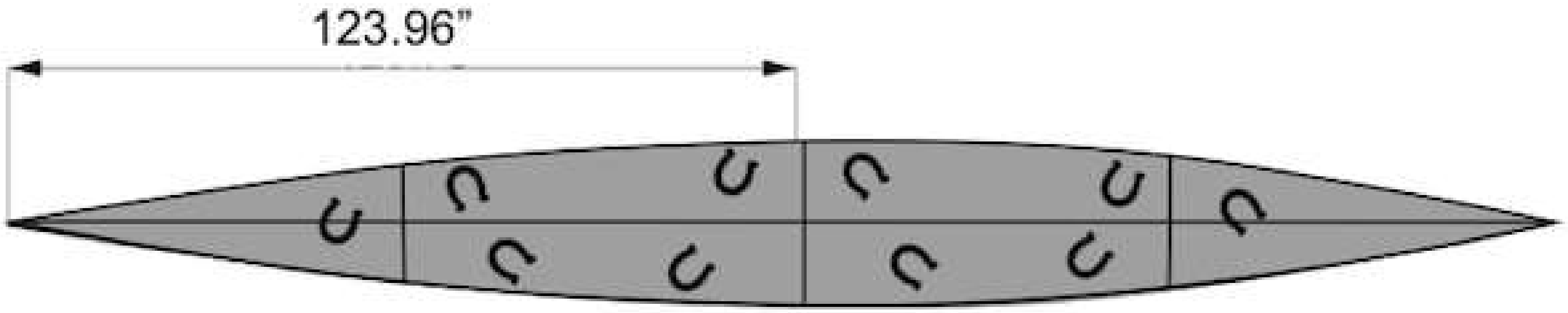
As an organization, MCCT cared for the sustainability of the team structure by continuing the leadership positions of Mix Design Assistant and Technical Submissions Lead added in 2020 and 2021, respectively. As MCCT gained many new members this year, new member onboarding information was consolidated in an easy to access place. Knowledge was transferred to new members by encouraging new students to practice hands-on learning and take on their own projects. This structure is sustainable because the team has many younger members; 32% of the team will graduate in 2023 and 28% in 2024.

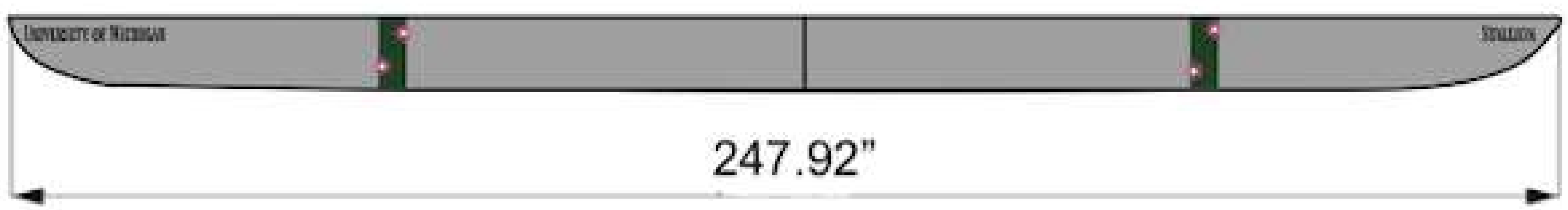
Health and Safety

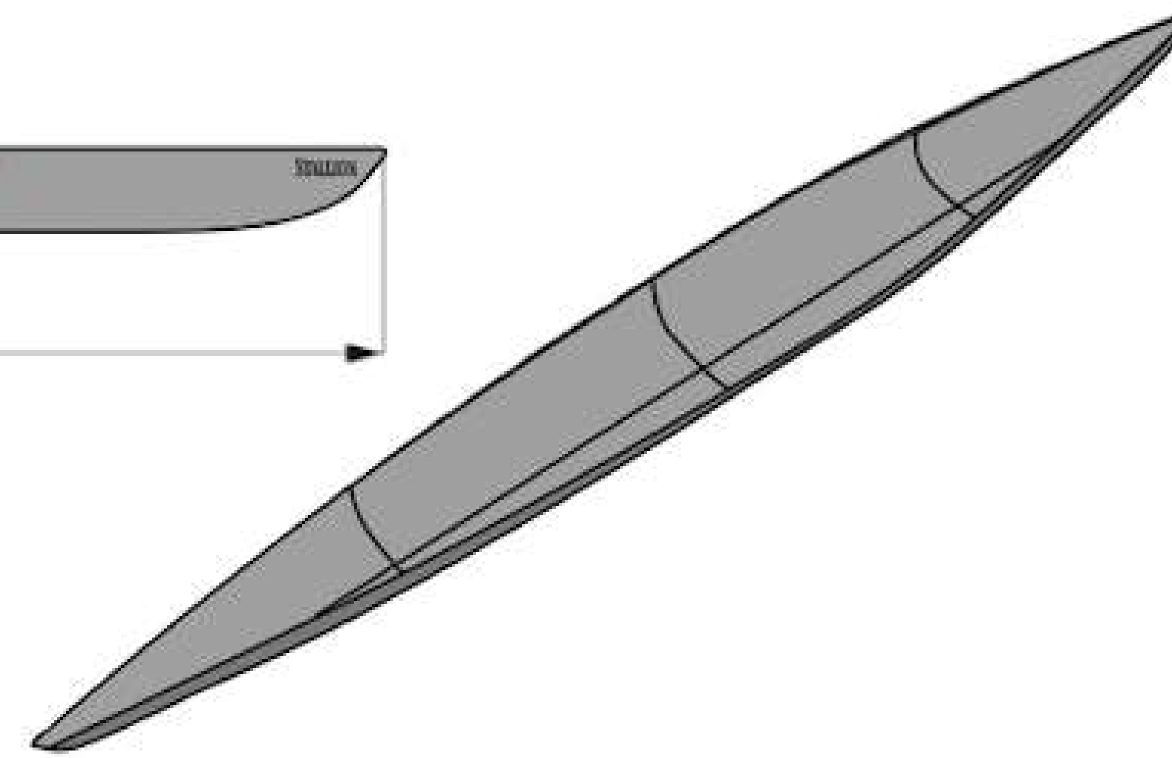
Health and safety are always MCCT's highest priority, especially during the COVID-19 pandemic. All team members are required to follow the University of Michigan's COVID-19 regulations which include wearing face masks, following vaccination policies, and completing daily health screenings. Members that work in the design space are required to complete a safety module, pass an online exam, and then participate in an in-person safety training before being granted access to the team's work area.

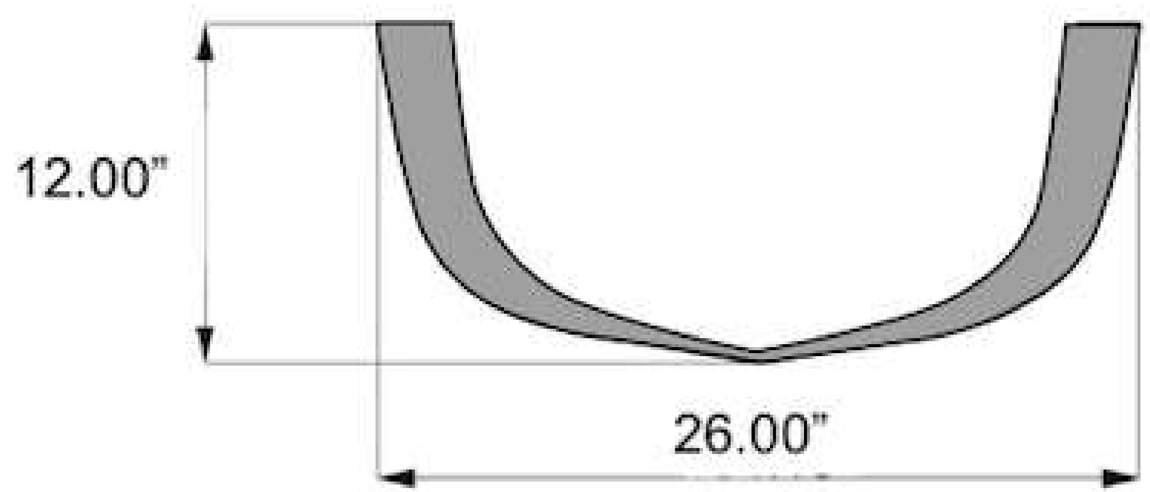
During all Mix Design and Construction subteam events, team members were required to wear protective eyewear, gloves, closed-toed shoes, and long pants, as well as a mask. Additionally, to protect against the inhalation of particulate matter, team members received supplemental respirator training and were required to wear a respirator when making mixes that had a hazardous component or sanding the canoe. The team more rigorously enforced new safety strategies for hazardous inhaled particles in the form of a labeling system of colored tape to indicate the type of material and distinguish safety concerns.

In addition, the team purchased a cone bottom tank for easy and safe storage of K20, a material that requires a respirator. The tank prevents K20 from leaking out of the container, a dust cloud from accumulating, and limits possible skin contact when accessing the material. The Mix Design subteam must participate in a supplemental structural laboratory training to test molded cylinders for their mechanical properties. To ensure safety measures under SDSs, OSHA, and University of Michigan were rigorously met, an elected team Safety Officer was present at all meetings led by the university project team workspace.









Michigan Concrete Canoe Team	
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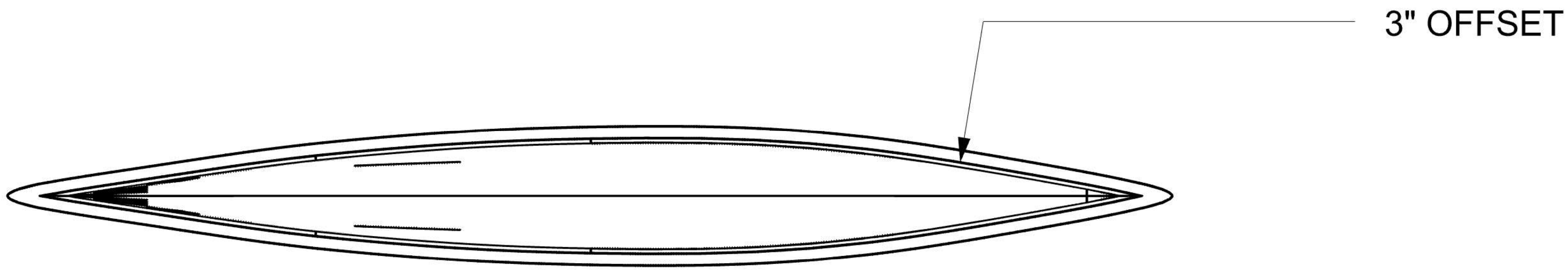
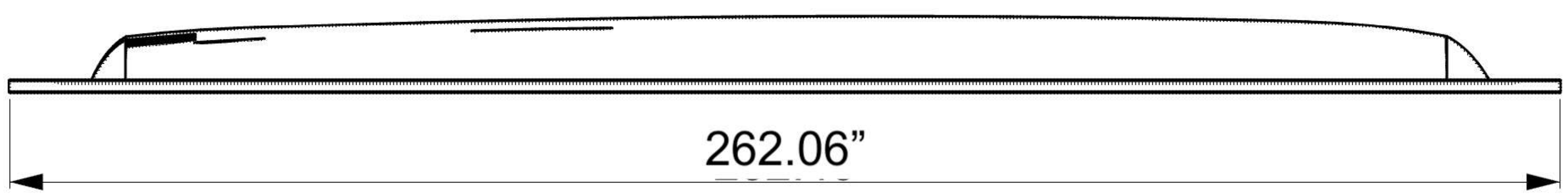
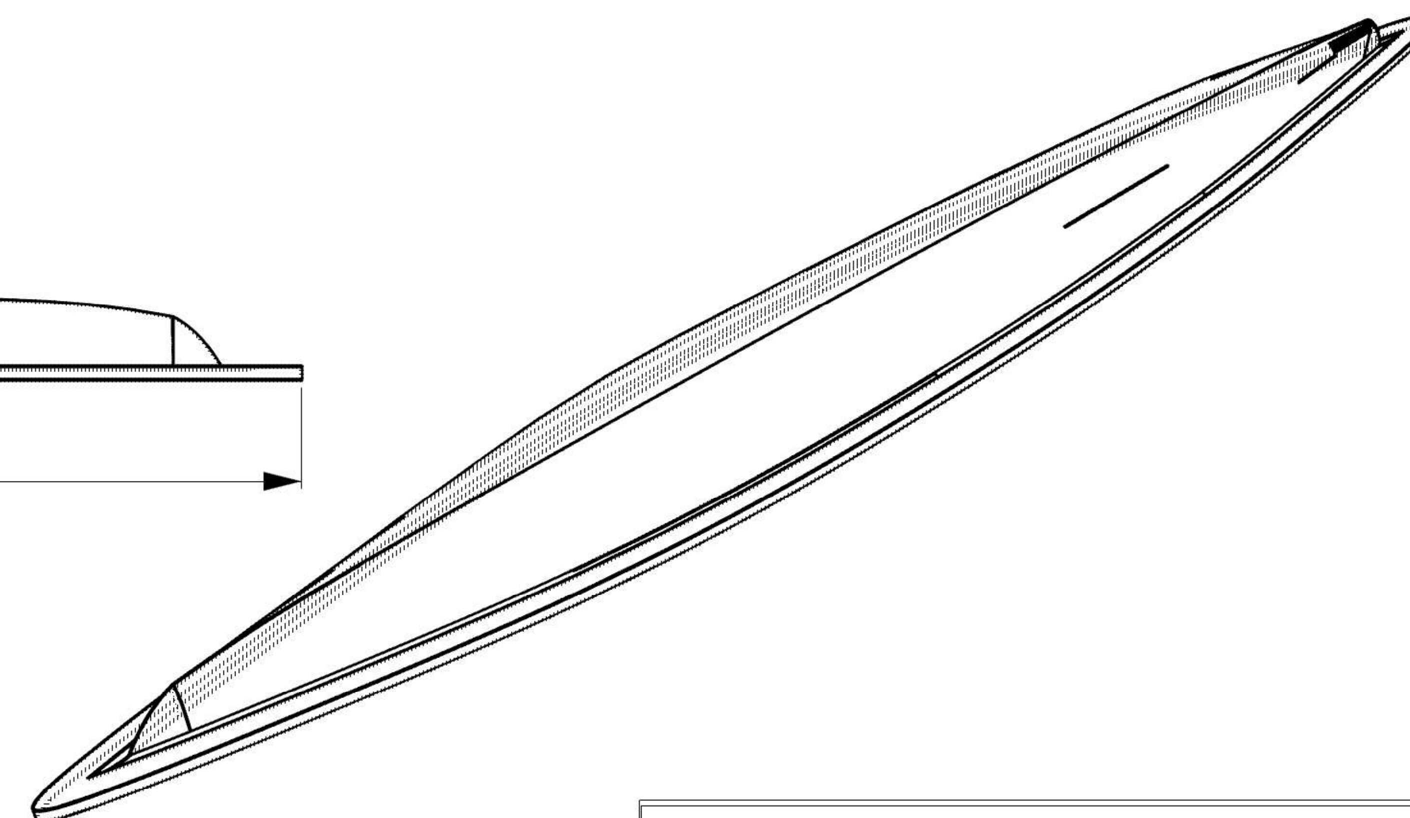
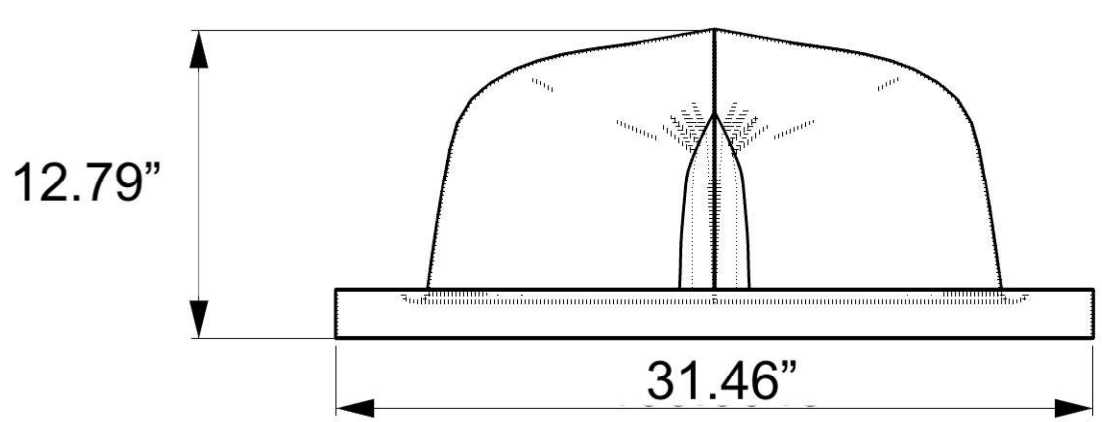
DRAWN BY:	Lily Gandhi
DATE:	02/12/22



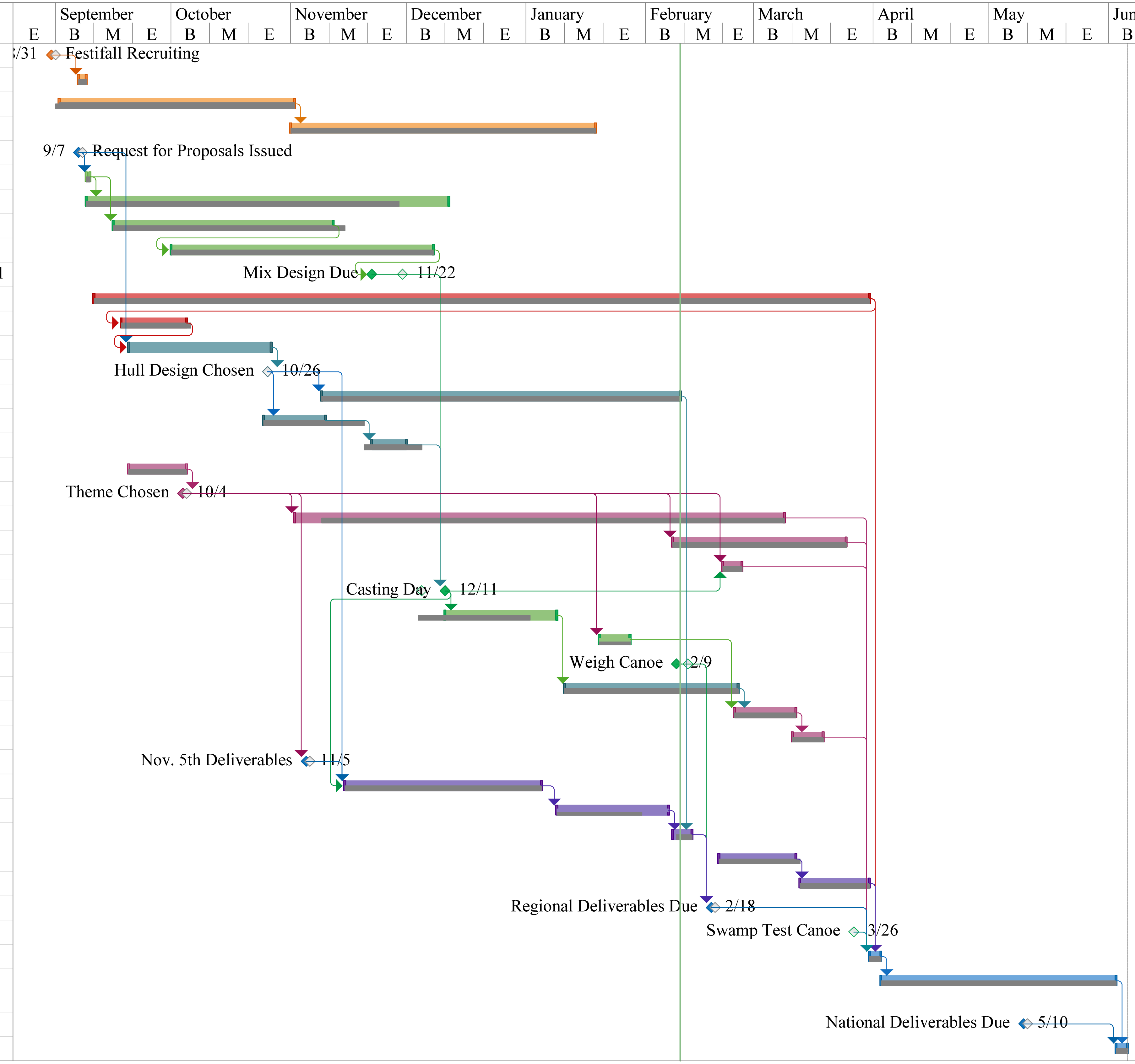






Michigan Concrete Canoe Team	
TITLE:	STALLION Mold
DESCRIPTION:	Mold Drawing and Specification
DRAWN BY:	Gina Kittleson
DATE:	02/12/21

ID	Task Name	Baseline Start	Actual Start	Baseline Finish	Actual Finish
1	**Festifall Recruiting**	Tue 8/31/21	Tue 8/31/21	Tue 8/31/21	Tue 8/31/21
2	**Mass Meetings**	Tue 9/7/21	Tue 9/7/21	Wed 9/8/21	Wed 9/8/21
3	**Draft Sponsor Letters**	Wed 9/1/21	Thu 9/2/21	Mon 11/1/21	Mon 11/1/21
4	**Send Sponsor Letters**	Mon 11/1/21	Mon 11/1/21	Tue 1/18/22	Tue 1/18/22
5	**Request for Proposals Issued**	Tue 9/7/21	Tue 9/7/21	Tue 9/7/21	Tue 9/7/21
6	**Inventory**	Thu 9/9/21	Thu 9/9/21	Thu 9/9/21	Thu 9/9/21
7	**Research and Order Materials**	Thu 9/9/21	Thu 9/9/21	Sun 11/28/21	Sat 12/11/21
8	**Mix Testing**	Thu 9/16/21	Thu 9/16/21	Sun 11/14/21	Thu 11/11/21
9	**Strength Testing**	Fri 10/1/21	Fri 10/1/21	Tue 12/7/21	Tue 12/7/21
10	**Mix Design Due**	Mon 11/29/21	Mon 11/22/21	Mon 11/29/21	Mon 11/22/21
11	**Paddling Practice**	Sat 9/11/21	Sat 9/11/21	Wed 3/30/22	NA
12	**Paddler Feedback Analysis**	Sat 9/18/21	Sat 9/18/21	Tue 10/5/21	Mon 10/4/21
13	**Hull Design and Prototyping**	Mon 9/20/21	Mon 9/20/21	Fri 10/25/19	Tue 10/26/21
14	**Hull Design Chosen**	Mon 10/25/21	Tue 10/26/21	Mon 10/25/21	Tue 10/26/21
15	**Structural Calculations**	Tue 11/9/21	Tue 11/9/21	Wed 2/9/22	Wed 2/9/22
16	**Mill Mold**	Mon 10/25/21	Mon 10/25/21	Fri 11/19/21	Tue 11/9/21
17	**Assemble Mold**	Sat 11/20/21	Mon 11/22/21	Sat 12/4/21	Tue 11/30/21
18	**Theme Brainstorming**	Mon 9/20/21	Mon 9/20/21	Mon 10/4/21	Mon 10/4/21
19	**Theme Chosen**	Mon 10/4/21	Mon 10/4/21	Mon 10/4/21	Mon 10/4/21
20	**Stand Construction**	Tue 11/9/21	Tue 11/2/21	Tue 3/8/22	Tue 3/8/22
21	**Poster Construction**	Tue 2/8/22	Tue 2/8/22	Thu 3/24/22	NA
22	**Make Cross Section**	Mon 2/21/22	NA	Fri 2/25/22	NA
23	**Casting Day**	Sat 12/4/21	Sat 12/11/21	Sat 12/4/21	Sat 12/11/21
24	**Canoe Curing**	Sat 12/4/21	Sat 12/11/21	Sat 1/1/22	Sat 1/8/22
25	**Slurry Testing**	Thu 1/20/22	Thu 1/20/22	Thu 1/27/22	Thu 1/27/22
26	**Weigh Canoe**	Fri 2/11/22	NA	Fri 2/11/22	NA
27	**Sanding**	Tue 1/11/22	Tue 1/11/22	Thu 2/24/22	NA
28	**Apply Slurry**	Thu 2/24/22	NA	Fri 3/11/22	NA
29	**Apply Lettering and Sealer**	Fri 3/11/22	NA	Fri 3/18/22	NA
30	**Nov. 5th Deliverables**	Fri 11/5/21	Fri 11/5/21	Fri 11/5/21	Fri 11/5/21
31	**Write Technical Proposal**	Mon 11/15/21	Mon 11/15/21	Tue 1/4/22	Tue 1/4/22
32	**Edit Technical Proposal**	Sun 1/9/22	Sun 1/9/22	Sun 1/30/22	Sun 2/6/22
33	**Format Technical Proposal**	Wed 2/9/22	Tue 2/8/22	Sat 2/12/22	NA
34	**Make Presentation**	Sun 2/20/22	NA	Sat 3/12/22	NA
35	**Practice Presentation**	Sun 3/13/22	NA	Wed 3/30/22	NA
36	**Regional Deliverables Due**	Fri 2/18/22	Fri 2/18/22	Fri 2/18/22	Fri 2/18/22
37	**Swamp Test Canoe**	Sat 3/26/22	NA	Sat 3/26/22	NA
38	**Regional Conference**	Thu 3/31/22	Thu 3/31/22	Sat 4/2/22	Sat 4/2/22
39	**Prepare for National Conference**	Sun 4/3/22	Sun 4/3/22	Thu 6/2/22	Thu 6/2/22
40	**National Deliverables Due**	Tue 5/10/22	Tue 5/10/22	Tue 5/10/22	Tue 5/10/22
41	**National Conference**	Fri 6/3/22	Fri 6/3/22	Sun 6/5/22	Sun 6/5/22



Appendices

Appendix A - Bibliography

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[41] ASTM (American Society for Testing Materials). (2010). "Standard Specification for Air-Entraining Admixtures for Concrete." C260/C260M-10a, West Conshohocken, Pennsylvania.

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[43] ASTM (American Society for Testing Materials). (2019). "Standard Specification for Coal Fly Ash and Raw or Calcined Natural Pozzolan for Use in Concrete." C618-19, West Conshohocken, Pennsylvania.

Appendix B – Mixture Proportions and Primary Mixture Calculation
Structural Mixture

Cementitious Materials				
Component	*Specific Gravity*	*Volume*	*Amount of CM*	
Portland Cement Type I	3.15	0.44 ft3	86.48 lb/yd3	Total cm (includes c) 453.88 lb/yd3 c/cm ratio, by mass 0.19
GGBFS 100	3.08	0.34 ft3	64.66 lb/yd3	
Komponent	3.10	0.23 ft3	45.06 lb/yd3	
VCAS	2.60	0.96 ft3	155.36 lb/yd3	
Fly Ash Class C (Respirator)	2.64	0.62 ft3	102.32 lb/yd3	

Fibers				
Component	*Specific Gravity*	*Volume*	*Amount of Fibers*	
PVA 6mm	1.3	0.03 ft3	2.13 lb/yd3	Total Amount of Fibers 6.39 lb/yd3
PVA 8mm	1.3	0.03 ft3	2.13 lb/yd3	
PVA 12mm	1.3	0.03 ft3	2.13 lb/yd3	

Aggregates (Excluding Mineral Fillers Passing No. 200 Sieve)							
Aggregates	*ASTM C330 OR RCA*	*Abs (%)*	*SGOD*	*SGSSD*	*Base Quantity, W*		*Volume, $V_{agg, SSD}$*
					WOD	*WSSD*	
Poraver 1.0 - 2.0	Yes	19%	0.34	0.40	22.99 lb/yd3	27.36 lb/yd3	1.10 ft3
Poraver 0.5 - 1.0	Yes	18%	0.42	0.50	24.84 lb/yd3	29.32 lb/yd3	0.94 ft3
Poraver 0.25 - 0.5	Yes	21%	0.58	0.70	11.31 lb/yd3	13.68 lb/yd3	0.31 ft3
SG 300 (Respirator)	No	1%	0.71	0.72	20.90 lb/yd3	21.11 lb/yd3	0.47 ft3
K20 (Respirator)	No	1%	0.20	0.20	61.92 lb/yd3	62.54 lb/yd3	5.01 ft3
Buildex	Yes	12%	1.07	1.20	209.40 lb/yd3	234.52 lb/yd3	3.13 ft3
Norlite	Yes	7%	1.45	1.55	424.66 lb/yd3	454.39 lb/yd3	4.70 ft3

Liquid Admixtures					
Admixture	*lb/ US gal*	*Dosage (fl. oz/cwt)*	*% Solids*	*Amount of Water in Admixture*	
Water Reducer	8.9	40	5%	11.99 lb/yd3	Total Water from
Air Entrainer	8.7	30	5%	8.79 lb/yd3	Liquid Admixtures, $\sum W_{admx}$
					20.78 lb/yd3

Solids (Dyes, Powdered Admixtures)				
Amount	*Specific Gravity*	*Volume (ft^3)*	*Amount (lb/yd^3)*	
Pigment	5.24	0.00	0.00	Total Solids. S_{total}
SG-300 (mineral filler)	0.72	0.03	1.38	**14.75 lb/yd3**
K20 (mineral filler)	0.20	1.07	13.37	

Water			
	Amount		Volume
Water, *w, [=∑ (w_{free} + w_{admx} + w_{batch})]*	*w/c ratio, by mass*	*226.94 lb/yd3*	*3.64 ft3*
Total Free Water from All Aggregates, *∑w_{free}*	*2.62*	*-12.04 lb/yd3*	
Total Water from All Admixtures, *∑w_{admx}*	*w/cm ratio, by mass*	*20.78 lb/yd3*	
Batch Water, *w_{batch}*	*0.50*	*218.20 lb/yd3*	

Densities, Air Content, Ratios, and Slump						
Values for 1 cy of concrete	***cm***	***Fibers***	***Aggregate*** *(SSD)*	***Solids, S_{total}***	***Water, w***	***Total***
Mass, *M*	*453.88 lb*	*6.39 lb*	*842.92 lb*	*0.00 lb*	*218.20 lb*	*∑M: 1536.14 lb*
Absolute Volume, *V*	*2.59 ft3*	*0.08 ft3*	*15.66 ft3*	*0.00 ft3*	*3.50 ft3*	*∑V: 21.82 ft3*
Theoretical Density, *T, (=∑M / ∑V)*	*70.39 lb/ft3*		***Air Content, Air,*** *[= (T – D)/T x 100%]*			*100.00%*
Anticipated Density, *D*	*0.00 lb/ft3*		***Air Content, Air,*** *[= (27 – ∑V))/27 x 100%]*			*18.6%*
Total Aggregate Ratio *(=V_{agg} / 27)*	*58.00%*		***Slump, Slump flow, Spread*** *(as applicable)*			*0.25 in.*
C330 + RCA Ratio *(=$V_{C330+RCA}$ / V_{agg})*	*65.00%*					

Finishing Mixture

Cementitious Materials				
Component	***Specific Gravity***	***Volume***	***Amount of CM***	
Portland Cement Type I	*3.15*	*4.28 ft3*	*841.75 lb/yd3*	*Total cm (includes c) 841.75 lb/yd3 c/cm ratio, by mass 1.00*
Fibers				
Component	***Specific Gravity***	***Volume***	***Amount of Fibers***	
N/A	N/A	N/A	N/A	*Total Amount of Fibers 0.00 lb/yd3*

Aggregates (Excluding Mineral Fillers Passing No. 200 Sieve)							
Aggregates	***ASTM C330 OR RCA***	***Abs (%)***	***SGOD***	***SGSSD***	***Base Quantity, W***		***Volume, $V_{agg, SSD}$***
					WOD	***WSSD***	
Poraver 0.25 - 0.5	*Yes*	*21%*	*0.58*	*0.70*	*146.20 lb/yd3*	*176.90 lb/yd3*	*4.05 ft3*
Pummice G8	*Yes*	*30%*	*1.81*	*2.35*	*456.84 lb/yd3*	*593.89 lb/yd3*	*4.05 ft3*

Liquid Admixtures					
Admixture	***lb/ US gal***	***Dosage (fl. oz/cwt)***	***% Solids***	***Amount of Water in Admixture***	
N/A	N/A	N/A	N/A	N/A	*Total Water from Liquid Admixtures, $\sum W_{admx}$* ***0.00 lb/yd3***

Solids (dyes, powdered admixtures)				
Amount	***Specific Gravity***	***Volume (ft3)***	***Amount (lb/yd3)***	
Pigment	*5.24*	*0.00*	*0.00*	*Total Solids. S_{total}*

Water			
	Amount		***Volume***
Water, *w, [=$\sum$ (W_{free} + W_{admx} + W_{batch})]*	*w/c ratio, by mass*	*729.51 lb/yd3*	*11.69 ft3*
Total Free Water from All Aggregates, *$\sum W_{free}$*	*0.87*	*-167.75 lb/yd3*	
Total Water from All Admixtures, *$\sum W_{admx}$*	*w/cm ratio, by mass*	*0.00 lb/yd3*	
Batch Water, *W_{batch}*	*0.87*	*897.26 lb/yd3*	

Densities, Air Content, Ratios, and Slump						
Values for 1 cy of concrete	***cm***	***Fibers***	***Aggregate** (SSD)*	***Solids, S_{total}***	***Water, w***	***Total***
Mass, *M*	*841.75 lb*	*0.00 lb*	*770.80 lb*	*0.00 lb*	*897.26 lb*	*$\sum$M: 2509.81 lb*
Absolute Volume, *V*	*4.28 ft3*	*0.00 ft3*	*8.10 ft3*	*0.00 ft3*	*14.38 ft3*	*$\sum$V: 26.76 ft3*
Theoretical Density, *T, (=$\sum$M / $\sum$V)*	*93.78 lb/ft3*		***Air Content, Air,*** *[= (T – D)/T x 100%]*			*100.00%*
Anticipated Density, *D*	*92.96 lb/ft3*		***Air Content, Air,*** *[= (27 – $\sum$V))/27 x 100%]*			*0.88%*
Total Aggregate Ratio *(=V_{agg} / 27)*	*30.00%*		***Slump, Slump flow, Spread*** *(as applicable)*			*0.00 in.*
C330 + RCA Ratio *(=$V_{C330+RCA}$ / V_{agg})*	*100.00%*					

Detailed Step by Step Calculation

Design parameters:

Cementitious Material	Mass (lb/yd^3)	SG
Portland Cement Type I	86.48	3.15
Komponent	45.06	3.1
VCAS 160	155.36	2.6
Fly Ash Class C	102.32	2.64
NewCem GGBFS Gr. 100	64.44	3.08
Total	453.66	

w/cm ratio	0.50

Fibers	Mass (lb/yd^3)	SG
PVA (6mm)	2.13	1.30
PVA (8mm)	2.13	1.30
PVA (12mm)	2.13	1.30

Admixture	Dosage	Solids (%)
HRWR (8.9 lb/gal)	40.0 fl oz/cwt	5
Air Entrainer (8.7 lb/gal)	30.0 fl oz/cwt	5

Aggregate	SG_{OD}	SG_{SSD}	W_{OD} (lb)	W_{SSD} (lb)	W_{stk} (lb)	Abs (%)	MC_{stk} (%)
Poraver (1-2mm)	0.34	0.40	22.99	27.36	22.99	19%	-19%
Poraver (0.5-1mm)	0.42	0.50	24.84	29.32	24.84	18%	-18%
Poraver (0.25-0.5mm)	0.58	0.70	11.31	13.68	11.31	21%	-21%
SG 300	0.71	0.72	20.9	21.11	20.9	1%	-1%
K20	0.2	0.20	61.92	62.54	61.92	1%	-1%
Buildex	1.07	1.20	209.4	234.52	234.52	12%	-2%
Norlite	1.45	1.55	424.66	454.39	454.39	7%	0%

Cementitious Materials/Fibers:

$\text{Absolute Volume} = \frac{mass\ (lb)}{SG*62.4\left(\frac{lb}{ft^3}\right)}$
$V_{portland} = \frac{86.48}{3.15*62.4} = \mathbf{0.44\ ft^3}$
$V_{komponent} = \frac{45.06}{3.10*62.4} = \mathbf{0.23\ ft^3}$
$V_{VCAS} = \frac{155.36}{2.60*62.4} = \mathbf{0.96\ ft^3}$
$V_{fly\ ash} = \frac{102.32}{2.64*62.4} = \mathbf{0.62\ ft^3}$
$V_{GGBFS} = \frac{64.44}{3.08*62.4} = \mathbf{0.34 ft^3}$
$V_{fibers\ 6mm} = \frac{2.13}{1.30*62.4} = \mathbf{0.03\ ft^3}$
$V_{fibers\ 8mm} = \frac{2.13}{1.30*62.4} = \mathbf{0.03\ ft^3}$
$V_{fibers\ 12mm} = \frac{2.13}{1.30*62.4} = \mathbf{0.03\ ft^3}$
$Total_{CM} = \mathbf{2.59\ ft^3}$
$Total_{fiber} = \mathbf{0.09\ ft^3}$

Aggregates:

$\mathbf{Absorption} = \mathbf{Abs} = \frac{W_{SSD}(lb) - W_{OD}\ (lb)}{W_{OD}\ (lb)} * 100\%$
Poraver (1-2mm) $= \frac{27.36-22.99}{22.99} * 100\% = \mathbf{19.0\%}$
Poraver (0.5-1mm) $= \frac{29.32-24.84}{24.84} * 100\% = \mathbf{18.0\%}$
Poraver (0.25-0.5mm) $= \frac{13.68-11.31}{11.31} * 100\% = \mathbf{21.0\%}$
SG 300 $= \frac{21.11-20.9}{20.9} * 100\%\ \% = \mathbf{1.0\%}$
K20 $= \frac{62.54-61.92}{61.92} * 100\% = \mathbf{1.0\%}$
Buildex $= \frac{234.52-209.4}{209.4} * 100\% = \mathbf{12.0\%}$
Norlite $= \frac{454.39-424.66}{424.66} * 100\% = \mathbf{7.0\%}$

Aggregate Absolute Volume (ft^3) $= \frac{W_{SSD}(lb)}{SG_{SSD} * 62.4\left(\frac{lb}{ft^3}\right)}$
$V_{Poraver\ (1-2)} = \frac{27.36}{0.40*62.4} =$ **1.10 ft^3**
$V_{Poraver\ (0.5-1))} = \frac{29.32}{0.5*62.4} =$ **0.94 ft^3**
$V_{Poraver\ (0.25-0.5)} = \frac{13.68}{0.7*62.4} =$ **0.31 ft^3**
$V_{SG\ 300} = \frac{21.11}{0.72*62.4} =$ **0.47 ft^3**
$V_{K20} = \frac{62.54}{0.2*62.4} =$ **5.01 ft^3**
$V_{Buildex} = \frac{234.52}{1.20*62.4} =$ **3.13 ft^3**
$V_{Norlite} = \frac{454.39}{1.55*62.4} =$ **4.70 ft^3**
Total = **15.66 ft^3**

Water: Moisture content of Haydite, Norlite, and Buildex takes into account the conditioning of the aggregate to the saturated, surface dry (SSD) condition. In the equation below $(0)/W_{OD} \times 100\% = 0$.

Water:

Water = w/cm * cm
w = 0.5 * 453.66 lb = **226.83 lb**
$MC_{total} = \frac{W_{stk} - W_{OD}}{W_{OD}} * 100\%$
$MC_{total,\ Poraver\ 1\text{-}2} = 0.0\%$
$MC_{total,\ Poraver\ 0.5\text{-}1} = 0.0\%$
$MC_{total,\ Poraver\ 0.25\text{-}0.5} = 0.0\%$
$MC_{total,\ SG300} = 0.0\%$
$MC_{total,\ K20} = 0.0\%$
$MC_{total,\ Buildex} = 12.0\%$
$MC_{total,\ Norlite} = 7.0\%$
$MC_{free} = MC_{total} - Abs$
$MC_{free,\ Poraver\ 1\text{-}2} = 0.0\% - 19.0\% = -19.0\%$
$MC_{free,\ Poraver\ 0.5\text{-}1} = 0.0\% - 18.0\% = -18.0\%$
$MC_{free,\ Poraver\ 0.25\text{-}0.5} = 0.0\% - 21.0\% = -21.0\%$
$MC_{free,\ SG300} = 0.0\% - 1.0\% = -1.0\%$
$MC_{free,\ K20} = 0.0\% - 1.0\% = -1.0\%$
$MC_{free,\ Buildex} = 12.0\% - 12.0\% = 0.0\%$
$MC_{free,\ Norlite} = 7.0\% - 7.0\% = 0.0\%$
$w_{free} = W_{OD}(lb) * \frac{MC_{free}}{100\%}$
$w_{free,\ Poraver\ 1\text{-}2} = 22.99 * \frac{-19.0}{100\%} =$ **-4.37 lb**
$w_{free,\ Poraver\ 0.5\text{-}1} = 24.84 * \frac{-18.0}{100\%} =$ **-4.47 lb**
$w_{free,\ Poraver\ 0.25\text{-}0.5} = 11.31 * \frac{-21.0}{100\%} =$ **-2.38 lb**
$w_{free,\ SG300} = 20.9 * \frac{-1.0}{100\%} =$ **-0.21 lb**
$w_{free,\ K20} = 61.92 * \frac{-1.0}{100\%} =$ **-0.62 lb**
$w_{free,\ Buildex} = 78.4 * \frac{0.0}{100\%} =$ **0 lb**
$w_{free,\ Norlite} = 256.7 * \frac{0.0}{100\%} =$ **0 lb**
Combined free water = $\sum(w_{free})$ = **-12.05 lb**

Water in admixture = $dosage\left(\frac{fl\ oz}{cwt}\right) * cwt\ of\ cm\left(\frac{lb}{yd^3}\right) * \frac{\%\ water}{100} * \frac{1\ gal}{128\ fl\ oz} * \left(\frac{lb}{gal}\right)$ ***of admixture***
$w_{HRWR} = 40.0 * \frac{453.66}{100} * \frac{100-5}{100} * \frac{1\ gal}{128\ fl\ oz} * 8.90\frac{lb}{gal} =$ **11.99 lb**
$w_{AEA} = 30.0 * \frac{453.66}{100} * \frac{100-5}{100} * \frac{1\ gal}{128\ fl\ oz} * 8.70\frac{lb}{gal} =$ **8.79 lb**
Total Water from admixtures = 11.99 + 8.79 = **20.78 lb**

$w_{batch} = w - (w_{free} + ©w_{admx})$
w_{batch} = 226.83 lb – (-12.05 lb + 20.78 lb) = **227.0 lb**
$V_{water} = \frac{Mass_{water}\ (lb)}{62.4\left(\frac{lb}{ft^3}\right)}$
$V_{water} = \frac{226.83}{62.4} =$ **3.64 ft³**

Densities, Air Content, Slump, and Ratios:

Mass of Concrete = $Amount_{cm}$ + $Amount_{fibers}$ + $Amount_{SSD\ aggregate}$ + $Amount_{water}$ + $Amount_{solids}$
M = 453.66 lb + 6.4 lb + 842.92 lb + 226.83 lb = **1529.81 lb**
Volume of Concrete = $Volume_{cm}$ + $Volume_{fibers}$ + $Volume_{aggregate}$ + $Volume_{water}$ + $Volume_{solids}$
V = 2.59 ft^3 + 0.09 ft^3 + 15.66 ft^3 + 3.64 ft^3 = **21.98 ft^3**
Theoretical Density T = M/V
T = 1556.7 lb / 22.63 ft^3 = **69.6 lb/ft^3**
Design Density D = M/27
D = 1556.7 lb / 27 ft^3 = **56.7 lb/ft^3**
Air Content = $\frac{T\left(\frac{lb}{ft^3}\right)-D\left(\frac{lb}{ft^3}\right)}{T\left(\frac{lb}{ft^3}\right)}$ *** 100%**
Air Content = $\frac{69.6-56.7}{69.6}$ * 100% = **18.5%**
Cement to Cementitious Materials Ratio, c/cm = 86.5 lb / 453.66 lb = **0.19**
Water to Cementitious ratio, w/cm = 226.83 lb / 453.66 lb = **0.50**
Water to Cement ratio, w/c = 226.83 lb / 86.5 lb = **2.62**
Slump (Measured) = 0.25 in

Concrete Ratios:

Volume Mineral Filler = V_{agg}(ft^3) * ($\frac{\%\ passing\ 200\ sieve}{100\ \%}$)
$V_{SG300\ filler}$ = 0.47 * (0.066) = **0.03 ft^3**
$V_{K20\ filler}$ = 5.01 * (0.216) = **1.08 ft^3**
$V_{filler\ Total}$ = **1.11 ft^3**
Aggregate Ratio (%) = $\frac{V_{aggregate}(ft^3) - V_{filler\ Total}}{27}$ ***100%**
Aggregate Ratio (%) = $\frac{15.66 - 1.11}{27}$ *100%= **53.9%** > 30% **Compliant!**
$V_{agg,SSD}$ = **15.66 ft^3** $V_{C330+RCA}$ = **7.83 ft^3** $V_{filler\ Total}$ = **1.11 ft^3** (note: all contributions made to mineral filler are from non C330 aggregates)
C330 + RCA Ratio = $V_{C330+RCA}$ /($V_{agg,SSD}$ - $V_{filler\ Total}$*100% = **50.1%** > 50% **Compliant!**

Appendix C – Structural & Freeboard Calculations

Female Tandem Load Case

Assumptions:

$W_{max} = 21.15\ lb/ft$ $B_{max} = 58.89\ lb/ft$

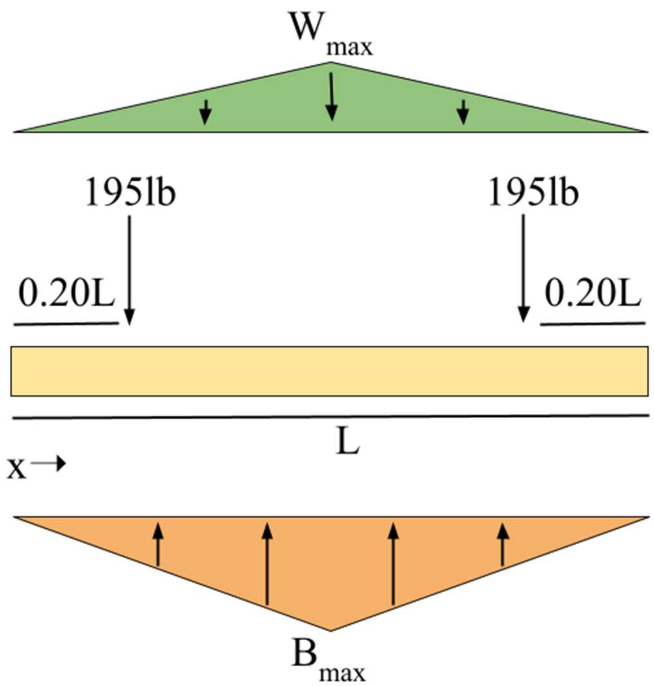

Figure C-1. Loading along the longitudinal axis

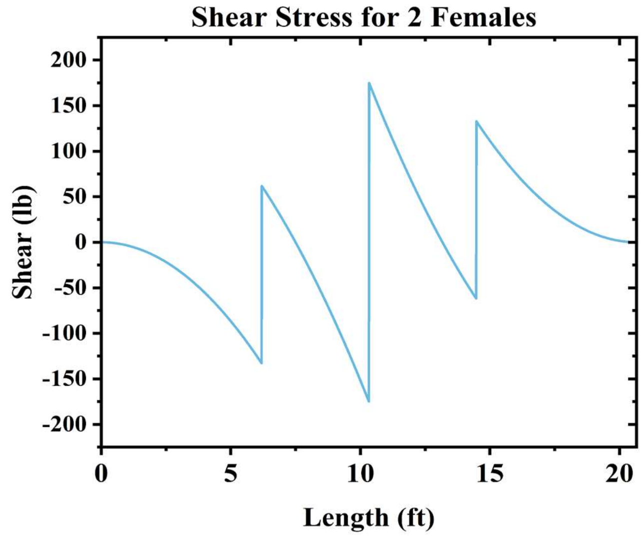

Figure C-2. Shear force diagram for the Female Tandem load case

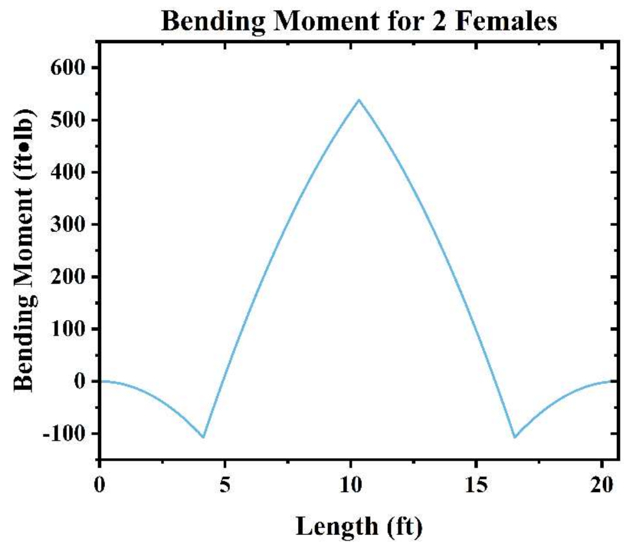

Figure C-3. Bending moment diagram for the Female Tandem load case

$$L = 20'8''$$

$$M(0 \le x < 4.13) = -\frac{x^2}{3} * \frac{(58.89 - 21.15)}{2}$$

$$M(4.13 \le x \le 10.33) = -\frac{x^2}{3} * \frac{(58.89 - 21.15)}{2} + 195(x - 4.13)$$

$$M(10.33 < x \le 16.53) = \frac{x^2}{3} * \frac{(58.89 - 21.15)}{2} - 195(x - 4.13)$$

$$M(16.53 < x \le 20.66) = \frac{x^2}{2} * \frac{(10.60 - 48.54)}{10.33}$$

$M_{max}(10.33) = 537.77$ lb*ft

$M_{min}(4.13) = -107.29$ lb*ft

Male Tandem Load Case

Assumptions:

$W_{max} = 21.15\ lb/ft$ $\qquad$ $B_{max} = 56.96\ lb/ft$

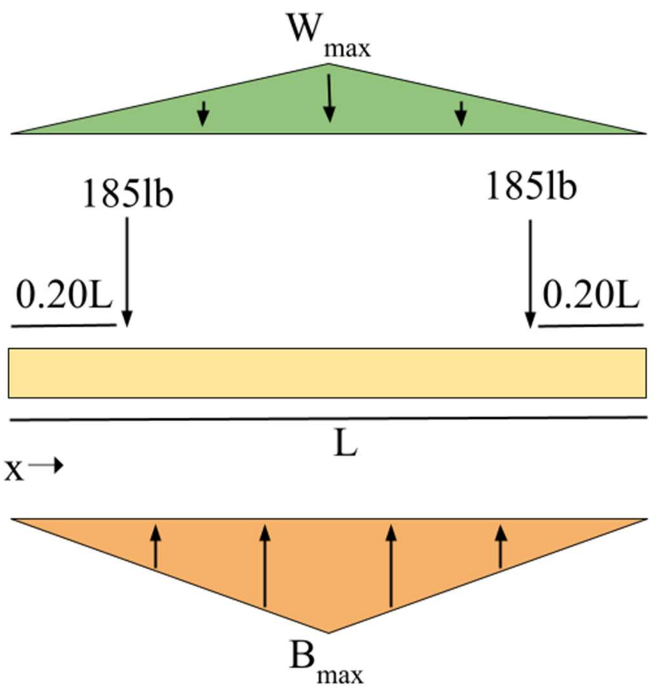

Figure C-4. Loading along the longitudinal axis

$$L = 20'8"$$

$$M(0 \le x < 4.13) = -\frac{x^2}{3} * \frac{(56.96 - 21.15)}{2}$$

$$M(4.13 \le x \le 10.33) = -\frac{x^2}{3} * \frac{(56.96 - 21.15)}{2} + 185(x - 4.13)$$

$$M(10.33 < x \le 16.53) = \frac{x^2}{3} * \frac{(56.96 - 21.15)}{2} - 185(x - 4.13)$$

$$M(16.53 < x \le 20.66) = \frac{x^2}{3} * \frac{(56.96 - 21.15)}{2}$$

$M_{max}(10.33) = 448.19$ lb*ft

$M_{min}(4.13) = -101.79$ lb*ft

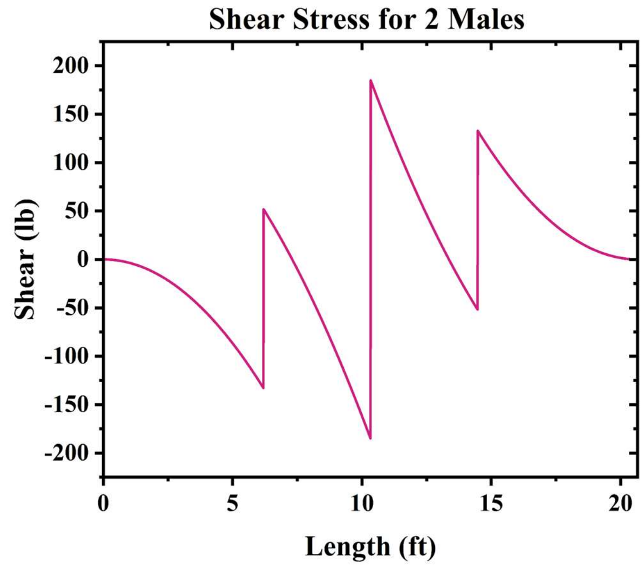

Figure C-5. Shear force diagram for the Male Tandem load case

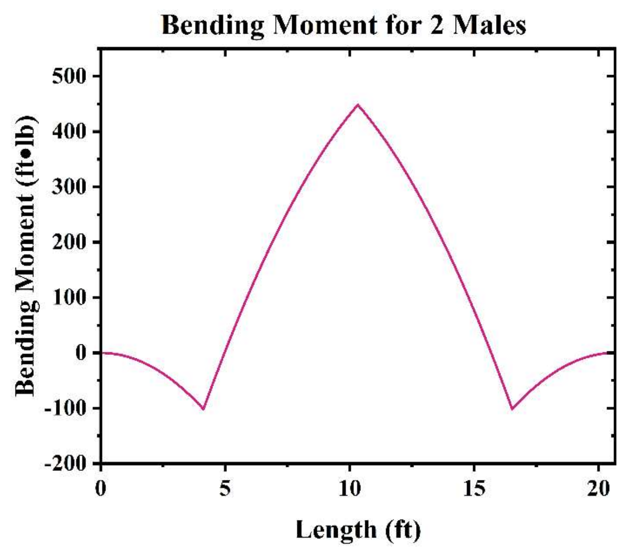

Figure C-6. Bending Moment diagram for the Male Tandem load case

Four Person Co-Ed Load Case

Assumptions:

$W_{max} = 21.15 lb/ft$ $\qquad B_{max} = 92.76\ lb/ft$

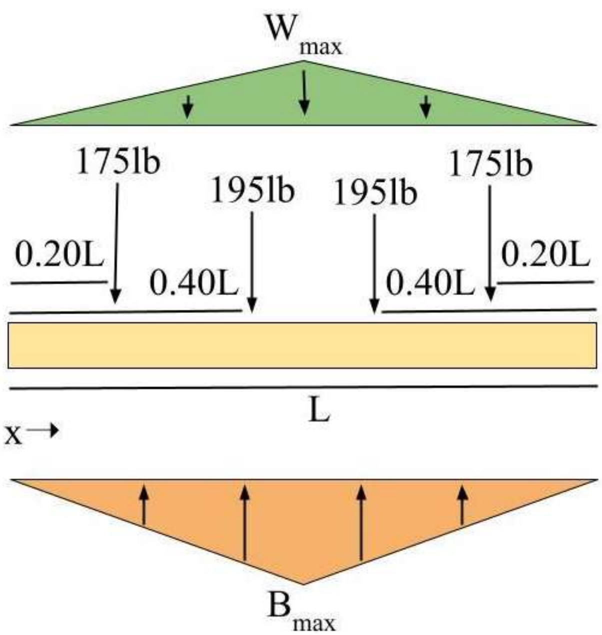

Figure C-7. Loading along the longitudinal axis

$$L = 20'8"$$

$$M(0 \leq x < 4.13) = -\frac{(92.76 - 21.15)}{2} * \frac{x^2}{3}$$

$$M(4.13 \leq x < 8.26) = -\frac{(92.76 - 21.15)}{2} * \frac{x^2}{3} + 175(x - 4.13)$$

$$M(8.26 \leq x \leq 10.33) = -\frac{(92.76 - 21.15)}{2} * \frac{x^2}{3} + 175(x - 4.13) + 195(x - 8.26)$$

$$M(10.33 < x \leq 12.4) = \frac{(92.76 - 21.15)}{2} * \frac{x^2}{3} - 175(x - 4.13) - 195(x - 8.26)$$

$$M(12.4 < x \leq 16.53) = \frac{(92.76 - 21.15)}{2} * \frac{x^2}{3} - 175(x - 4.13)$$

$$M(16.53 < x \leq 20.66) = \frac{(92.76 - 21.15)}{2} * \frac{x^2}{3}$$

$M_{max}(10.33) = 215.03$ lb $\quad M_{min}(4.13) = -203.58$ lb*ft

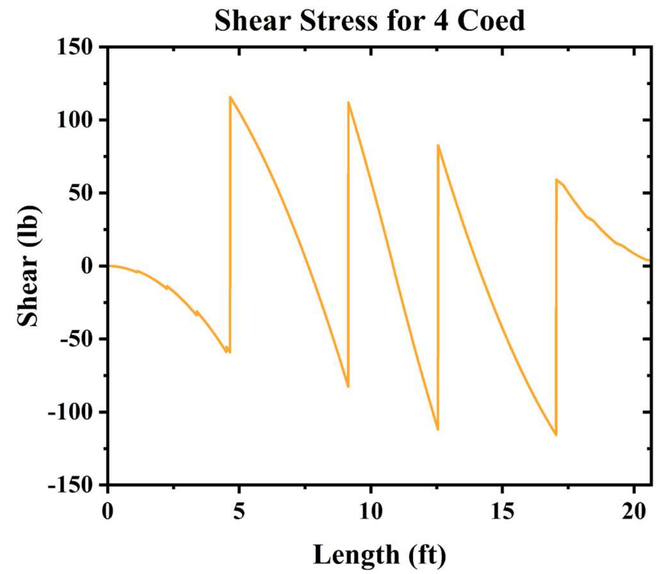

Figure C-8. Shear force diagram for the Four Person Coed load case

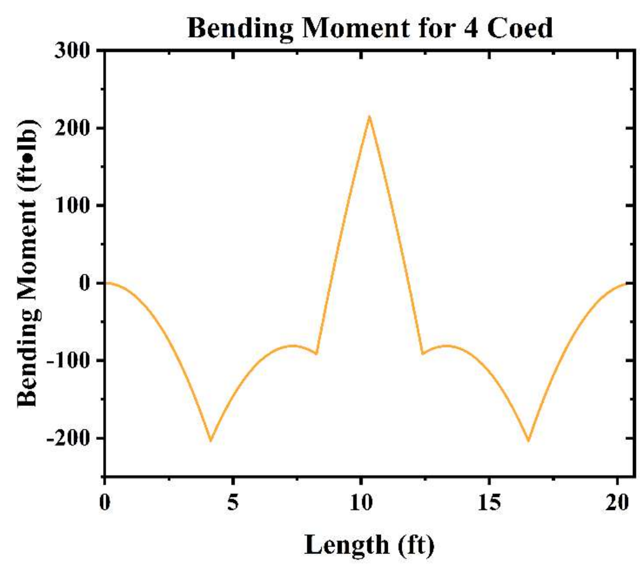

Figure C-9. Bending Moment diagram for the 4 Person Coed load case

Simply Supported Right Side Up load case:

Assumptions: $W_{max} = 21.15\ lb/ft \qquad L = 20'8"$

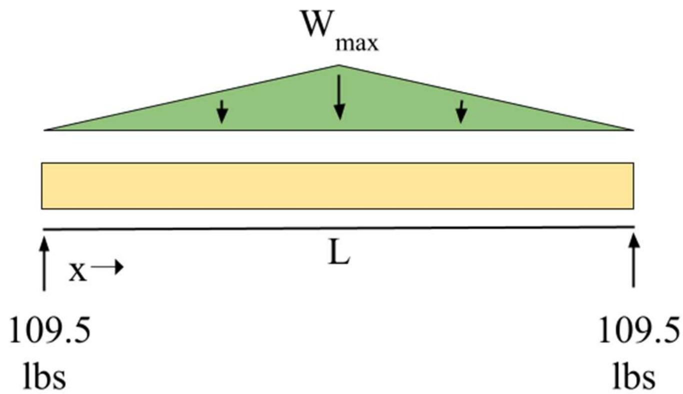

Figure C-10. Loading along the longitudinal axis

$$M(0 \le x \le\ 10.33)\ = 109.5x\ -\ 10.6 * x^2/2$$
$$M(10.33 \le x \le\ 20.66)\ = -109.5x\ +\ 10.6 * x^2/2$$

$M_{max}(10.33) = 565.56$ lb*ft
$M_{min}(0) = 0$ lb*ft

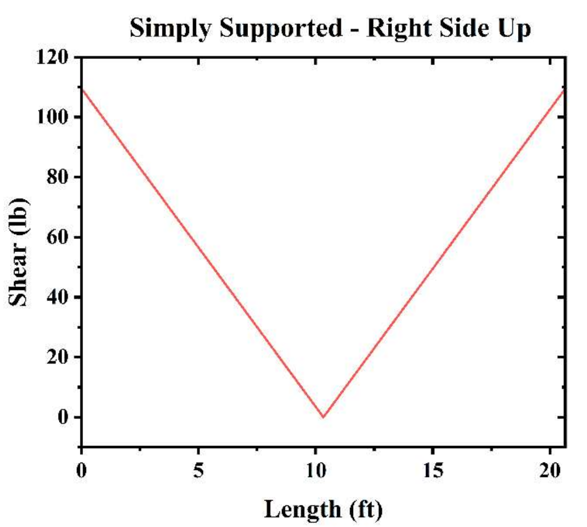

Figure C-11. Shear Force diagram for Simply Supported Right Side Up load case

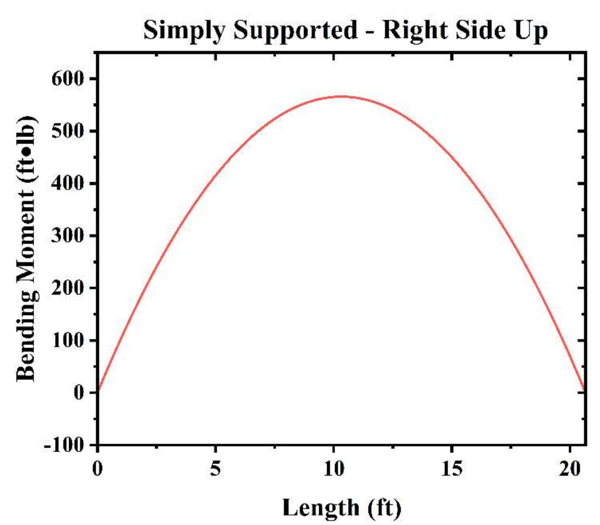

Figure C-12. Bending Moment diagram for the Simply Supported Right Side Up load case

Simply Supported Upside Down load case:

Assumptions: $W_{max} = 21.15\ lb/ft \quad L = 20'8"$

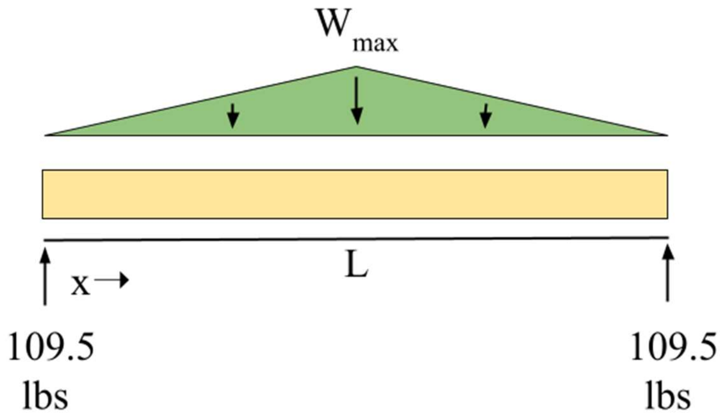

Figure C-13. Loading along the longitudinal axis

$$M(0 \le x \le 10.33) = 109.5x - 10.6 * x^2/2$$
$$M(10.33 \le x \le 20.66) = -109.5x + 10.6 * x^2/2$$

$$M_{max}(10.33) = 565.56\ lb*ft$$
$$M_{min}(0) = 0\ lb*ft$$

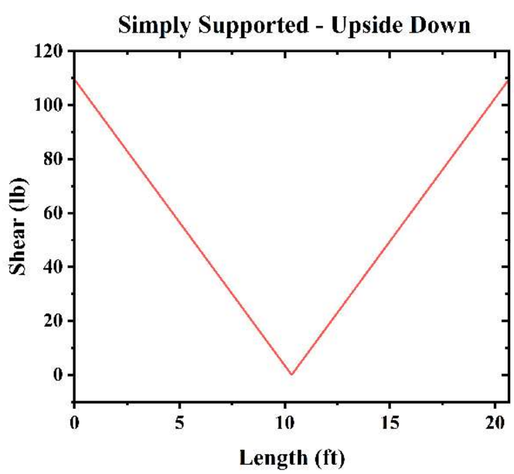

Figure C-14. Shear Force diagram for Simply Supported Upside Down load case

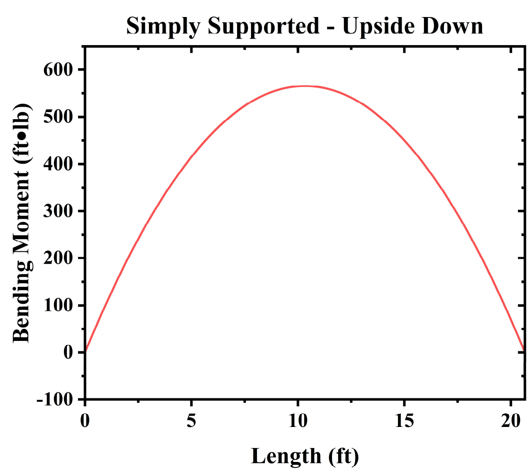

Figure C-15. Bending Moment diagram for the Simply Supported Upside Down load case

Table C-1. Summary of Bending Moments

	Maximum Positive Bending Moment		Maximum Negative Bending Moment	
Load Case	**Magnitude (ft*lb)**	**Location (ft)**	**Magnitude (ft*lb)**	**Location (ft)**
Female Tandem	537.77	10.33	107.29	4.13
Male Tandem	448.19	10.33	101.79	4.13
4 Person Coed	215.03	10.33	203.58	4.13
Simply Supported Right Side Up	565.56	10.33	0	0
Simply Supported Upside Down	565.56	10.33	0	0

Freeboard Calculation

$$\Delta = \rho * g * \nabla$$

Values for the draft were obtained using Naval Architecture Software (PolyCAD)

Displacement (lb)	Draft (in.)	Freeboard (in.)
219	3.396	8.604
299	4.052	7.948
369	4.591	7.409
439	5.114	6.886
509	5.623	6.377
579	6.127	5.873
649	6.617	5.383
719	7.102	4.898
789	7.589	4.411
859	8.060	3.940
929	8.539	3.461
999	8.998	3.002
1069	9.461	2.539
1139	9.919	2.081
1219	10.439	1.561

Table C-2. Estimated Drafts and Freeboards at Varying Displacements

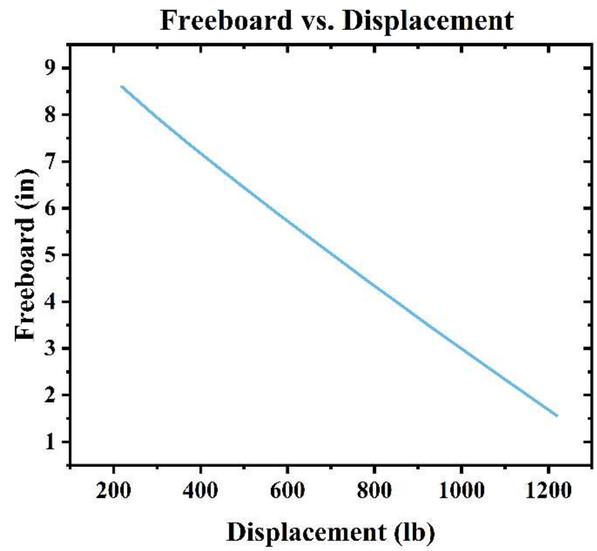

Figure C-16. Estimated Freeboard vs. Displacement

$$Freeboard(\Delta) = -6.56 * 10^{-3} * \Delta + 10.1\ in$$

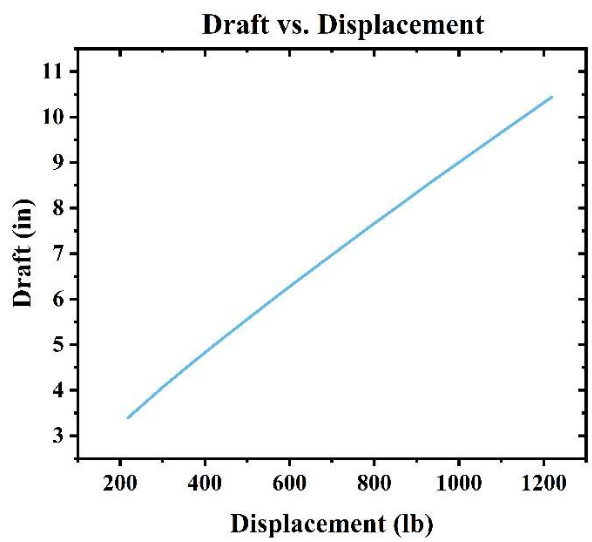

Figure C-17. Estimated Draft vs. Displacement

$$T(\Delta) = 6.56 * 10^{-3} * \Delta + 1.95\ in$$

Load Case	**2 Male**	**2 Female**	**Co-Ed**
Displacement (lb)	589	609	959
Draft (in.)	6.201	6.340	8.726
Freeboard (in.)	5.799	5.66	3.274

Table C-3. Estimated Draft and Freeboard for Tandem Male, Tandem Female, and Co-Ed Load Cases

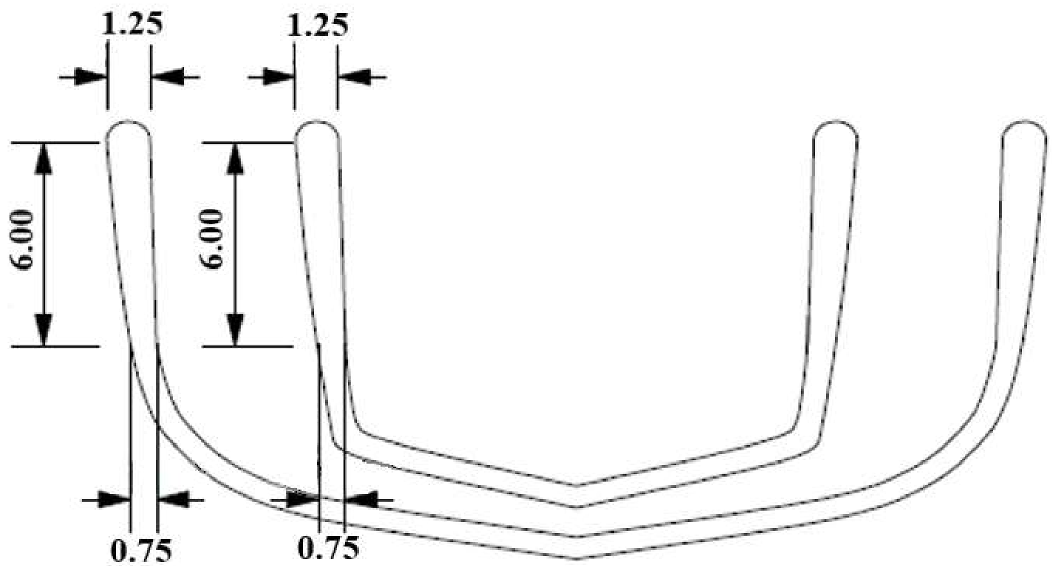

Figure D-1. Hull cross-section thickness

MCCT used a consistent overall thickness of ¾ inches for the bilge and sidewalls of the canoe with 6 inches of the sidewalls gradually increasing the thickness to 1 ¼ inch at the gunwales. These thicknesses are consistent along the entirety of the canoe. MCCT used a 1/16-inch Spiderlath fiberglass reinforcement in a single layer for the entirety of the canoe. The calculations below confirm that the mesh reinforcement does not exceed 50% of the thickness of the canoe at any point.

First Layer of Concrete (Interior): 0.375 inches

Mesh Reinforcement: 0.0625 inches

Second Layer of Concrete (Exterior): 0.3125 inches

Net Thickness: 0.375 + 0.0625 + 0.3125 = 0.75 inches

Percent of Mesh Reinforcement by Thickness: 0.0625/0.75 = **8.3% Mesh by Thickness = Compliant**

Percent Open Area:

One layer of fiberglass mesh was used in the layering scheme chosen for *STALLION*. Calculations are presented below.

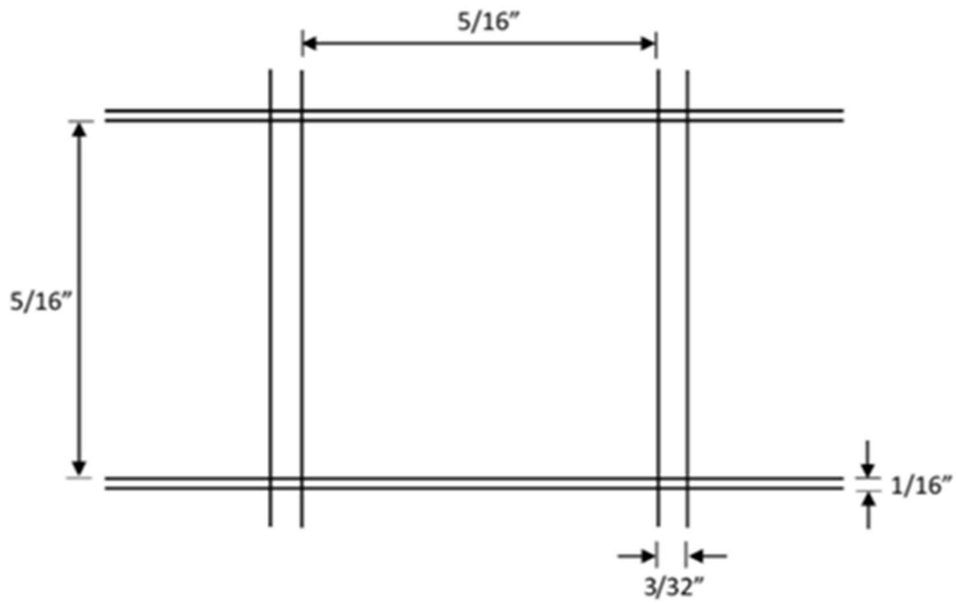

Figure D-2. Detailed view of the mesh reinforcement

Number of apertures along sample width = 20

Number of apertures along sample length = 20

$$Open\ Area = 20 \times 20 \times \frac{5}{16} \times \frac{5}{16} = 39.06\ in.^2\ Aperture\ Area\ \left(consider \frac{1}{2}\ of\ strand\ thickness\right) W$$

$$= \frac{5}{16}'' + \frac{1}{2}\left(2 \times \frac{3}{32}''\right) = \frac{13}{32}''$$

$$L = \frac{5}{16}'' + \frac{1}{2}\left(2 \times \frac{1}{16}''\right) = \frac{6}{16}'' Width\ of\ Sample = 20 \times \frac{13}{32}'' = 8.13\ in.$$

$$Length\ of\ Sample = 20 \times \frac{6}{16}'' = 7.50\ in.$$

$$Total\ Sample\ Area = 8.13'' \times 7.50'' = 60.98\ in^2$$

$$Percent\ Open\ Area = \frac{39.06\ in.^2}{60.98\ in.^2} \times 100 = 49.3\% = Compliant$$

Appendix E – Detailed Fee Estimate

Table E-1. Labor Costs

Projected Total Manhours and Direct Labor Costs		
Position	**Raw Labor Rate (RLR)**	**Labor Hours (HRS)**
Project Management		
Design Manager	$45/hr	130
Laborer/Tehcnician	$25/hr	335
Clerck/Office Admin	$15/hr	31
Hull Design		
Principal Design Engineer	$50/hr	9
Project Design Engineer	$35/hr	1
Technician/Drafter	$20/hr	12
Structural Analysis		
Principal Design Engineer	$50/hr	25
Project Design Engineer	$35/hr	2
Technician/Drafter	$20/hr	13
Mixture Design Development and Testing		
Principal Design Engineer	$50/hr	41
Project Design Engineer	$35/hr	25
Labrorer/Technician	$25/hr	155
Mold Construction and Canoe Construction		
Project Construction Management	$40/hr	74
Labrorer/Technician	$25/hr	133
Preparation of Technical Proposal		
Design Manager	$45/hr	20
Labrorer/Technician	$25/hr	59
Preparation of Enhanced Focus Area		
Design Manager	$45/hr	22
Labrorer/Technician	$25/hr	18
Preparation of Technical Presentation		
Design Manager	$45/hr	18
Labrorer/Technician	$25/hr	54
TOTAL		
Direct Labor DL = $DL = [\sum(RLR * \text{HRS})]*(1.50+1.30)*(1.18)$		**$119,125.72**

Table E-2. Canoe Material Costs

Costs to Produce One Canoe				
Material	**Total Used**	**Unit Cost ($)**	**Source & Notes**	**Material Cost (MC) ($)**
Portland Cement Type I	21.2 lb	$0.17 /lb	Redford Building Supply Co.	$3.61
GGBFS 100	13.4 lb	$0.02 /lb	MDPI	$0.27
Komponent	9.4 lb	$0.04 /lb	Virginia Transportation Research Council	$0.38
VCAS	32.2 lb	$0.92 /lb	VitroMinerals.com	$29.62
Fly Ash Class C (Resp)	21.3 lb	$0.20 /lb	Aberdeen Group	$4.26
PVA 6mm	0.4 lb	$15.00 /lb	Fishstone Studio, Inc.	$6.64
PVA 8mm	0.4 lb	$13.90 /lb	Fishstone Studio, Inc.	$6.15
PVA 12mm	0.4 lb	$15.00 /lb	Fishstone Studio, Inc.	$6.64
Poraver 1.0 - 2.0	4.8 lb	$1.23 /lb	Concrete Texturing Tool and Supply	$5.85
Poraver 0.5 - 1.0	5.2 lb	$1.13 /lb	Concrete Texturing Tool and Supply	$5.85
Poraver 0.25 - 0.5	3.0 lb	$0.99 /lb	Concrete Texturing Tool and Supply	$2.96
SG 300 (Respirator)	4.6 lb	$0.18 /lb	MCCT 2020, not purchased this season	$0.83
K20 (Respirator)	15.7 lb	$7.51 /lb	3M	$117.76
Buildex	47.7 lb	$0.01 /lb	MCCT 2021	$0.29
Norlite	94.2 lb	$ 0.01 /lb	MCCT 2021	$0.57
Pumice G8	2.4 lb	$5.71 /lb	Hess Pumice, not purchased this season	$13.85
Water Reducer	2.6 lb	$18.51 /lb	MCCT 2021, not purchased this season	$48.50
Air Entrainer	1.9 lb	$25.09 /lb	MCCT 2021, not purchased this season	$48.21
Pigment	0.1 lb	$7.59 /lb	Direct Colors, not purchased this season	$1.00
Fiberglass Mesh	72 ft^2	$0.57 /$ft^2$	The Home Depot	$41.04
Water	31 gal	$0.01 /gal	City of Ann Arbor	$0.31
SILRES BS 6920	16 lb	$2.71 /lb	MCCT 2021	$43.36
Vinyl Lettering	56 letters	$4.38 /letter	BoatUS.com	$245.28
TOTAL				
$\boldsymbol{Expenses\ E = (\sum MC + \sum DE) * 1.10}$				**$696.54**

Table E-3. Mold and Shipping Costs

Mold Construction and Lump Sum Fee	$5,000.00
Shipping Cost Roundtrip to Athens, OH from Ann Arbor, MI	$627

Pre-Qualification Form (Page 1 of 3) *2022 ASCE Concrete Canoe Competition™ Request for Proposals*

University of Michigan

(school name)

We acknowledge that we have read the 2022 ASCE Society-wide Concrete Canoe Competition Request for Proposal and understand the following (*initialed by team captain and ASCE Faculty Advisor*):

The requirements of all teams to qualify as a participant in the ASCE Student Symposium and Society-wide Competitions as outlined in Section 3.0 and Exhibit 3.	DR WH
The eligibility requirements of registered participants (Section 3.0 and Exhibit 3)	DR WH
The deadline for the submission of *Letter of Intent, Preliminary Project Delivery Schedule* and *Pre-Qualification Form* (uploaded to ASCE server) is November 5, 2021; 5:00 p.m. Eastern.	DR WH
The last day to submit *ASCE Student Chapter Annual Reports* to be eligible for qualifying (so that they may be graded) is February 1, 2022.	DR WH
The last day to submit *Request for Information* (RFI) to the C4 is January 22, 2022.	DR WH
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.	DR WH
The submission date of *Project Proposal, Enhanced Focus Area Report,* and *MTDS Addendum* for the Student Symposium Competition (hard copies to Host School and uploading of electronic copies to ASCE server) is Friday, February 18, 2022.	DR WH
The submission date of *Project Proposal, Enhanced Focus Area Report,* and *MTDS Addendum* for the Society-wide Final Competition (hard copies to ASCE and uploading of electronic copies to ASCE server) is May 20, 2022; 5:00 p.m. Eastern.	DR WH

Deborah Reisner	10/26/21	Will Hansen	10/27/21
Team Captain	*(date)*	*A ASCE Student Chapter Faculty Advisor*	*(date)*
Deborah Reisner		Will Hansen	
(signature)		*(signature)*	

University of Michigan

(school name)

As of the date of issuance of this Request for Proposal, what is the status of your school / university's 2021-22 classroom instruction (in-person, remote, hybrid)? What is anticipated after Thanksgiving and winter holiday break? If in-person or hybrid, do you have access to laboratory space or other facilities outside of classes?

The University of Michigan is currently in a mixed, but primarily in-person, format; 93% of classes are offered fully in-person, 5% are hybrid, and 2% are fully remote. Many of the in-person classes include options to attend remotely and/or asynchronously. This will be unaffected by Thanksgiving and winter holiday break. The team has access to laboratory spaces and facilities to mix and test concrete, with no restrictions on the number of attendees. Some facilities for paddling practice are not available. Hours for most facilities remain less accessible than pre-COVID-19. Most of the team's business is conducted in-person, but some meetings are virtual.

In 250 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? Include a discussion on the impact of COVID-19 on the team's ability to perform work and what plans would be implemented assuming work could be performed.

Michigan Concrete Canoe Team (MCCT) is operating under the public health plans of the state of Michigan, city of Ann Arbor, University of Michigan, College of Engineering (CoE), and the facilities in which it operates, including the Wilson Student Team Project Center (WSTPC). MCCT also adheres to personal health requirements in all facilities, requiring proper PPE, training, and safe work environments. The team is continually working with the WSTPC and Office of Student Affairs to ensure safe in-person events to prevent the spread of COVID-19. The University of Michigan has mandated vaccination against COVID-19 for all students, faculty, and staff. Masks are mandated inside of all university buildings. Daily Health Screenings are mandatory for all CoE and MCCT Events. COVID-19 testing is free and accessible to all students.

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 Michigan Concrete Canoe Team's current construction and RFP Adherence QA/QC program is headed by the QA/QC Lead. This person is responsible for monitoring whether the rest of the team is following ASCE's official Request for Proposals and MCCT's internal quality standards. Each team lead is also responsible for reading their own portion of the RFP. If the leads are ever confused by the guidelines, the quality control officer is the person to clarify this. This system works well because each subteam individually knows what is expected of them, while also having a leader who is available if they have any problems. Technical Submissions QA/QC is headed by the Technical Submissions Lead. The next officers for both positions are voted in at the end of the school year through an election and the previous officers leave them with guidelines for how to operate for the coming year.

University of Michigan

(school name)

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?
MCCT complies with all policies regarding material research, testing, and construction and is in continuous contact with the proper groups to maintain a safe environment for students.

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).*

We anticipate the theme to be "Western" and our canoe name to be "Stallion". We intend to connect our theme to our university's approach to pioneering new technologies and pursuing experimental fieldwork.

Has this theme been discussed with the team's Faculty Advisor about potential Trademark or Copyright issues?
Yes. No trademark or copyright issues are anticipated.

The core project team is made up of 34 ***number of people.***