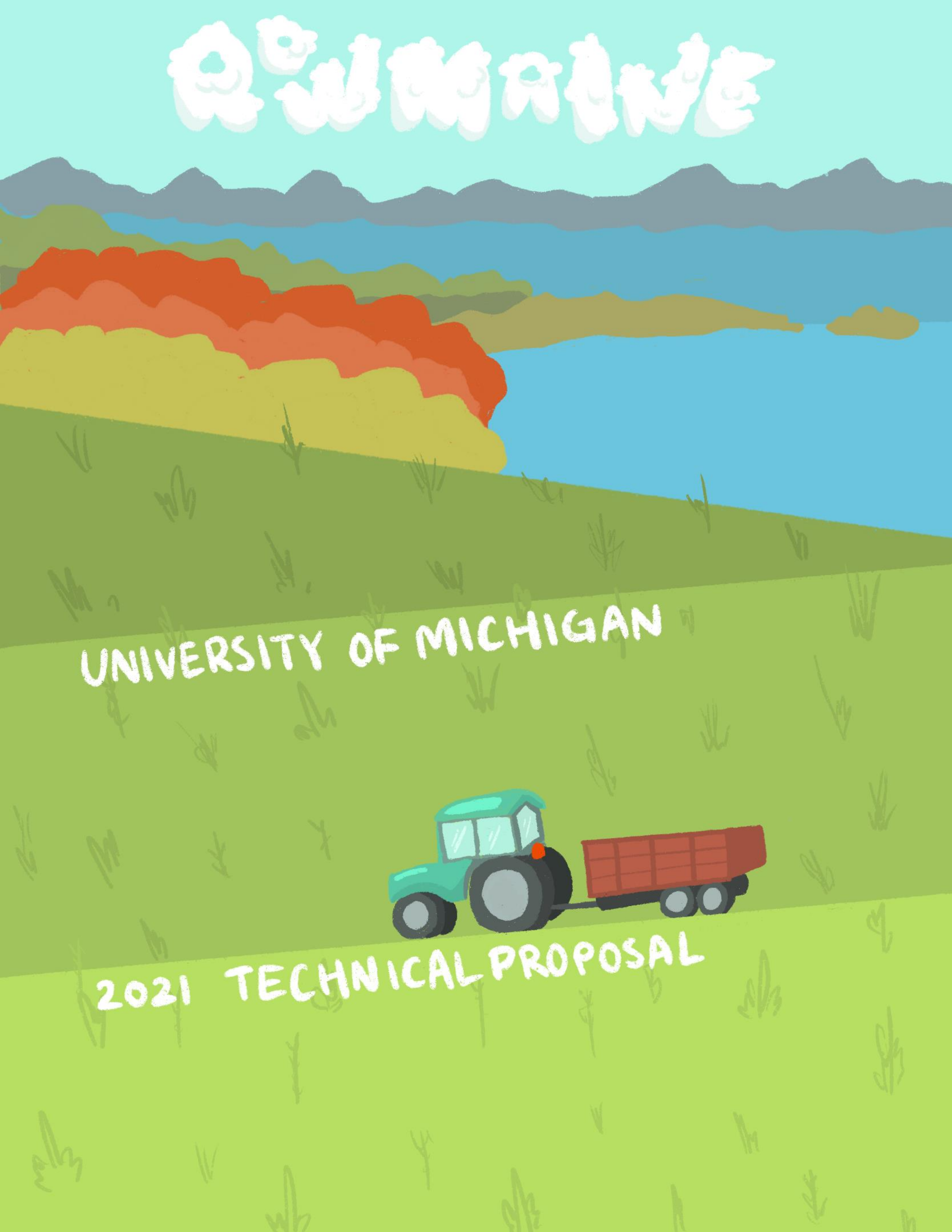

ROVMAINE
UNIVERSITY OF MICHIGAN
2021 TECHNICAL PROPOSAL

Date: February 19, 2021
To: Committee on Concrete Canoe Competitions
Subject: Response to RFP – 2021 Technical Proposal, ROWMAINE

Dear Committee on Concrete Canoe Competitions,

Michigan Concrete Canoe Team declares that this proposal, and the canoe design contained within, including the hull design, layering scheme, and concrete mix design, fully comply with the requirements specified in the *Request for Proposal* (RFP). We have reviewed all Material Technical Data Sheets (MTDS) and Safety Data Sheets (SDS) for the included materials. The *Request for Information (RFI) Summary* has been reviewed by the team, and it has been determined that the team's proposal meets all requirements from said summary. The 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. These participants meet all eligibility requirements.

University of Michigan

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Table of Contents

Executive Summary

A favorite choice of food for Michiganders around the Detroit area is the Michigan salad, which features cherries, walnuts, blue cheese, and a vinaigrette. This unlikely combination stands as both a celebration of the bounty of the region and the pride that Michiganders take in their community. Michigan Dining embraces that celebration of the region by producing healthy meals that benefit the students, Ann Arbor, and the environment. Michigan Dining takes steps to source local and sustainable ingredients, and compost waste. To-date they have recovered more than thirty one thousand pounds of perishable food[1]. They work with student leaders to provide resources such as food distribution centers and farmers' markets that support the university's goals. By combining the varied flavors and textures of the Michigan salad, it creates a product beyond the sum of its components. The Michigan Concrete Canoe Team (MCCT) strives to exemplify the achievements and principles of the Michigan Dining community. MCCT works as a group to become more experienced, knowledgeable, and inclusive engineers. Like the Michigan salad, MCCT uses individuality and creativity to work harmoniously and include unique perspectives. Whether it is mixing concrete, testing a new hull, or paddling the canoe, MCCT members rely on each other to produce the best possible result.

The University of Michigan has a stellar record of education excellence, being regarded as the top public university in the country[2]. The education of these students is put to use in the College of Engineering's mission to "serve the people of Michigan and the world" and produce "leaders and citizens who will challenge the present and enrich the future"[3]. 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 seen incredible team growth and the solidification of these developments into institutional changes. In 2017, *VALIANT* placed second at the North Central conference. In 2018 and 2019, *MAJESTY* and *TERRA* placed first and second, respectively. Unfortunately, MCCT was unable to compete using *KEPLER* in 2020 due to the COVID-19 pandemic, but the team was able to translate much of the knowledge and experience from *KEPLER* into this year's proposal. MCCT's continued success posits a deep institutional attention to the training of younger members and the care taken toward working cohesively in a manner beneficial to the team's performance. MCCT's current expertise and dependable future performance makes the team an excellent candidate to be awarded ASCE's contract.

This year has been very different from previous years of competition. COVID-19 fundamentally changed the way in which MCCT has engaged its members and progressed in a year of adversities. 60% of MCCT's leadership is composed of graduating seniors, and there are many areas of knowledge where it is essential to transfer procedures and previous experiences onto incoming leadership. Team leadership focused on instituting new safety procedures and practices in coordination with the university to create a safe in-person environment. Most team meetings were conducted remotely to limit risk. A large, virtual recruitment process resulted in many new faces. This created the largest team compared to previous years: more than 35 MCCT members. Leadership used the subteam system, new apprenticeship positions, and virtual format to transfer knowledge to incoming members while performing the tasks possible in a mostly virtual environment. Casting a full-scale canoe was not possible due to strict COVID-19 restrictions. Mixing and concrete testing are a notable exception, being primarily in-person events. By working with the university and facility staff, MCCT was able to conduct these tasks in person, thereby resulting in a more thoroughly tested concrete mix.

The mix design subteam worked diligently to meet the new requirements of the *Request for Proposal* (RFP). The most difficult parameter was the exclusion of manufactured microspheres and cenospheres. To meet these requirements, the mix design subteam included Expanded Polystyrene (EPS) and increased the amount of expanded shale to lower the density of the mix. The team has also continued to conform to last year's rule of latex exclusion, which affects the workability of the mix.

This year, the hull design subteam revolutionized the design and testing process to create an exciting new direction for the team. Starting from the highly optimized canoe from last year, *KEPLER*, the team expanded the design space by including new hull geometries. These geometries were then tested in a new and user friendly computational hydrostatics analysis software. The designs then underwent scale model hydrodynamics testing to finalize the selection process. MCCT focused on creating a more stable canoe that would be more accessible to younger members without compromising the straight-line performance.

The Michigan Concrete Canoe Team is continually adapting to the aforementioned challenges to create this proposal in response to ASCE's RFP. In its approach to these challenges, the team continues to demonstrate its commitment to ASCE's vision and to the future of the team and its community. MCCT believes that their superior performance displays the team's advantages as a contractor. MCCT presents its 2021 design, *ROWMAINE*.

Table 1. Canoe specifications.

ROWMAINE			
Anticipated Weight	223 lb	Concrete Unit Weight	56 lb/ft^3 (dry) 57.7 lb/ft^3 (plastic)
Length	248 in.	Air Content	16.1%
Width	28.9 in.	Compressive Strength	730 psi
Depth	12.1 in.	Split Tensile Strength	200 psi
Average Hull Thickness	0.82 in.	Flexural Strength	200 psi
Reinforcement	Fiberglass Mesh	Slump	¼ in.

Introduction to the Project Team

ASCE Student Chapter Profile

The ASCE Student Chapter at the University of Michigan has a strong presence on and off campus. The chapter contains eleven student officers and holds bi-weekly executive board meetings to discuss current and future events. The chapter also hosts weekly general member meetings, along with coordinating an average of four large events every academic year.

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. The career fair is paid for and organized by the ASCE Student Chapter. This event helps students in the department find internships, land 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 and are part of the weekly general member meetings. They have been a staple within the department for several years and attract a group of 20-40 people consisting of undergraduate and graduate students from all civil and environmental engineering concentrations, as well as a handful of professors. This year due to COVID-19, we decided to continue the series in a virtual format. The series also provides an opportunity for companies to recruit and introduce themselves to students and create a presence on campus. The presentations themselves are generally a mix of a technical engineering presentation and a fun, behind-the-scenes look at projects that the speaker has worked on. The chapter tries to create a relaxed environment where students can ask questions and learn while enjoying lunch.

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. A virtual weekend in Chicago is currently being planned, where alumni will virtually take students on company tours. This will be a great opportunity for networking with alumni, faculty, and other students. Shorter social events are also organized, such as Zoom movie nights and Zoom trivia nights.

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.

Core Team Members

Captain, Jacob Cieply: The captain creates a project plan for the year and monitors the team's progress. This position holds weekly general meetings, plans outreach events to recruit new members, 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, Nathan Jarski: The secretary writes weekly meeting recap emails to ensure all members are involved and informed. This position keeps team member information up to date and plans social events.

Treasurer, Rachel Kass: 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 team fundraising.

Hull Design Lead, Koby Khoo: The hull design lead utilizes modeling and analysis software to determine the hull of the canoe and tests small-scale designs.

Mix Design Lead, Claire O'Donnel: The mix design lead designs and tests concrete mixes in order to determine the optimal mix to fit the designated requirements. This position keeps track of mix curing and strength properties.

Mix Design Assistant, Elijah Richards: The mix design assistant works closely with the mix design lead to plan and run subteam meetings. The purpose of this position is to lessen the workload of the mix design lead and to improve the efficiency of subteam meetings. The intention is that the assistant will become next year's mix design lead.

Structural Design Lead, Connor Arrigan: The structural lead creates and analyzes load cases, reports shear and bending moments, and ensures the structural integrity of the canoe.

Construction Lead, Emma Anielak: The construction lead manages peripheral projects on the team, such as the R. John Craig Legacy Competition video and helping other subteams perform their duties.

Aesthetics Lead, Lucy Zhang: The aesthetics lead designs the overall look of the canoe and implements the theme cohesive throughout all display elements.

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

Finishing Lead, Erik Rehkopf: The finishing lead establishes methods to complete the final look of the canoe. This position prepares the mold, assists in designing the curing environment and process, smoothes the canoe during casting, and organizes post-processing of the canoe after it has cured.

Quality Control Manager, Julia Healy: The quality control manager thoroughly reads and understands the rules and effectively relays necessary information to the relevant team members. As well, the quality control manager develops tools to measure the consistency and accuracy of concrete casting.

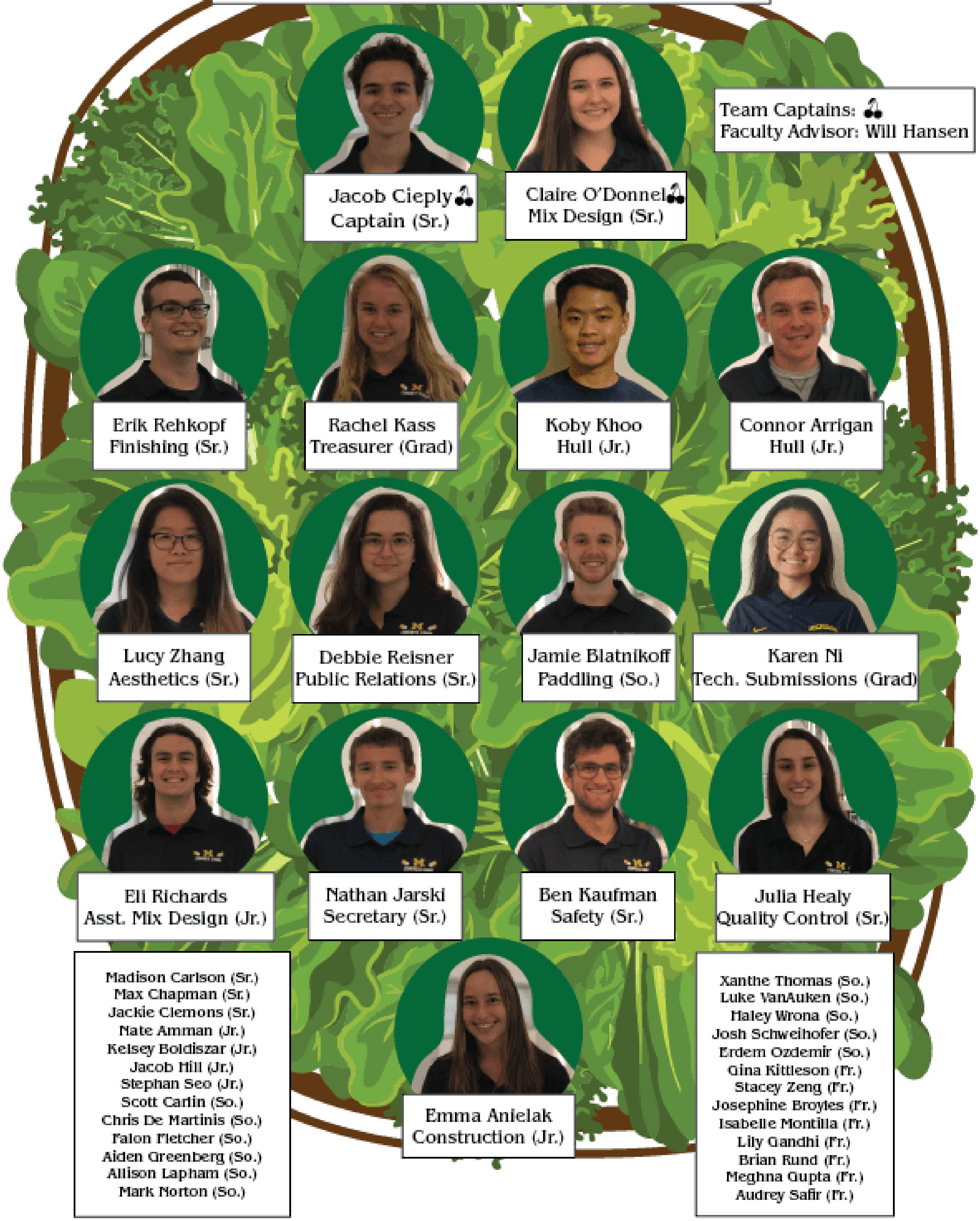
Paddling Lead, Jamie Blatnikoff: The paddling lead recruits the paddling subteam and organizes team workouts. This position also reserves paddling locations and teaches members how to properly paddle.

Safety Officer, Benjamin Kaufman: The safety officer learns all of 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, Deborah Reisner: The public relations officer increases awareness of the team on campus. This includes all of the team's social media posts as well as planning outreach events for the team.

Webmaster, Lucy Zhang: The webmaster updates the team's website.

Organizational Chart



Technical Approach

Hull Configuration

This year, the hull design subteam focused on implementing fundamental naval architecture techniques into the design of the canoe. Specific goals for the subteam included using more current naval architecture software and instituting regular changes that fully explore the design space. The hull design subteam allocated more time to improve the design process due to the reduced number of deliverables this year. In September, team members researched canoe design parameters. Members were also taught how to design new canoes in Rhinoceros 6.3 using standardized tutorials created by the team[4]. For hydrostatic analysis, the team switched from using MAXSURF 18.0 to PolyCAD 10.4[5][6]. MAXSURF is more complicated and takes longer to use than PolyCAD to perform similar tasks. The team also focused on information retention by creating a central document to catalog every hull tested, providing evidence of how different parameters affect the performance of the canoe. These changes will allow team members to understand canoe design at a more fundamental level and enable the team to improve the canoe hull in future years.

Due to COVID-19 and the resulting reduction in paddling practices, MCCT anticipates a need for a more stable canoe which will be easier for less experienced members to use. The specific goal for this year's design was to select a hull with low resistance and high stability. A canoe with increased stability allows inexperienced paddlers to focus on their paddling technique without worrying about capsizing. The subteam started the design process by researching what parameters affect the canoe's performance. MCCT considered the following dependent variables: transverse metacentric height (GMT), downflooding angle, righting moment at 20 degrees of heel (GZ), and resistance[7]. The independent variables were length-to-beam ratio and prismatic coefficient. After designing new canoes in Rhino, the hydrostatic data were compared to narrow down the canoe selection[4]. Three canoes were chosen on which to perform additional testing: *KEPLER* for a baseline, *KEPLER* with a different length-to-beam ratio (*KEPLER*–New L/B), and one with a different prismatic coefficient through changing underwater curvature (V-keel Hull)[8]. The stability of the hulls was judged by their GMT and GZ. Based on the PolyCAD data, *KEPLER*–New L/B was the most stable, and *KEPLER* and V-keel Hull had similar stability[6]. Scale model resistance tests were performed on the three potential canoe models. More details on the resistance tests can be found in the Enhanced Focus Area Report. *KEPLER's* hull was chosen because it had the lowest average drag at the estimated race speed. *KEPLER's* hull met MCCT's goal of maintaining high stability while minimizing resistance.

Figure 1. Three scale model hull designs were resistance tested in the hydrodynamics lab. From farthest to nearest: *KEPLER*-New L/B, *KEPLER*, and V-keel Hull.

Table 2. Specifications of the full-scale canoes being tested for the a 650 lb load[8].

Canoe Prototype	Length (in.)	Beam (in.)	Draft (in.)	Block Coefficient	GMT (in.)	GZ (in.)	Average Drag (lbf)
KEPLER (1)	248	28.92	6.286	0.445	7.699	2.664	2.713
KEPLER - New L/B (2)	232	30.83	6.294	0.446	8.990	3.081	3.018
V-keel Hull (3)	248	28.96	5.152	0.538	7.623	2.559	2.852

Structural Analysis

The main goal for the structural analysis subteam this year was to continue to improve on the techniques used to calculate the structural integrity of the canoe. The subteam relies on MAXSURF and hand calculations to generate data for maximum shear and moment loads in a variety of load cases[5]. The shear and bending moments for the canoe were calculated by hand using a triangular load approximation for weight and buoyancy.

Four different load cases were used to analyze the structural performance of the canoe: two males, two females, four coed paddlers, and two display stands. In the two-paddler cases, paddlers were considered point loads with varying weights depending on gender and were positioned at 15% and 85% of the canoe length. In the four-person case, paddlers were also considered point loads, positioned at 15%, 30%, 70%, and 85% of the canoe length. Based on the results of the analyses, the two male load case was found to have the highest maximum moment as can be seen in Figure 2.

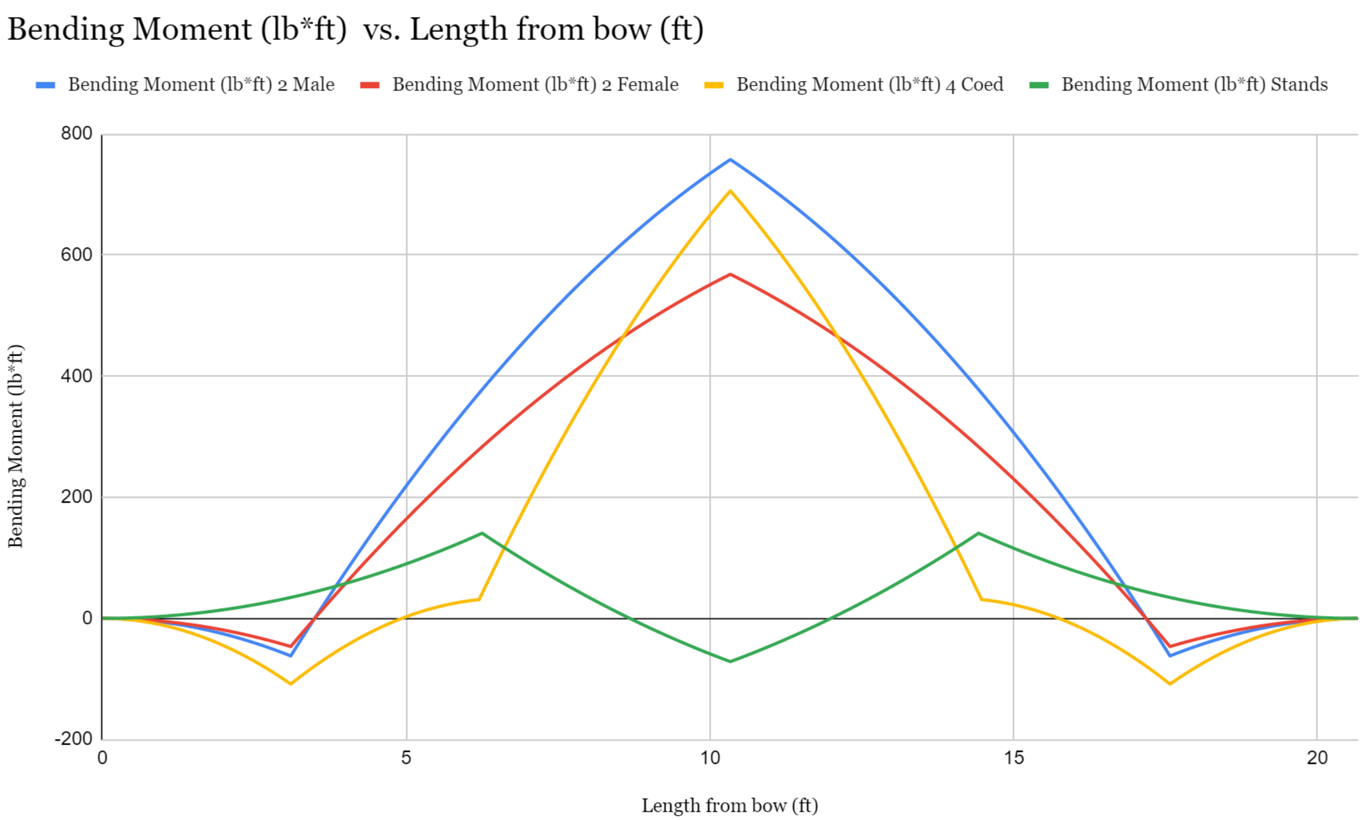


Figure 2. The bending moment diagram for various load cases.

Material Design Requirements

After calculating the maximum bending moments and communicating with the mix design team, a mix was created with a tensile strength of 200 psi. This achieves a safety factor >2 and can withstand dynamic loading on the water. The structural mesh will be the same as the one used last year[8]. The fiberglass mesh worked well for the canoe and provided ample support and rigidity to mitigate cracking.

Materials Selection and Testing Protocol

The mix design subteam's primary goal, established at the start of the 2021 competition season, was to find an effective aggregate replacement for glass microspheres while maintaining a low density. New RFP rules and strict safety measures in response to the COVID-19 pandemic presented unique challenges for the subteam to overcome this year. Access to the team project center was limited by stay-at-home orders, the restriction in the number of people allowed in the design space, and its two month closure between the first and second semesters. These constraints significantly limited the ability of MCCT to make and test 8 different mixes before the project center closed, which made it possible to still obtain experimental values to help estimate the density, air content, and strength of the concrete. The team's ability to adapt to these changes in combination with thorough research, testing, and collaboration enabled MCCT to achieve its goals for the season.

Figure 3. Mix 6 of the 8 mixed that were tested.

ROWMAINE's mix is based on *KEPLER*'s mix design as it demonstrated desirable strengths, buoyancy, and did not incorporate latex[8]. The greatest challenge in producing this year's mix was eliminating all manufactured microspheres as required by the RFP and finding suitable replacements that would maintain a low density and high strength.

The mix subteam tested many different ratios of cementitious materials for the *KEPLER* mix and thus felt confident in preserving those materials and proportions for *ROWMAINE*. VCAS™ 160 is a pozzolanic material and was used at a greater wt.% compared to other cementitious materials. It had considerable contributions to the compressive and tensile strengths of the concrete and has a lower specific gravity, hence reducing the density of the mix[9]. The next cementitious material included was GGBFS 120, a lightweight and sustainable alternative to portland cement that improves the workability of the concrete in the absence of latex[10][11]. Class C fly ash is another pozzolanic material chosen as a replacement for portland cement; it is desirable due to its low specific gravity, environmentally sustainable properties, and contributions to the strength of the concrete. It also reduced shrinkage, lowered water demand, improved workability, and reduced permeability and absorption[12]. Komponent® was incorporated into the mix in the same proportion as it was for *KEPLER* to minimize shrinkage cracking during curing[8][13].

New aggregate rules prohibited the use of manufactured microspheres and required at least 50% of aggregate volume to consist of ASTM C330 compliant aggregate and/or recycled concrete aggregate (RCA). The subteam performed extensive research into new rule-compliant aggregates, ultimately including Buildex Expanded Shale and CityMix Expanded Polystyrene (EPS) in the mix for the first time this year in addition to Haydite Shale. Haydite was used in previous years' mixes and was maintained in *ROWMAINE*'s mix design as it provides substantial strength to the concrete, with the added benefit of a low specific gravity, which is why the team chose to use it as a primary natural aggregate in the concrete[14].

Norlite, a lightweight aggregate first used in *KEPLER*'s mix, was incorporated into the mix design again this year. Norlite has a specific gravity comparable to that of Haydite and it contributes to the strength, density reduction, and sustainability of the concrete mix. Norlite also has a high absorption capacity, which aids the internal curing process[15]. Due to Haydite having a slightly lower specific gravity than Norlite, the volume of Norlite used in the mix was decreased in favor of Haydite.

The subteam also adopted Buildex, which has a similar composition to Haydite but has a significantly lower specific gravity and higher absorption capacity[16]. Despite these benefits, the team was still conservative with the amount of Buildex added because it had a larger particle size. This has an adverse effect on the smooth gradation of the mix. A smoother gradation minimizes the total volume of voids between aggregates, improving the workability of the mix[17].

CityMix EPS beads are another new aggregate incorporated into *ROWMAINE*'s mix design. Of all the aggregates used in the mix, CityMix has the lowest specific gravity and absorption capacity and consists of 99% recycled content by volume, improving the sustainability of the mix[18]. The foam beads were primarily chosen as a replacement for the Poraver®, K20, and SG-300 used in previous years' mixes, as the specific gravity and absorption capacity is very similar. However, a decrease in strength is attributed to an increase in CityMix volume, so the majority of the aggregate strength contribution comes from the Haydite, Buildex, and Norlite.

Table 3: Aggregate Properties.

Aggregate	Composition	SSD Specific Gravity	Abs (%)	Particle Size (in.)
Buildex Shale	Expanded Shale	1.34	12	0.125-0.25
Haydite	Expanded Shale	1.56	9.2	0-0.187
Norlite	Ceramic Shale	1.66	7	0-0.187
CityMix	Expanded Polystyrene	0.05	0	0-0.125

The team incorporated internal curing in *KEPLER*'s mix as an innovative way to increase the strength of the concrete; however, limited accessibility to the team project space under COVID-19 restrictions prevented the execution of this method[8]. Despite this setback, the mix subteam still developed a plan to re-use this method for the 2022 season. The Haydite and Norlite would be soaked for 48 hours and then drained for 24 hours before mixing to achieve saturated, surface dry (SSD) conditions. This absorption by the aggregates aids in the hydration process and replaces any moisture lost from evaporation. Data about the absorptivity of the aggregates would be used to calculate the amount of water necessary for sufficient soaking[14]. The volume of water added to the aggregates during this SSD conditioning step must then be subtracted from the total volume of water needed during the mixing process. Internal curing promotes hydration of the mix throughout the entire canoe cross-section, which saturates the pores in the cement paste and prevents early age shrinkage and cracking. As *KEPLER*'s mix and *ROMAINE*'s mix both included higher amounts of pozzolanic cementitious materials, the internal curing process serves to meet the additional water demand required. Additionally, internal curing helps to lower the permeability of concrete[19]. This curing method has been found to improve many qualities of the concrete mix and the subteam intends it to be an essential part of the design process during the 2022 season.

The addition of PVA fibers prevents plastic shrinkage cracking in the concrete mix. An effective quantity of fibers was determined in 2018's mix for *MAJESTY* and was retained in the 2021[20]. The fibers were dosed at 6.5 lb/yd^3 and a combination of 6 mm, 8 mm, and 12 mm sizes were used [21][22][23].

The amount of high range water reducer incorporated into the mix was maintained at the same amount added for *KEPLER*. Water reducer increases the workability of the mix without significantly increasing the water usage and consequently decreasing the strength of the concrete. Many mixes with different dosages of air entrainer were tested last year and evaluated based on density and air content. It was determined that a 30 fl oz/cwt dosage of air entrainer optimized these properties in *KEPLER*, and thus this dosage was repeated for *ROWMAINE*'s mix[8]. In addition, to maintain a low density while preventing water from penetrating the concrete, the SILRES BS 6920 sealer chosen last year will be used on the finished product. MCCT also chose this sealer because it dries to a glossy finish, providing a desirable aesthetic appearance to the canoe[24].

Due to limited access to MCCT's project center, the team was not able to perform sufficient testing of its final mix design to provide purely experimental values in its results. Therefore, the following quantitative results were calculated using a combination of the limited testing performed, previous years' test results, and published research. The subteam calculated the anticipated wet density of 57.7 lb/ft^3 by dividing the anticipated mass of the concrete by the 27 lb/ft^3 design volume, as shown in the calculations in Appendix B. Several of the test mixes made this year demonstrated a 3% decrease in density after the concrete dried, which was then used to estimate *ROWMAINE*'s oven-dried density of 56.0 lb/ft^3. An air content of 16.1% was calculated using this anticipated density, playing a key role in ensuring the floatation of the mix. In the event that the experimental density obtained during the 2022 season does not match the anticipated density, MCCT also plans to incorporate foam caps into *ROWMAINE* to ensure sufficient buoyancy. The subteam was able to perform a slump test in accordance with ASTM C143 on one of its test mixes, yielding a slump of ¼ in. The team was confident in reporting this experimental slump value as it is consistent with the previous year's slump, and minor differences between the test mix and final mix design likely would not significantly impact the slump results[8]. Compressive and tensile tests following ASTM C496 and ASTM C39 guidelines were performed on several test mixes. The test mixes did experience considerable decreases in compressive and tensile strengths from the previous year, which is also affected by shorter cylinder curing times in addition to the absence of glass microspheres[8]. The typical 28-day cure period was reduced to 14 days for the test mixes due to the early closure of campus facilities in the first semester and the late reopening of campus facilities in the second semester. Had the cylinders cured for the desired 28 days, the mix subteam anticipates that the compressive strength of its mix would increase to 730 psi based on research on the relationship between concrete strength and cure time[17]. All quantitative test results are compiled in Table 4.

Table 4: Anticipated Test Results.

Concrete Property	Anticipated Test Results
Dry Unit Weight (lb/ft^3)	56
Plastic Unit Weight (lb/ft^3)	57.7
28-Day Compressive Strength (psi)	730
28-Day Tensile Strength (psi)	200
Air Content (%)	16.1
Slump (in.)	¼

The mix design team was successful in meeting its goals for *ROWMAINE*'s mix through extensive research, innovative use of new materials, and careful planning to sustain access to mixing and testing equipment. Norlite, Haydite, and PVA fibers were donated by vendors, which greatly benefited the team's budget, and the use of recycled aggregates in the mix significantly contributed to the sustainability of the mix. Transfer of knowledge was also improved this year due to the mix subteam lead working closely with the mix design assistant, as well as through the increased participation of younger subteam members. Overall, the team was successful in improving its design process while laying the groundwork for additional innovation in the future.

Proposed Construction Process

MCCT's approach to the canoe construction would be similar to the executed action plan implemented on *KEPLER*[8].

Form Material Selection

MCCT would use EPS as the material for the male mold, as has been done in the past. This material is selected for its compatibility with the outside vendor's machinery. Most of the foam used for this mold are sourced from repurposed scraps of foam from the outside vendor's previous projects, improving its sustainability.

Form Construction

The cutting of the foam mold would be done completely by an outside vendor. This, along with the continued implementation of casting day preparation steps, would couple to see further improvement of the final product.

The team would follow a similar process that was piloted on *KEPLER* to finalize the canoe. The mold cut by the outside vendor would arrive in three pieces and be secured together with dowel rods on top of leveled and clamped tables. Afterwards, a layer of automotive body filler would be applied to the entirety of the canoe mold. This layer of filler remedies any pitting of the foam mold that may hinder final smoothness and de-molding. To ensure that the filler is sealed from moisture interaction, it would be sanded and have a primer applied to it. This process would complete the form's construction.

Methodology of Mixing Concrete

Prior to mixing, the mix subteam members measure out all of the cementitious materials, aggregates, admixtures and fibers. The cementitious materials are then added to the mixing bowl, followed by the aggregates, which reduces the likelihood of the heavier natural aggregates sticking to the bottom of the bowl once mixing begins. Finally, the air entrainer is poured directly into the mix; this method of adding air entrainer was decided upon during the 2019 mix design process because it was found to maximize air content[25]. The mixing process then begins in the team's Hobart D300 mixer, with water being added in intervals. Roughly ten seconds into mixing, the fibers are added. Once roughly 75% of the mix's required water has been added, the water reducer is poured in, followed by the remainder of the water. The mixing process is complete once the concrete appears saturated.

Placement of Concrete & Reinforcement

The placement of concrete and reinforcement for *ROWMAINE* would follow the scheme the team has used in previous years, which was named the "Chasing Method". Implementing this method allows several team members to carry out different tasks along the length of the canoe simultaneously.

Casting would begin with a ⅜ in. thick layer of concrete being applied to the mold. Several members perform this task to place this layer down the length of the canoe, followed by a second team laying 3 ft. pre-cut sections of fiberglass mesh. The second layering team would be close behind, applying the second ⅜ in. layer of concrete. The finishing team would then follow, working with trowels and spray water bottles to establish the smoothness of the canoe exterior and limit any delamination problems. MCCT expects that this method would produce an exceptional final product as it has in the past.

Figure 4. Concrete placement and layering scheme on casting day for *KEPLER*[8].

Curing

MCCT plans to utilize the same wet curing method for *ROWMAINE* as was used for *KEPLER*. This process would take place in the Wilson Student Team Project Center paint booth, which has a consistent ambient temperature of 70°F, providing a favorable curing environment. MCCT members would place damp sheets on the canoe to initiate the curing process and maximize concrete strength. The sheets would then be saturated and replaced every 12 hours for 28 days. Internal curing is implemented early in the canoe making process by soaking the Haydite and Norlite for 48 hours and draining for 24 hours to produce saturated, surface dry (SSD) conditions prior to mixing. This method improves the strength, reduces the risk of shrinkage, and minimizes the permeability of the final product.

Form Removal & Concrete Finishing

On casting day, MCCT would apply the water-based release agent used for the first time on *KEPLER* to the entire mold for *ROWMAINE*. This water-based release agent was chosen over oil-based alternatives because it is a more sustainable option. The release agent would be applied to the canoe with air spray guns in the paint booth.

After curing, the exterior of the canoe would be sanded. The mold would then be removed from the canoe interior by flipping the canoe and resting it on female mold pieces for support. The first piece of the mold would be levered out at the stern, and then the rest would be removed. Afterward, the interior of the canoe is sanded. The mold pieces would be saved for future transportation support, workability testing, and practice sections.

In the event that the experimental density of the mix is higher than the anticipated density, the placement of concrete over foam caps will be a new addition to *ROWMAINE*. The foam caps will provide additional buoyancy required for the canoe. To maintain sustainable practices, MCCT would cut the desired volume of foam from the ends of the mold post-demolding. These foam ends would be inserted at the bow and stern of *ROWMAINE*. Once in place, the mold sections would be encapsulated in a ½ in. thick layer of concrete. The concrete over each foam cap would then be wet cured following the same process as the body of the canoe. Once the entirety of the canoe had cured, the team would carry out the finishing process.

MCCT expects that the innovations of previous years being implemented on *ROWMAINE* will improve its initial finish once cured. However, sanding will still be necessary. The finishing lead would organize sanding sessions, before and after demolding, to sand the interior and exterior of the canoe. The sanding would be done in an enclosed tent with the proper ventilation. The finishing team would start sanding with 80 grit paper and work up to 320 grit paper.

Aesthetics

MCCT plans to utilize several pigmented structural concrete mixes. The different colors will be used on casting day to create aesthetic designs on the interior and exterior of the canoe, respectively. After final sanding, two coats of SILRES BS 6920 sealer will be applied to the entirety of the vessel.

Project Management: Scope, Schedule, and Fee

Due to the change in RFP structure and the onset of COVID-19, MCCT was forced to reevaluate the risks associated with the team's activities and their respective contributions to the Engineering and Design Phase. The first, and most necessary, change was the elimination of casting day. MCCT adapted to this change by focusing on methodical testing and creating a flexible schedule that was more appropriate to the changing environment of COVID-19. The most important in-person process became concrete mixing and testing. The RFP's change in allowable materials, the challenges of acquiring materials, and the new facility rules meant that mixing and testing became more involved and difficult to conduct. Other processes, such as finalizing the hull design and preparing technical documents, had high priority because they could also delay the critical path. Therefore, the team started these projects at or near the outset of the year and built in extra time as a buffer. There are still events that could delay the team's critical path, such as the acquisition of materials and mold components for the construction of the canoe. Given the vendor's ability to deliver components in a timely fashion, we are highly confident that we will adhere to the chosen critical path and the final delivery deadline.

At the beginning of the design process, MCCT created a project schedule to detail the anticipated milestones, resulting in 20 events overall: 11 in the Engineering and Design Phase and 9 in the Construction Phase. The Engineering and Design Phase milestones included recruiting new members, deciding the theme, receiving concrete mix materials for testing, finishing hydrostatic analysis to select finalists for the hull design, receipt of hull models from vendor, selection of the hull design, selection of final mix, submission of Technical Proposal and EFA Report, submission of Comment Resolution Document, completion of technical presentation, and participating in the 2021 Conference Competition. For the Construction Phase, the team's milestones included receipt of concrete materials, selection of concrete pigments and quantities, receipt of mold and foam caps from the vendor, casting, curing, sanding, sealing, and swamp testing the canoe, and product delivery. There were delays in concrete material ordering and delivery, but this did not delay subsequent items on the critical path.

MCCT outlined a budget of $3210 for the 2020-2021 year. Due to lower estimates for transportation, Conference Competition expenses, and paddling practices, this was significantly smaller than the 2019-2020 year[8]. Donations for concrete materials further reduced this figure, such that only EPS materials were purchased at cost. These cost reductions ensure that the team has adequate financial reserves for long term projects. The anticipated budget for the 2021-2022 year is calculated to be $4375 due to increases in costs associated with mold construction, paddling practices, and competition appearances.

This year saw a successful implementation of MCCT's subteam structure. Members can join multiple subteams and stay engaged on their own terms. This structure allows members to contribute in meaningful ways while exploring which subteam best suits their interests. The team's structure also clearly defines the responsibilities of leadership roles.

Quality Control and Quality Assurance

MCCT's quality control and quality assurance program is led by the quality control officer of the team. This person is the lead on all quality assurance devices and is an expert on the RFP released by ASCE. The quality control officer reviews the details of the RFP and relays the relevant information to each subteam lead through individual meetings. This member is also in charge of informing the team of the RFIs released by ASCE as well as addendums to the RFP.

One of the main events the QA/QC team prepares for is casting day. This is the day when the team meets and makes the canoe. Due to COVID-19 restrictions, resulting in a full-scale canoe not being made, the team was unable to practice typical quality assurance procedures such as weighing aggregates to make sure that they fall within the specified weight category. Usually, ideas for quality assurance devices are brainstormed by the entire team for casting day. The main concerns for casting day are keeping the thickness consistent throughout the canoe and keeping the keel line straight. One of the quality assurance devices used are nails painted at two different levels, one for each layer of concrete. This allows the team to test for the thickness of the laid down concrete for its uniformity during casting.

Additionally, for quality assurance, the team planned to use foam tape of 3/8 in. thickness, the desired depth of one layer, to guide the layering procedure along the mold from bow to stern. Sections of concrete would be placed down with the tape moving along the length of the canoe. Finally, wooden dowels and string were secured at the bow and stern of the canoe, making a line that marked the keel. This is a useful guide for the finishing subteam to follow when troweling the canoe.

For quality control measures, MCCT will swamp test the canoe prior to product delivery. This will demonstrate that the design and implementation strategy are viable to deliver a final product that meets the design specifications.

Sustainability

Sustainability on the team took a different form this year, as MCCT wanted to incorporate it directly into the theme. *ROWMAINE* has been cultivated with the idea of local food in mind. Both buying and eating locally grown foods reduces one's carbon footprint as it decreases the distance the food travels. It also tends to have more nutritional value, and to some, even tastes better! In the last few years, the University of Michigan has made significant progress toward sustainability in the food sector regarding locally grown produce. The university's efforts include increased incorporation of local produce in dining hall meals and the creation of a campus community garden where students can harvest seasonal fruits and vegetables.

Sustainability has also been accounted for in the physical design of *ROWMAINE*. The mixes that were designed and tested utilized environmentally friendly materials such as GGBFS and fly ash, which acts as replacements for portland cement and require significantly less energy to produce. Additionally, the EPS foam used in the mix is manufactured from 99% recycled material. In the mold preparation process, the release agent used to remove the canoe from the mold is water based instead of oil based. To obtain some of the needed materials, the team targeted local vendors, resulting in lower transportation emissions due to their proximity to campus. The mostly virtual format of this year's activities also resulted in less carbon emissions from transportation to meetings, paddling practices and competition. In addition, far less volatile organic compounds were released due to the inability to mix and cast a canoe this year.

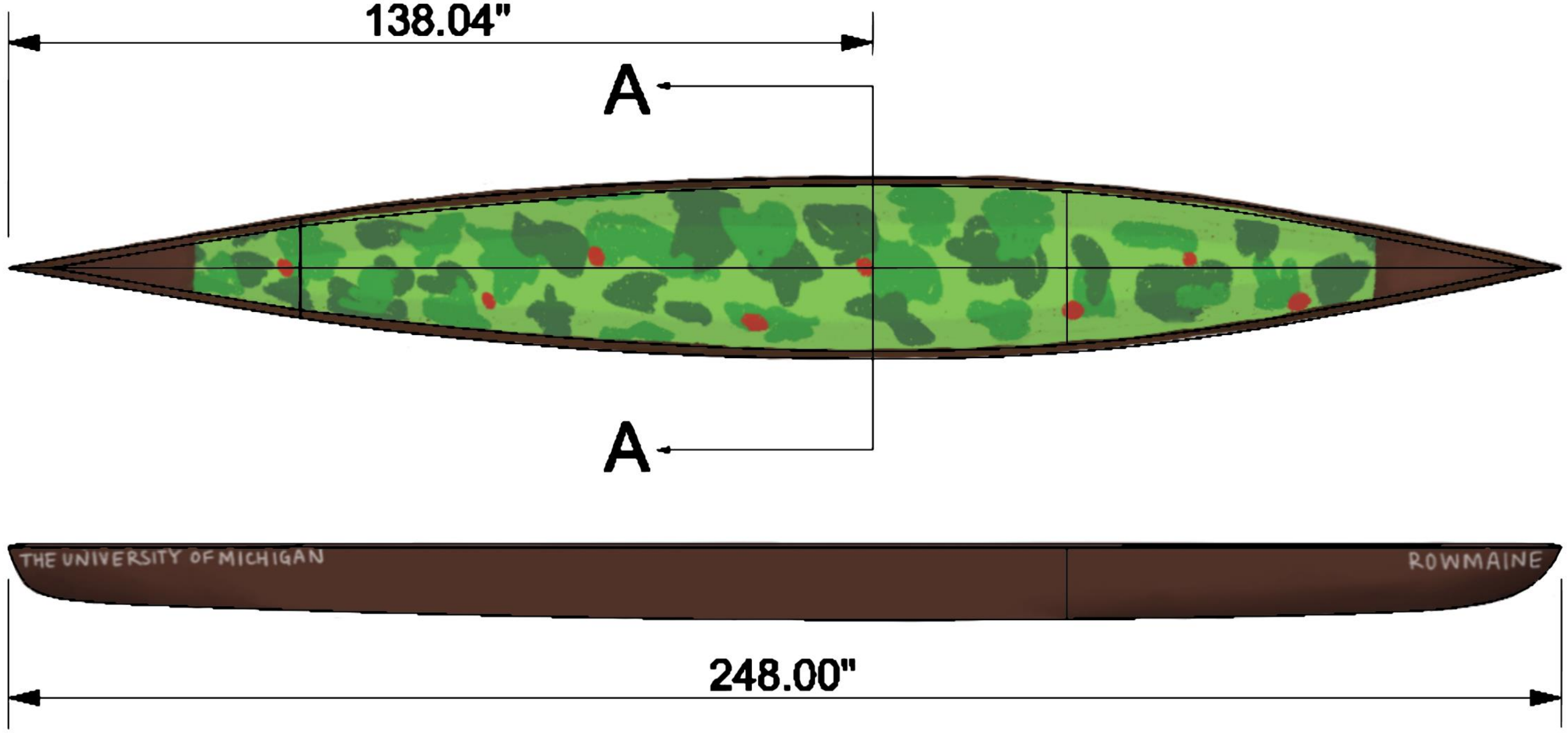
MCCT has also continued to develop new ways to improve the sustainability of the team's structure and practices. The mix design subteam introduced the new role of the mix design assistant during the 2020 season and further refined the role this year. The purpose of this role is to reduce the workload of the mix design lead and make the assistant more familiar with the mix design process. The member appointed to this position works closely with the mix design lead to develop mixes and run subteam meetings, with the long term goal of succeeding the lead position the following year.

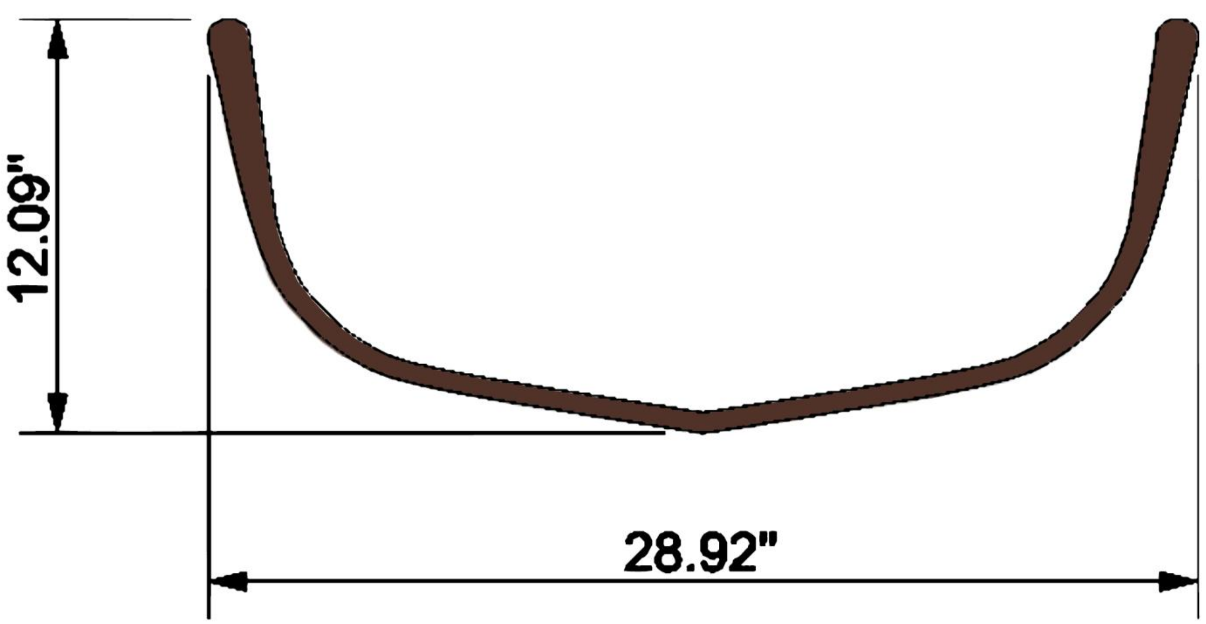
Health & Safety/Impact of COVID-19

Safety was a high priority for the team and was especially important because of the pandemic. An emphasis was placed on reducing the number of in-person events. Essentially all meetings, except for mix design, were made virtual. Prior to holding any in-person events, a thorough COVID-19 Event Safety Plan had to be filled out and approved by the university. These plans included implementations of maintaining hygiene, tracking attendance, adhering to social distancing, and communicating new procedures. All students were required to wear masks while on campus, and this rule was strictly followed while working in MCCT's project area. Face shields were also offered to members as an extra layer of protection. Additionally, starting in the second semester, all students who wished to participate in on-campus activities had to complete a COVID-19 test at least once a week.

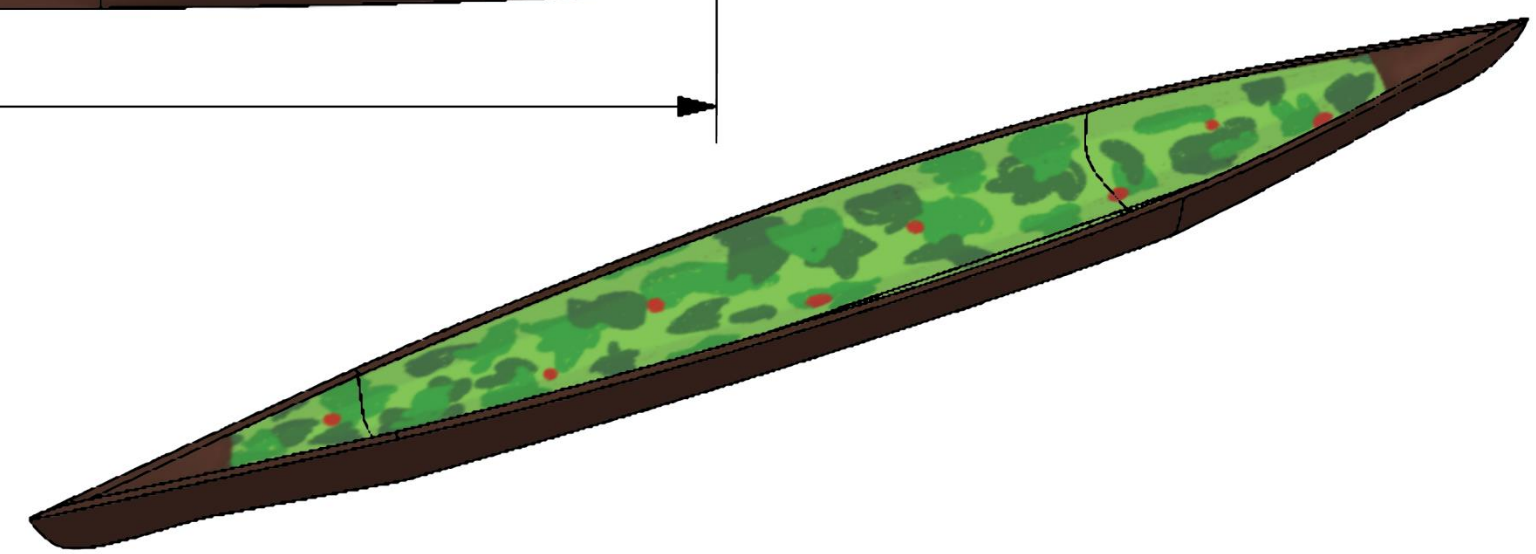
MCCT followed many stringent safety protocols specific to operating in our project space. New members were required to receive university-sponsored safety training, pass an online exam, and prove they could work safely before being granted access to the team's work area. During all in-person meetings, team members were required to wear protective eyewear, closed-toed shoes, and long pants. Team members also received supplemental respirator training and wore a respirator while mixing to protect against the inhalation of particulate matter. An elected team safety officer ensured all safety data sheets (SDS), Occupational Safety and Health Administration (OSHA), and University of Michigan safety standards were met and attended weekly meetings to be up to date with any changing protocols, which was especially vital during the COVID-19 pandemic. All materials used by MCCT were labeled according to OSHA standards, and the required personal protective equipment (PPE) was worn by members when handling these materials.

Figure 5. Team members wore closed toed shoes, long pants, safety goggles, and respirators.

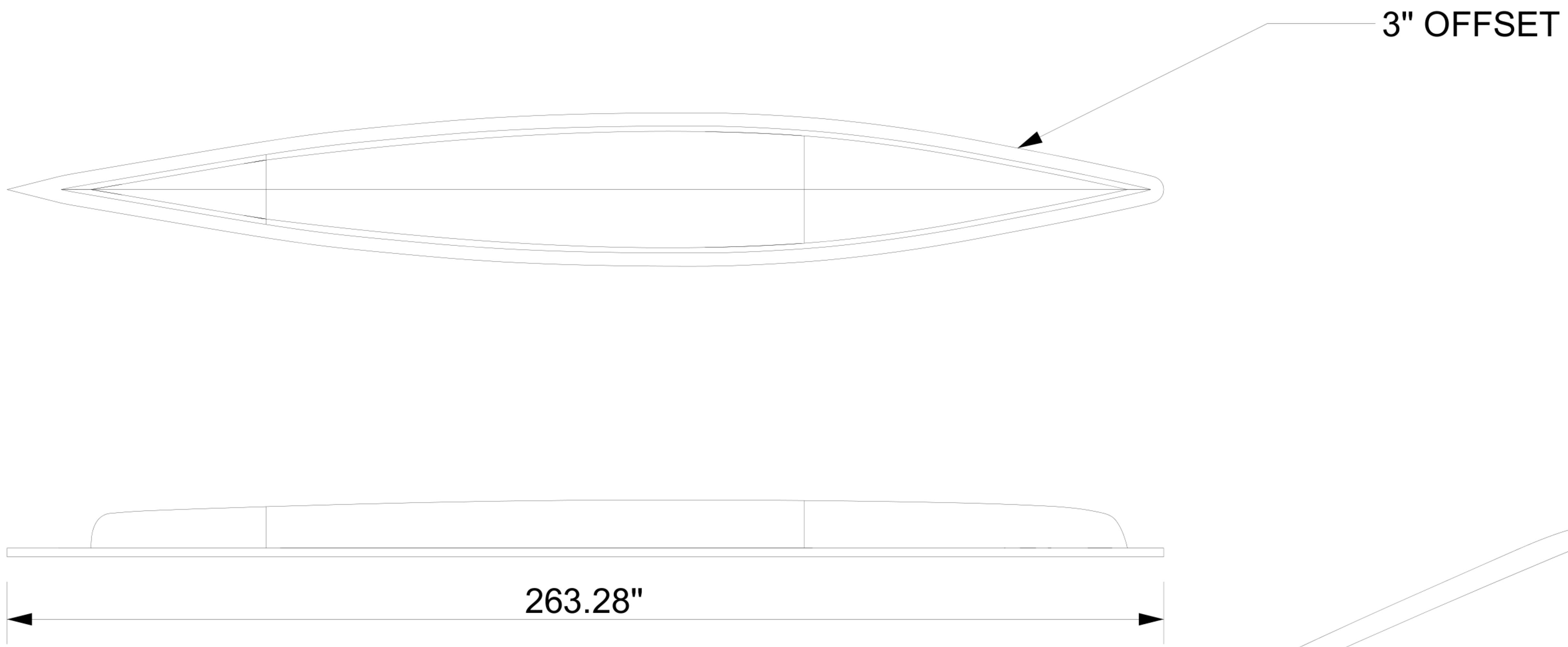


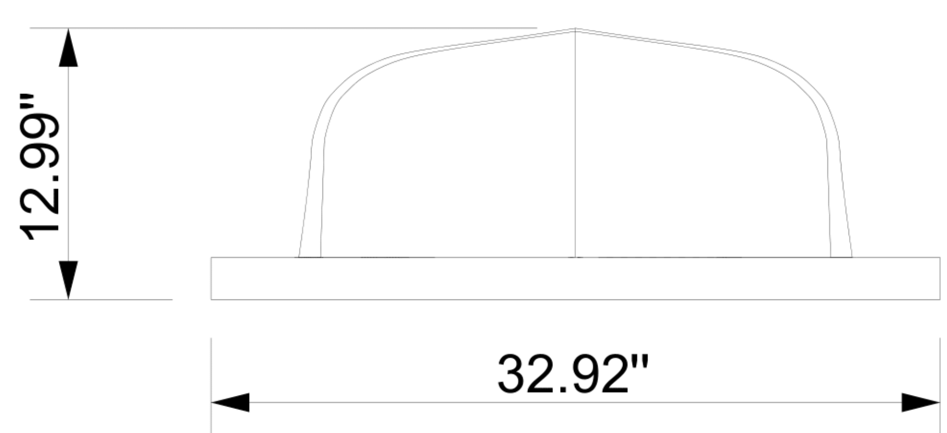


SECTION A-A



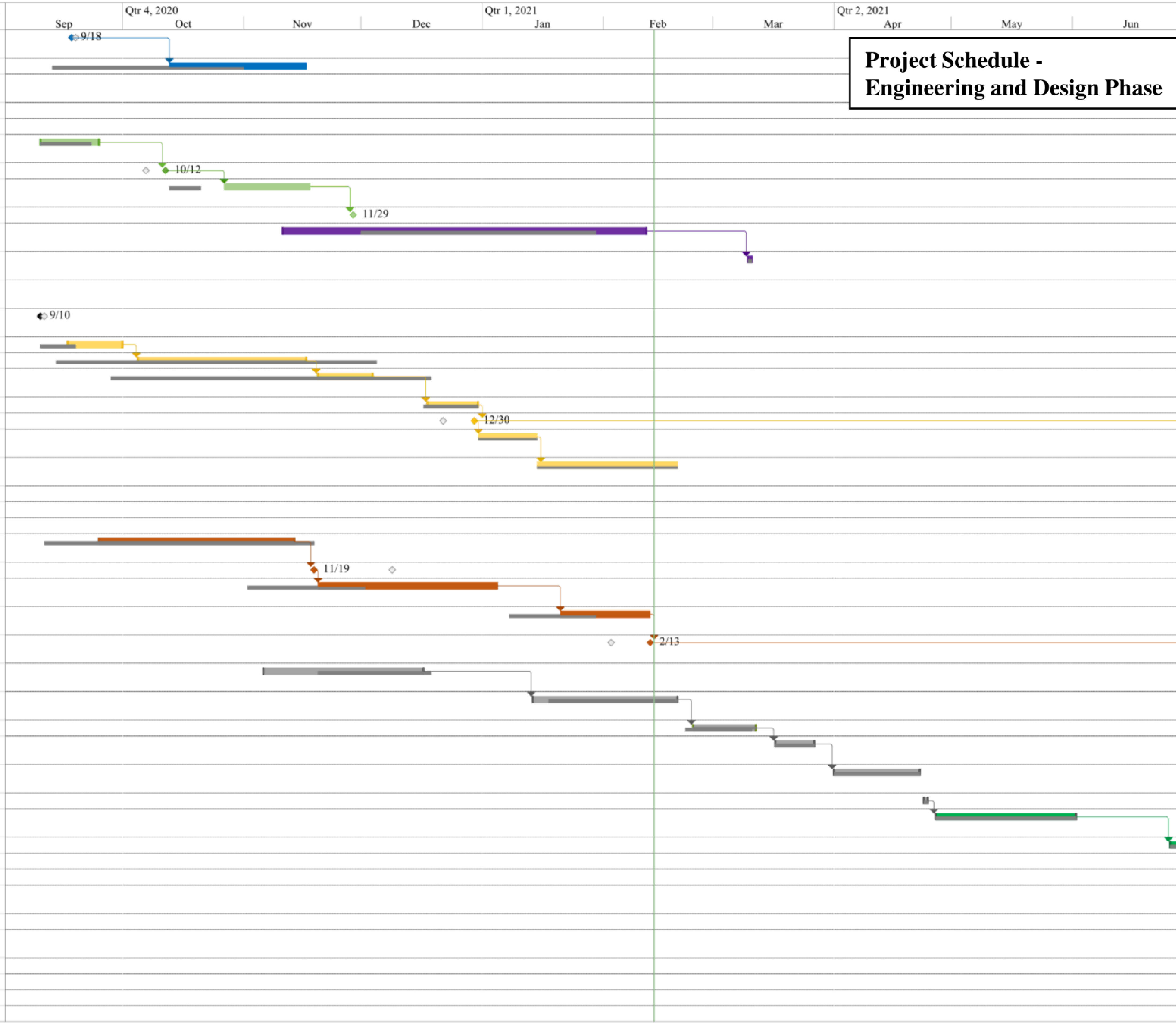
Michigan Concrete Canoe Team	
TITLE:	ROWMAINE
DESCRIPTION:	Canoe Drawing and Specification
DRAWN BY:	Koby Khoo
DATE:	02/12/2021





Michigan Concrete Canoe Team	
TITLE:	ROWMAINE Mold
DESCRIPTION:	Mold Drawing and Specification
DRAWN BY:	Koby Khoo
DATE:	02/12/2021

ID	Task Name	Actual Start	Actual Finish	Baseline Start	Baseline Finish
1	MSE Student Outreach Event	Fri 9/18/20	Fri 9/18/20	Fri 9/18/20	Fri 9/18/20
2	2020 Basic Training	Tue 10/13/20	Mon 11/16/20	Sun 9/13/20	Sat 10/31/20
3	2021 First Executive Board	Wed 9/1/21	Wed 9/1/21	Wed 9/1/21	Wed 9/1/21
4	2021 Mass Meeting	Wed 9/8/21	Thu 9/9/21	Wed 9/8/21	Thu 9/9/21
5	2021 Basic Training	Mon 9/13/21	Fri 11/19/21	Mon 9/13/21	Fri 11/19/21
6	Theme Brainstorming	Thu 9/10/20	Thu 9/24/20	Thu 9/10/20	Tue 9/22/20
7	Theme Chosen	Mon 10/12/20	Mon 10/12/20	Tue 10/6/20	Tue 10/6/20
8	Canoe Name Brainstorming	Tue 10/27/20	Tue 11/17/20	Tue 10/13/20	Tue 10/20/20
9	Canoe Name Chosei	Sun 11/29/20	Sun 11/29/20	Sun 11/29/20	NA
10	2020 Draft and Send Sponsor	Wed 11/11/20	Thu 2/11/21	Tue 12/1/20	Fri 1/29/21
11	2021 Giving BlueDay	Wed 3/10/21	Wed 3/10/21	Wed 3/10/21	Wed 3/10/21
12	2021 Draft and Send Sponsor	Tue 11/2/21	Wed 12/15/21	Tue 11/2/21	Wed 12/15/21
13	Request for Proposals Released	Thu 9/10/20	Thu 9/10/20	Thu 9/10/20	Thu 9/10/20
14	Order Materials	Thu 9/17/20	Wed 9/30/20	Thu 9/10/20	Fri 9/18/20
15	Concrete Mixing	Mon 10/5/20	Mon 11/16/20	Mon 9/14/20	Fri 12/4/20
16	Concrete Strength Testing	Fri 11/20/20	Thu 12/3/20	Mon 9/28/20	Fri 12/18/20
17	Data Analysis	Fri 12/18/20	Wed 12/30/20	Thu 12/17/20	Wed 12/30/20
18	Mix Design Chosen	Wed 12/30/20	Wed 12/30/20	Mon 12/21/20	Mon 12/21/20
19	Make Life Cycle Analysis	Thu 12/31/20	Thu 1/14/21	Thu 12/31/20	Thu 1/14/21
20	Finalize Life Cycle Analysis	Fri 1/15/21	Fri 2/19/21	Fri 1/15/21	Fri 2/19/21
21	Pigment Testing	Mon 9/6/21	Mon 10/4/21	Mon 9/6/21	Mon 10/4/21
22	Advanced Testing	Wed 10/6/21	Fri 11/5/21	Wed 10/6/21	Fri 11/5/21
23	Reciept of Materials	Tue 10/26/21	Tue 10/26/21	Tue 10/26/21	Tue 10/26/21
24	Design and Prototyping	Fri 9/25/20	Fri 11/13/20	Fri 9/11/20	Wed 11/18/20
25	Hull Finalists Chose	Thu 11/19/20	Thu 11/19/20	Tue 12/8/20	Tue 12/8/20
26	Prototype Construction	Fri 11/20/20	Mon 1/4/21	Mon 11/2/20	Tue 12/1/20
27	Hydrodynamic Testing	Thu 1/21/21	Fri 2/12/21	Fri 1/8/21	Fri 1/29/21
28	Hull Design Determined	Sat 2/13/21	Sat 2/13/21	Tue 2/2/21	Tue 2/2/21
29	Write Technical Proposal	Fri 11/6/20	Wed 12/16/20	Fri 11/20/20	Fri 12/18/20
30	Finalize Technical Proposal	Thu 1/14/21	Fri 2/19/21	Mon 1/18/21	Fri 2/19/21
31	Write Peer Review	Wed 2/24/21	Thu 3/11/21	Mon 2/22/21	Wed 3/10/21
32	Make Technical Presentation	Wed 3/17/21	Fri 3/26/21	Wed 3/17/21	Fri 3/26/21
33	Practice Technical Presentation	Thu 4/1/21	Thu 4/22/21	Thu 4/1/21	Thu 4/22/21
34	Regional Conferenc	Sat 4/24/21	Sat 4/24/21	Sat 4/24/21	Sat 4/24/21
35	Prepare for National	Tue 4/27/21	Tue 6/1/21	Tue 4/27/21	Tue 6/1/21
36	National Conferenc	Sat 6/26/21	Mon 6/28/21	Sat 6/26/21	Mon 6/28/21
37	Reciept of Mold	Wed 11/3/21	Wed 11/3/21	Wed 11/3/21	Wed 11/3/21
38	Casting Day	Sat 11/13/21	Sat 11/13/21	Sat 11/13/21	Sat 11/13/21
39	Primary Curing Period	Sat 11/13/21	Sat 12/11/21	Sat 11/13/21	Sat 12/11/21
40	Install Bulkheads	Sat 12/11/21	Sat 12/11/21	Sat 12/11/21	Sat 12/11/21
41	Secondary Curing Period	Sat 12/11/21	Sat 12/25/21	Sat 12/11/21	Sat 12/25/21
42	Sand Canoe	Wed 1/5/22	Fri 2/4/22	Wed 1/5/22	Fri 2/4/22
43	Seal Canoe	Mon 2/7/22	Tue 2/8/22	Mon 2/7/22	Tue 2/8/22
44	Swamp Test Canoe	Thu 2/10/22	Thu 2/10/22	Thu 2/10/22	Thu 2/10/22
45	Product Delivery	Fri 3/11/22	Fri 3/11/22	Fri 3/11/22	Fri 3/11/22



Project Schedule - Construction Phase

ID	Task Name	Actual Start	Actual Finish	Baseline Start	Baseline Finish
1	MSE Student Outreach Event	Fri 9/18/20	Fri 9/18/20	Fri 9/18/20	Fri 9/18/20
2	2020 Basic Training	Tue 10/13/20	Mon 11/16/20	Sun 9/13/20	Sat 10/31/20
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8	Canoe Name Brainstorming	Tue 10/27/20	Tue 11/17/20	Tue 10/13/20	Tue 10/20/20
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18	Mix Design Chosen	Wed 12/30/20	Wed 12/30/20	Mon 12/21/20	Mon 12/21/20
19	Make Life Cycle Analysis	Thu 12/31/20	Thu 1/14/21	Thu 12/31/20	Thu 1/14/21
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36	National Conferenc	Sat 6/26/21	Mon 6/28/21	Sat 6/26/21	Mon 6/28/21
37	Reciept of Mold	Wed 11/3/21	Wed 11/3/21	Wed 11/3/21	Wed 11/3/21
38	Casting Day	Sat 11/13/21	Sat 11/13/21	Sat 11/13/21	Sat 11/13/21
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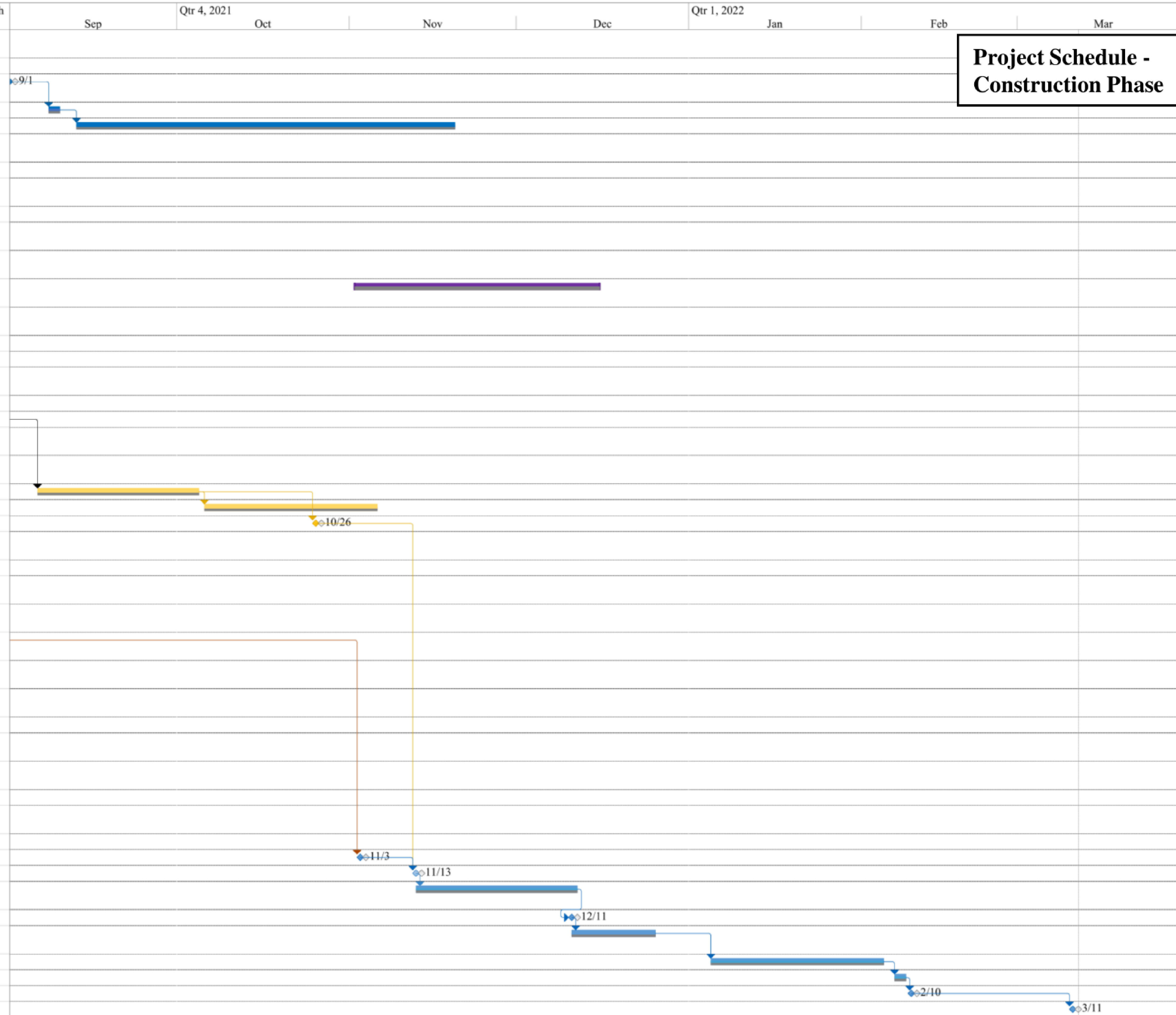

APPENDICES

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Appendix B – Mixture Proportions and Primary Mixture Calculation

Cementitious Materials

Component	Specific Gravity	Volume	Amount of CM	
Federal White Portland Cement Type I	3.15	0.50 ft^3	98.1 lb/yd^3	Total cm (includes c) 516.4 lb/yd^3
CTS Komponent ®	3.10	0.27 ft^3	51.6 lb/yd^3	
VCAS™-160 White Pozzolans	2.60	1.08 ft^3	175.6 lb/yd^3	c/cm ratio, by mass 0.19
Phoenix Fly Ash Class C Pozzolan	2.64	0.72 ft^3	118.8 lb/yd^3	
NewCem ® GGBFS Grade 120	3.08	0.38 ft^3	72.3 lb/yd^3	

Fibers

Component	Specific Gravity	Volume	Amount of Fibers	
NYCON-PVA RMS702 6mm	1.30	0.03 ft^3	2.13 lb/yd^3	Total Amount of Fibers 6.39 lb/yd^3
NYCON-PVA RECS15 8mm	1.30	0.03 ft^3	2.13 lb/yd^3	
NYCON-PVA RECS100 12mm	1.30	0.03 ft^3	2.13 lb/yd^3	

Aggregates

Aggregates	Abs (%)	SG_{OD}	SG_{SSD}	Base Quantity, W		Volume, $V_{agg,\,SSD}$
				W_{OD}	W_{SSD}	
"AX" Haydite	9.2%	1.43	1.56	356.5 lb/yd^3	389.3 lb/yd^3	4.00 ft^3
Norlite Fines	7.0%	1.55	1.66	256.7 lb/yd^3	274.7 lb/yd^3	2.65 ft^3
Buildex Expanded Shale	12.0%	1.20	1.34	78.4 lb/yd^3	87.8 lb/yd^3	1.05 ft^3
CityMix EPS	0%	0.05	0.05	23.9 lb/yd^3	23.9 lb/yd^3	7.66 ft^3

Liquid Admixtures

Admixture	lb/ US gal	Dosage (fl. oz / cwt)	% Solids	Amount of Water in Admixture	
Water Reducer ADVA® Cast 555	8.90	20.0	5.0%	6.82 lb/yd^3	Total Water from Liquid Admixtures, $\sum w_{admx}$ 16.82 lb/yd^3
Darex® II Air Entrainer	8.70	30.0	5.0%	10.00 lb/yd^3	

Solids (dyes, powdered admixtures)

Component	Specific Gravity	Volume (ft^3)	Amount (lb/yd^3)	
Solid Component of Liquid Dye, S_{ld}				Total Solids. S_{total} ____ lb/yd^3
Powdered Admixture, $S_{p\ admix}$				

Water

	Amount		Volume
Water, w, $[=\sum(w_{free} + w_{admx} + w_{batch})]$	w/c ratio, by mass 2.63	258.2 lb/yd^3	4.14 ft^3
Total Free Water from All Aggregates, $\sum w_{free}$		67.5 lb/yd^3	
Total Water from All Admixtures, $\sum w_{admx}$	w/cm ratio, by mass 0.5	16.8 lb/yd^3	
Batch Water, w_{batch}		173.9 lb/yd^3	

Densities, Air Content, Ratios, and Slump

Values for 1 cy of concrete	cm	Fibers	Aggregate (SSD)	Solids, S_{total}	Water, w	Total
Mass, M	516.4 lb	6.4 lb	775.7 lb	0 lb	258.2 lb	$\sum M$: 1556.7 lb
Absolute Volume, V	3.04 ft^3	0.09 ft^3	15.36 ft^3	0 ft^3	4.14 ft^3	$\sum V$: 22.63 ft^3
Theoretical Density, T, $(=\sum M / \sum V)$	68.8 lb/ft^3		Air Content, Air, $[= (T - D)/T \times 100\%]$			16.1%
Anticipated Density, D	57.7 lb/ft^3		Air Content, Air, $[= (27 - \sum V))/27 \times 100\%]$			16.2%
Total Aggregate Ratio $(=V_{agg,SSD} / 27)$	56.9%		Slump, Slump flow, Spread (as applicable)			0.25 in.
C330 + RCA Ratio $(=V_{C330+RCA} / V_{agg})$	50.1%					

Detailed Step by Step Calculation

Design parameters:

Cementitious Material	Mass (lb/yd^3)	SG
Portland Cement Type I	98.1	3.15
Komponent	51.6	3.10
VCAS 160	175.6	2.60
Fly Ash Class C	118.8	2.64
NewCem GGBFS Gr. 120	72.3	3.08

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

w/cm ratio	0.50

Admixture	Dosage	Solids (%)
HRWR (8.9 lb/gal)	20.0 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} (%)
CityMix EPS	0.05	0.05	23.9	23.9	23.9	0	0
Buildex Expanded Shale	1.20	1.34	78.4	87.8	94.1	12.0	20.4
"AX" Haydite	1.43	1.56	356.5	389.3	429.2	9.2	15.3
Norlite Fines	1.55	1.66	256.7	274.7	296.0	7.0	20.0

Cementitious Materials/Fibers:

$$\textbf{Absolute Volume} = \frac{mass\ (lb)}{SG*62.4\left(\frac{lb}{ft^3}\right)}$$

$$V_{portland} = \frac{98.1}{3.15*62.4} = \mathbf{0.50\ ft^3}$$

$$V_{komponent} = \frac{51.6}{3.10*62.4} = \mathbf{0.27\ ft^3}$$

$$V_{VCAS} = \frac{175.6}{2.60*62.4} = \mathbf{1.08\ ft^3}$$

$$V_{fly\ ash} = \frac{118.8}{2.64*62.4} = \mathbf{0.72\ ft^3}$$

$$V_{GGBFS} = \frac{72.3}{3.08*62.4} = \mathbf{0.38\ ft^3}$$

$$V_{fibers\ 6mm} = \frac{2.13}{1.30*62.4} = \mathbf{0.03\ ft^3}$$

$$V_{fibers\ 8mm} = \frac{2.13}{1.30*62.4} = \mathbf{0.03\ ft^3}$$

$$V_{fibers\ 12mm} = \frac{2.13}{1.30*62.4} = \mathbf{0.03\ ft^3}$$

Aggregates:

$$\textbf{Absorption} = \textbf{Abs} = \frac{W_{SSD}(lb) - W_{OD}\ (lb)}{W_{OD}\ (lb)} * 100\%$$

$$\text{"AX" Haydite} = \frac{389.3-356.5}{356.5} * 100\% = \mathbf{9.2\%}$$

$$\text{Norlite} = \frac{274.7-256.7}{256.7} * 100\% = \mathbf{7.0\%}$$

$$\text{Buildex} = \frac{87.8-78.4}{78.4} * 100\% = \mathbf{12.0\%}$$

$$\text{CityMix} = \frac{23.9-23.9}{23.9} * 100\%\ \% = \mathbf{0.0\%}$$

$$\textbf{Aggregate Absolute Volume}(ft^3) = \frac{W_{SSD}(lb)}{SG_{SSD}*62.4\left(\frac{lb}{ft^3}\right)}$$

$$V_{\text{"AX" Haydite}} = \frac{389.3}{1.56*62.4} = \mathbf{4.00\ ft^3}$$

$$V_{Norlite} = \frac{274.7}{1.66*62.4} = \mathbf{2.65\ ft^3}$$

$$V_{Buildex} = \frac{87.8}{1.34*62.4} = \mathbf{1.05\ ft^3}$$

$$V_{CityMix} = \frac{23.9}{0.05*62.4} = \mathbf{7.66\ ft^3}$$

Water: Moisture content of Haydite, Norlite, and Buildex takes into account the conditioning of the aggregate to the saturated, surface dry (SSD) condition. As CityMix EPS is stored at approximately its oven dried condition, it is assumed that the total moisture content is 0. In the equation below $(0)/W_{OD}$ x 100% = 0.

Water = w/cm * cm
w = 0.5 * 516.4 lb = **258.2 lb**
$$MC_{total} = \frac{W_{stk} - W_{OD}}{W_{OD}} * 100\%$$
$MC_{total,\ Haydite}$ = 20.4%
$MC_{total,\ Norlite}$ = 15.3%
$MC_{total,\ Buildex}$ = 20.0%
$MC_{total,\ CityMix}$ = 0.0%
MC_{free} = MC_{total} – Abs
$MC_{free,\ Haydite}$ = 20.4% - 9.2% = 11.2%
$MC_{free,\ Norlite}$ = 15.3% - 7.0% = 8.3%
$MC_{free,\ Buildex}$ = 20.0% - 12.0% = 8.0%
$MC_{free,\ CityMix}$ = 0.0% - 0.0% = 0.0%
$w_{free} = W_{OD}(lb) * \frac{MC_{free}}{100\%}$
$w_{free,\ AX\ Haydite} = 356.5 * \frac{11.2}{100\%}$ = **39.9 lb**
$w_{free,\ Norlite} = 256.7 * \frac{8.3}{100\%}$ = **21.3 lb**
$w_{free,\ Buildex} = 78.4 * \frac{8.0}{100\%}$ = **6.3 lb**
$w_{free,\ CityMix} = 23.9 * \frac{0}{100\%}$ = **0 lb**
Combined free water = $\sum(w_{free})$ = **67.5 lb**

Concrete Ratios:

$\textbf{Aggregate Ratio (\%)} = \frac{V_{aggregate}(ft^3)}{27} * 100\%$
Aggregate Ratio (%) = $\frac{15.36}{27}$ *100%= **56.9%** > 30% **Compliant!**
$V_{agg,SSD}$ = **15.36 ft³** $V_{C330+RCA}$ = **7.70 ft³**
C330 + RCA Ratio = $V_{C330+RCA} / V_{agg,SSD}$*100% = **50.1%** > 50% **Compliant!**

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*
$W_{HRWR} = 20.0 * \frac{516.31}{100} * \frac{100-5}{100} * \frac{1\ gal}{128\ fl\ oz} * 8.90 \frac{lb}{gal}$ = **6.82 lb**
$W_{AEA} = 30.0 * \frac{516.31}{100} * \frac{100-5}{100} * \frac{1\ gal}{128\ fl\ oz} * 8.70 \frac{lb}{gal}$ = **10.00 lb**
Total Water from admixtures = 6.82 + 11.50 = **16.82 lb**

$\mathbf{W_{batch} = w - (W_{free} + \Sigma W_{admx})}$
W_{batch} = 258.2 lb – (67.5 lb + 16.82 lb) = **173.9 lb**
$V_{water} = \frac{Mass_{water}\ (lb)}{62.4\left(\frac{lb}{ft^3}\right)}$
$V_{water} = \frac{258.2}{62.4}$ = **4.14 ft³**

Densities, Air Content, Slump, and Ratios:

Mass of Concrete = $\mathbf{Amount_{cm} + Amount_{fibers} + Amount_{SSD\ aggregate} + Amount_{water} + Amount_{solids}}$
M = 516.4 lb + 6.4 lb + 775.7 lb + 258.2 lb = **1556.7 lb**
Volume of Concrete = $\mathbf{Volume_{cm} + Volume_{fibers} + Volume_{aggregate} + Volume_{water} + Volume_{solids}}$
V = 3.04 ft³ + 0.09 ft³ + 15.36 ft³ + 4.14 ft³ = **22.63 ft³**
Theoretical Density T = M/V
T = 1556.7 lb / 22.63 ft³ = **68.8 lb/ft³**
Design Density D = M/27
D = 1556.7 lb / 27 ft³ = **57.7 lb/ft³**
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 = $\frac{68.8-57.7}{68.8} * 100\%$ = **16.1%**
Cement to Cementitious Materials Ratio, c/cm = 98.1 lb / 516.4 lb = **0.19**
Water to Cementitious ratio, w/cm = 258.2 lb / 516.4 lb = **0.50**
Water to Cement ratio, w/c = 258.2 lb / 98.1 lb = **2.63**
Slump (Measured) = **0.25 in.**

Appendix C - MTDS Table

Product Name, Type, ASTM Standard		**Link**
Arcosa Lightweight – “AX” Haydite		See attached test report
Aggregate	C330, C331	
Buildex – Expanded Shale		https://buildex.com/app/uploads/2020/01/Buildex-New-Market-Physical-Properties.pdf
Aggregate	C330, C331	
CityMix		https://citymix.com/wp-content/uploads/2014/01/CityMix-Product-Data-Sheet-Version-2-9-January-2014.pdf
Aggregate	C125	
DiGeronimo Aggregates – Haydite Shale		http://www.digeronimoaggregates.com/technical_info/
Aggregate	C330, C331, C332	
Norlite Corporation – Norlite		http://www.norliteagg.com/structuralconcrete/physical_properties.asp
Aggregate	C330, C331, C332	
Federal White Cement – Portland Cement Type I		http://www.federalwhitecement.com/astm_c150.htm
Cementitious Material	C150	
LAFARGE – NewCem GGBFS 120		https://semspub.epa.gov/work/10/500015620.pdf
Cementitious Material	C989	
CTS Cement – KOMPONENT		https://www.ctscement.com/assets/doc/datasheets/KOMPONENT_Datasheet_DS_062_EN.pdf
Cementitious Material	C845	
Vitro Minerals – VCAS 160 Pozzolans		http://www.vitrominerals.com/wp-content/uploads/2017/02/VCAS_White_Pozzolans_TDS_170209.pdf
Pozzolanic	C618, C1240	
Salt River Materials Group – Phoenix Fly Ash Class C		https://www.srmaterials.com/files/products/Phoenix%20Fly%20Ash%20Class%20C%20Tech%20Sheet%20FINAL.pdf
Pozzolanic	C618	
NYCON – PVA RECS15		https://cdn.shopify.com/s/files/1/0088/0764/5299/files/NyconPVARECS15Sheet042015.pdf?7980
PVA Fiber	C1116	
NYCON – PVA RECS100		https://cdn.shopify.com/s/files/1/0088/0764/5299/files/NyconPVARECS100Sheet042015.pdf?7980
PVA Fiber	C1116	
NYCON – PVA RMS702		https://cdn.shopify.com/s/files/1/0088/0764/5299/files/NyconPVARMS702Sheet042015.pdf?7980
PVA Fiber	C1116	
GRACE Construction Products – DAREX® II AEA		https://gcpat.com/sites/gcpat.com/files/pdf/current/resource/3906__darex_ii_aea_en.pdf
Air Entrainer	C260	
SpiderLath – Fiberglass Lath System		https://spiderlath.com/wp-content/uploads/2019/09/Test_Summary.pdf
Fiberglass Mesh	E2098	
WACKER – SILRES BS 6920		https://www.wacker.com/h/en-us/medias/SILRES-BS-6920-en-2019.11.05.pdf
Sealer	D412	
GRACE Construction Products – ADVA® Cast 555 Superplasticizer		https://gcpat.com/sites/gcpat.com/files/pdf/current/resource/956__adva_cast_555_en.pdf

Water Reducer	C494	
Harbor Foam Expanded Polystyrene (EPS)		https://drive.google.com/file/d/1XuNz1scqqEs4OUAsjvFcV5T8KXx10BMz/view?usp=sharing
Foam Caps	C578	

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TRINITY LIGHTWEIGHT PLANT #1683
C330 EVALUATION

STL File No. S018019
Report No.

February 2018

Samples of “C” (1/2-inch x #4), “AX” (4 x 0), “B” (3/8-inch x #8), and “BX” (3/8-inch x 0) Haydite were delivered from the Trinity lightweight Plant in Brooklyn, Indiana, for material analyses in accordance with Specifications ASTM C330 and C331. The test results are as follows:

AGGREGATE ANALYSIS

Sieve Size (ASTM C136)	% Passing (Passing Specification)			
	“AX” Haydite	“BX” Haydite	“B” Haydite	“C” Haydite
3/4”	---	---	---	100.0 (100)
1/2”	---	100.0 (100)	100.0 (100)	92.5 (90-100)
3/8”	100.0 (100)	99.9 (90-100)	96.5 (80-100)	64.2 (40-80)
#4	97.2 (85-100)	87.5 (65-90)	17.2 (5-40)	10.1 (0-20)
#8	63.9	65.0 (35-65)	4.0 (0-20)	3.7 (0-10)
#16	40.1 (40-80)	42.2	3.3 (0-10)	2.6
#30	24.7	25.0	3.0	1.9
#50	14.2 (10-35)	14.3 (10-25)	2.8	1.5
#100	7.2 (5-25)	8.5 (5-15)	2.4	1.1
#200	5.0	6.1 (0-10)	1.9 (0-10)	0.8 (0-10)

Fineness Modulus	3.53	3.58	5.71	6.22
Loose Unit Weight (dry), pcf (ASTM C29)	45.5 (70 max)	52.4(65 max)	38.3 (55 max)	38.9 (55 max)
Loose Unit Weight (damp), pcf (ASTM C29)	48.4	53.6	39.2	42.5
Rodded Weight (dry), pcf (ASTM C29)	50.4	57.6	42.2	43.0
Rodded Weight (damp), pcf (ASTM C29)	55.7	63.2	43.9	49.0
Organic Impurities (ASTM C40)	Lighter than standard (Standard)	Lighter than standard (Standard)	---	---
% Loss, Sodium Sulfate Soundness (5 cycles) (ASTM C88)	4.4	3.9	2.7	1.9
% Loss, Magnesium Sulfate Soundness (5 cycles) (ASTM C88)	6.6	6.2	3.2	2.6
% Loss on Ignition (dry basis) (ASTM C114)	0.16 (5 max)	0.13 (5 max)	0.00 (5 max)	0.01 (5 max)
% Clay Lumps/Friable pieces (ASTM C142)	0.79 (2 max)	1.56 (2 max)	0.08 (2 max)	0.16 (2 max)
Staining Index (ASTM C641)	20.00	20.00	0.00	0.00

% Absorption (after 72 hr. soak) (ASTM C127/C128)	9.2	7.0	12.2	9.7
Relative Density (specific gravity) (OD) (ASTM C127/C128)	1.43	1.65	1.17	1.17
Relative Density (specific gravity) (SSD) (ASTM C127/C128)	1.56	1.77	1.32	1.28
Apparent Relative Density (specific gravity) (ASTM C127/C128)	1.65	1.87	1.37	1.32
Density (oven dry) lb/ft^3	89.1	102.8	72.9	72.9
Density (SSD) lb/ft^3	97.2	110.3	82.2	79.7
Apparent Density lb/ft^3	102.8	116.5	85.4	82.2

STL File No. S018019
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Description	"C" Haydite and Concrete Sand	"A" and "C" Haydite	"B" Haydite and Concrete Sand
Concrete Mix Proportions (Mix Design)			
Cement Type I, Sack	6.00	6.00	6.00
Shalersville Sand, ft^3	14.00	---	14.00
"A" (4 x 0) Haydite, ft^3	---	18.00	---
"B" (3/8" x #8) Haydite, ft^3	---	---	17.50
"C" (1/2" x #4) Haydite, ft^3	17.50	15.00	---
BASF AE 200 Air, oz/cwt	0.10	0.10	0.10
Water, gal/bag	6.50	8.60	6.90
Slump, in	3.75	3.25	3.75
Air, %	6.00	5.75	6.00
Oven-Dry Weight (ASTM C567), pcf	101.90	78.70	102.60
Approximate Equilibrium Weight (ASTM C567), pcf	104.90	81.70	105.60
Measured Equilibrium Weight (ASTM C567), pcf	***	***	***
Specification (Maximum), pcf	110.00	100.00	110.00
Compressive Strength, psi			
7-Day Test	4,120	2,000	3,920
7-Day Test	4,110	1,890	4,010
7-Day Test	4,030	1,900	3,890
Average of 3 Tests	**4,090**	**1,930**	**3,940**
28-Day Test	5,000	2,890	5,080
28-Day Test	4,820	2,970	4,830
28-Day Test	4,900	2,950	4,890
Average of 3 Tests	**4,910**	**2,940**	**4,930**
Tensile Splitting Strength (ASTM C496), psi			
28-Day Test	448	345	477
28-Day Test	357	325	426
28-Day Test	475	367	448
28-Day Test	452	305	551
28-Day Test	355	286	441
28-Day Test	372	394	461
28-Day Test	363	344	528
28-Day Test	443	301	496
Average of 8 Tests	**408**	**333**	**479**
Popouts (ASTM C330)	**No Popouts**	**No Popouts**	**No Popouts**
Modulus of Elasticity (ASTM C469) **Average of 2 Cylinders**	**2,630,000**	**2,051,000**	**2,771,000**
Shrinkage (ASTM C330), % 35 Days (Specification: 0.07 % Maximum)	**0.026**	**0.021**	**0.026**

*** Results will be reported when complete

TECHNICIAN: DONALD HOLLENBAUGH

SOLAR TESTING LABORATORIES, INC.

____
Dennis L. Sanderson
Vice President/General Manager

Appendix D – Structural Calculations

Load Cases

<u>Two Paddlers with Cargo Load Case</u>

Assumptions

$$\sigma_{compression}^{yield} = 510\ psi \qquad \sigma_{tension}^{yield} = 140\ psi$$

$$\sigma^{ultimate} = \frac{\sigma^{yield}}{0.7} \qquad \sigma_{mesh\ tens}^{ultimate}\ per\ length = 233 lb/in$$ [26]

Moment Calculation

$$W_{max} = 21.6\ lb/ft \qquad B_{max} = 108.7\ lb/ft$$

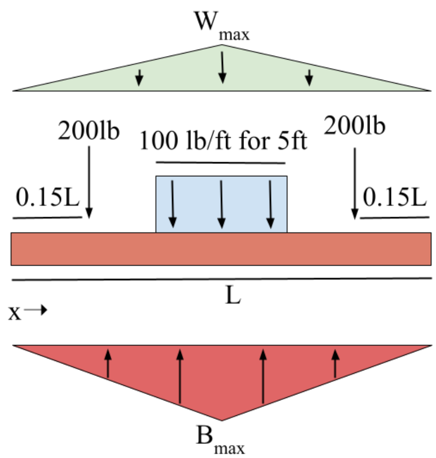

Figure D-1. Loading along the longitudinal axis

$$L = 20\ ft\ 8\ in.$$

$$V(0 < x < 3.1) = \frac{x^2}{2} * \frac{(21.6 - 108.7)}{10.33}$$

$$V(3.1 < x < 7.83) = \frac{x^2}{2} * \frac{(21.6 - 108.7)}{10.33} + 200$$

$$V(7.83 < x < 10.33) = \frac{x^2}{2} * \frac{(21.6 - 108.7)}{10.33} + 200 + 100(x - 7.83)$$

$$V(10.33 < x < 12.83) = -\frac{x^2}{2} * \frac{(21.6 - 108.7)}{10.33} - 200 + 100(7.83 - x)$$

$$V(12.83 < x < 17.57) = -\frac{x^2}{2} * \frac{(21.6 - 108.7)}{10.33} - 200$$

$$V(17.57 < x < 20.66) = -\frac{x^2}{2} * \frac{(21.6 - 108.7)}{10.33}$$

$$V_{max} = 159.2\ lb$$

$$shear\ stress = \frac{shear\ force}{area} = \frac{159.2}{41.44} = 3.8\ psi$$

$$\text{M}(10.33) = \frac{-x^2}{3} * \frac{(108.7 - 21.6)}{2} + 200(x - 3.1) + 50 * (x - 7.83)^2 = 210.5\ \text{lb*ft}$$

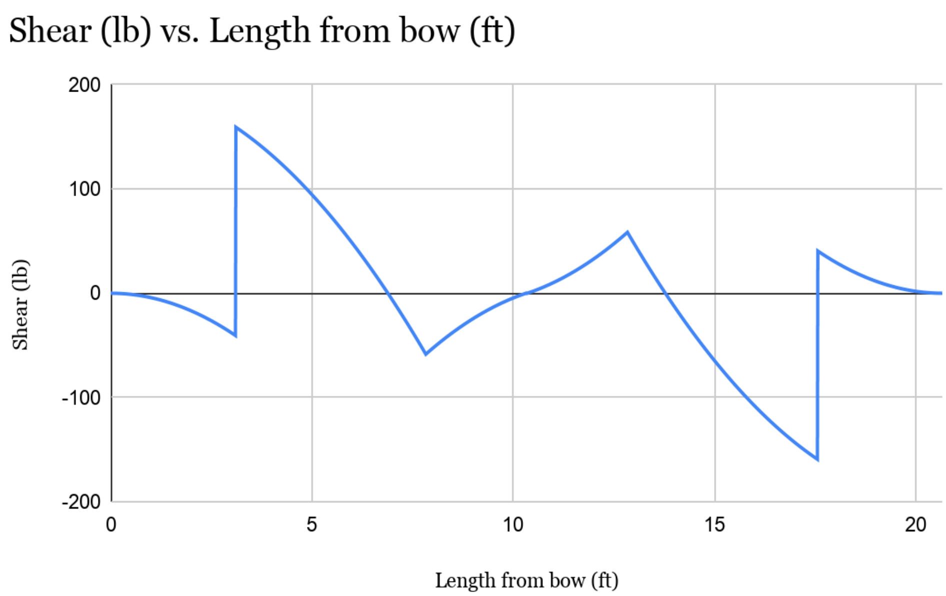

Figure D-2. Shear force diagram for the cargo load case

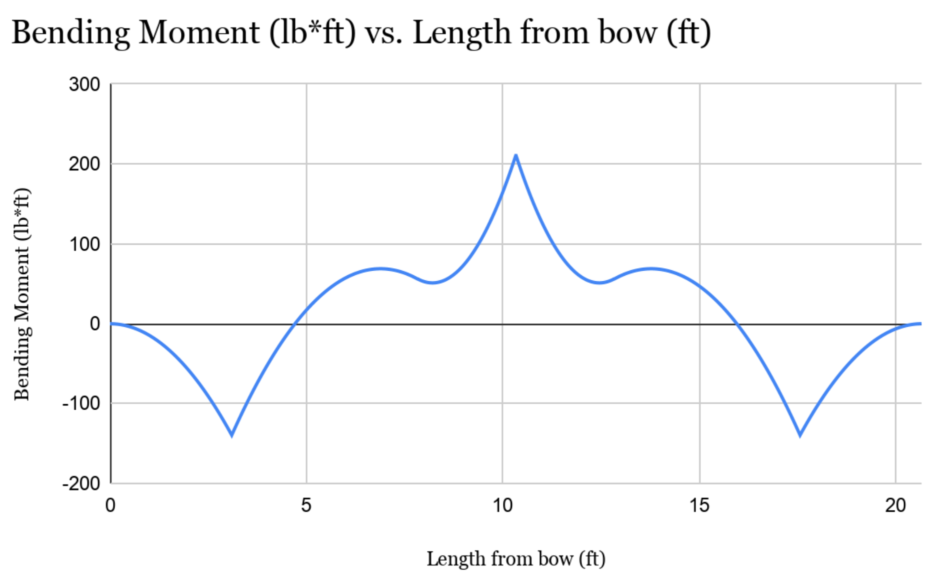

Figure D-3. Bending moment diagram for the cargo load case

<u>Four Person Co-Ed Load Case</u>

Assumptions

$$\sigma^{yield}_{compression} = 510\ psi \qquad \sigma^{yield}_{tension} = 140\ psi$$

$$\sigma^{ultimate} = \frac{\sigma^{yield}}{0.7} \qquad \sigma^{ultimate}_{mesh\ tens}\ per\ length = 233 lb/in$$ [26]

Moment Calculation

$$W_{max} = 21.6\ lb/ft \qquad B_{max} = 89.4\ lb/ft$$

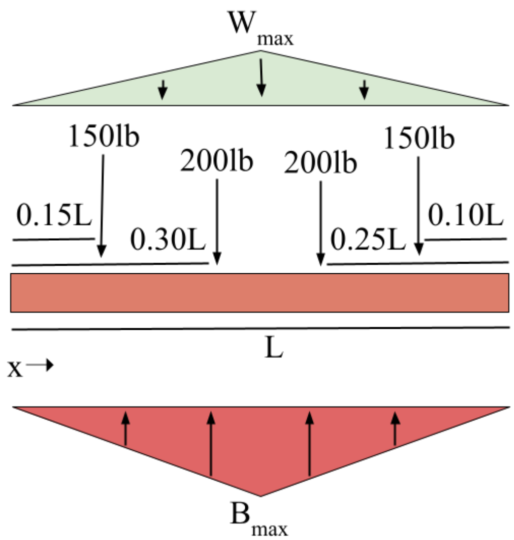

Figure D-4. Loading along the longitudinal axis

$$L = 20\ ft\ 8\ in$$

$$V(0 < x < 3.1) = \frac{x^2}{2} * \frac{(21.6 - 89.4)}{10.33}$$

$$V(3.1 < x < 6.21) = \frac{x^2}{2} * \frac{(21.6 - 89.4)}{10.33} + 150$$

$$V(6.21 < x < 10.33) = \frac{x^2}{2} * \frac{(21.6 - 89.4)}{10.33} + 150 + 200$$

$$V(10.33 < x < 15.5) = -\frac{x^2}{2} * \frac{(21.6 - 89.4)}{10.33} - 150 - 200$$

$$V(15.5 < x < 18.61) = -\frac{x^2}{2} * \frac{(21.6 - 89.4)}{10.33} - 150$$

$$V(18.61 < x < 20.66) = -\frac{x^2}{2} * \frac{(21.6 - 89.4)}{10.33}$$

$$V_{max} = 262.0\ lb$$

$$shear\ stress = \frac{shear\ force}{area} = \frac{262.0}{41.44} = 6.3\ psi$$

$$\text{M}(10.33) = \frac{-(20.66 - x)^2}{3} * \frac{(89.4 - 21.6)}{2} + 150(18.61 - x) + 200 * (15.5 - x) = 1068.6\ \text{lb*ft}$$

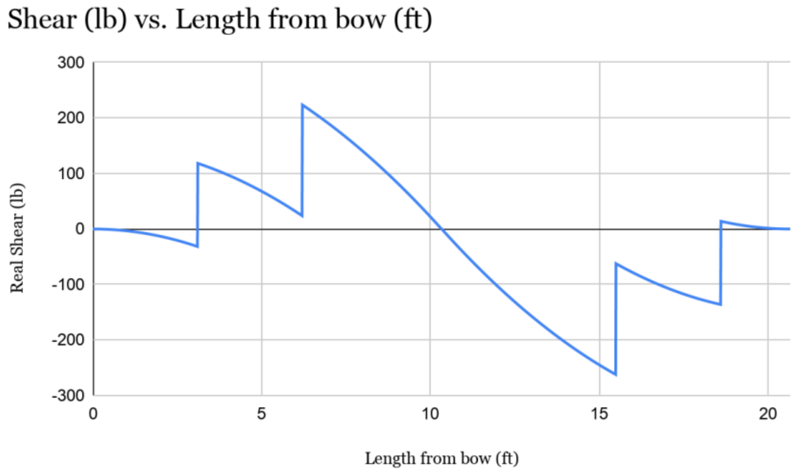

Figure D-5. Shear force diagram for the Co-Ed load case.

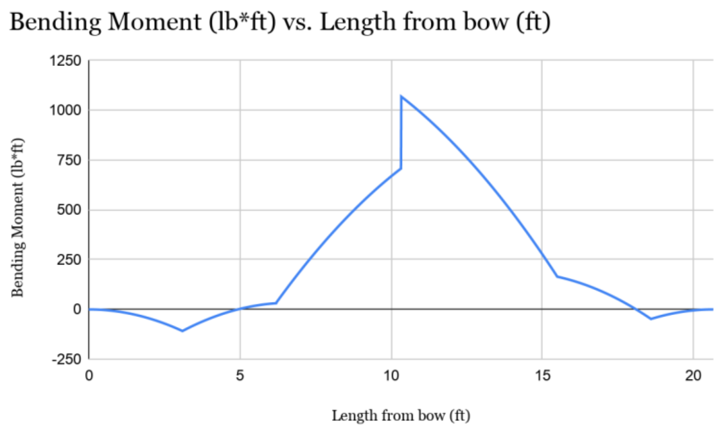

Figure D-6. Bending moment diagram for the Co-Ed load case.

Cross Section Bending

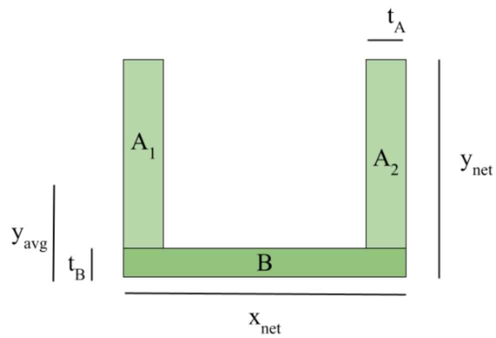

Figure D-7. Approximate hull cross section.

$$y_{net} = 12\ in \quad x_{net} = 28.85\ in \quad t_A = 0.88\ in \quad t_B = 0.75\ in \quad M_{Cargo\ Load} = -2526\ lb*in \text{ (above)}$$
$$M_{Co-ED\ Load} = -2001\ lb*in \text{ (above)}$$

$$y_{avg} = \frac{\sum y_i A_i}{\sum A_i} \qquad y_A = \frac{y_{net} - t_B}{2} + t_B = 6.38in \qquad y_B = \frac{t_B}{2} = 0.38in$$

$$A_A = (y_{net} - t_B)(t_A) = 9.90in^2 \qquad A_B = (x_{net})(t_B) = 21.64in^2$$

$$y_{avg} = \frac{(y_{A1})(A_{A1}) + (y_{A2})(A_{A2}) + (y_B)(A_B)}{A_{A1} + A_{A2} + A_B} = 3.24in$$

$$I_{rectangle} = \frac{bh^3}{12} \qquad I_{Ax} = \frac{(t_A)(y_{net} - t_B)^3}{12} = 104.41in^4 \qquad I_{Bx} = \frac{(x_{net})(t_B)^3}{12} = 1.01in^4$$

$$I = I_x + Ad^2 \qquad I_A = I_{Ax} + A_A(y_{avg} - y_A)^2 = 201.59in^4$$

$$I_B = I_{Bx} + A_B(y_{avg} - y_B)^2 = 178.86in^4$$

$$I_x = \sum I_{xi} = I_{A1} + I_{A2} + I_B = 582.05in^4$$

Cargo Load Internal Stresses

$$\sigma = \frac{-M_{load} * \Delta y}{I}$$

$$\sigma_{comp} = \frac{-M_{load} * (y_{net} - y_{avg})}{I_x} = 38.0\ psi\ compression\ at\ gunwales$$

$$\sigma_{tens} = \frac{-M_{load} * (y_{avg})}{I_x} = 14.1\ psi\ tension\ at\ bilge$$

$$\sigma_{shear} = \frac{Vshear}{cross\ sectional\ area} = \frac{0\ lb}{A_{A1} + A_{A2} + B} = 0\ psi$$

Co-ed Load Internal Stresses

$$\sigma_{comp} = \frac{-M_{Co-ED\ Load} * (y_{net} - y_{avg})}{I_x} = 30.1\ psi\ compression\ at\ gunwales$$

$$\sigma_{tens} = \frac{-M_{Co-ED\ Load} * (y_{avg})}{I_x} = 11.1\ psi\ tension\ at\ bilge$$

$$\sigma_{shear} = \frac{Vshear}{cross\ sectional\ area} = \frac{262\ lb}{A_{A1} + A_{A2} + B} = 6.3\ psi$$

Maximum Moment Before Cracking

$$\sigma_{comp}^{yield} = \frac{-M_{comp} * y}{I} \qquad \sigma_{tens}^{yield} = \frac{-M_{tens} * y}{I}$$

$$511\ psi = \frac{-M_{comp} * 8.76}{582.05} \qquad 140\ psi = \frac{-M_{tens} * 3.24}{582.05}$$

$$M_{comp} = -33953\ lb * in \qquad M_{tens} = -25150\ lb * in$$

$$M_{max} = min(M_{comp}, M_{tens}) = -25150\ lb * in$$

Maximum Moment Before Fracture

$$\sigma_{comp}^{ultimate} = \frac{\sigma_{comp}^{yield}}{0.7} = 730\ psi \qquad \sigma_{tens}^{ultimate} = \frac{\sigma_{tens}^{yield}}{0.7} = 200\ psi$$

$$\sigma_{mesh\ tens}^{ultimate} = \frac{233lb}{in} / t_B = 311 lb/in^2$$

$$\sigma_{tens\ with\ mesh}^{ultimate} = \sigma_{tens}^{ultimate} + \sigma_{mesh\ tens}^{ultimate} = 511\ psi$$

$$\sigma_{comp}^{ultimate} = \frac{-M_{comp} * y}{I} \qquad \sigma_{tens\ with\ mesh}^{ultimate} = \frac{-M_{tens} * y}{I}$$

$$730\ psi = \frac{-M_{comp} * 8.76}{582.05} \qquad 511\ psi = \frac{-M_{tens} * 3.24}{582.05}$$

$$M_{comp} = -48504\ lb * in \qquad M_{tens} = -91798\ lb * in$$

$$M_{max} = min(M_{comp}, M_{tens}) = -49000\ lb * in$$

Freeboard Calculation

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

Values for the draft were obtained using Naval Architecture Software (PolyCAD[6])

Table D-1. Estimated Drafts at Varying Displacements.

Displacement (lb)	Draft (in.)	Freeboard (in.)
223	3.29	8.80
248.9	3.50	8.59
316	4.00	8.09
386	4.50	7.59
456.9	5.00	7.09
531.6	5.50	6.59
650	6.29	5.80
683.2	6.50	5.59
761.1	7.00	5.09
839.2	7.50	4.59
919.9	8.00	4.09
1000.7	8.50	3.59
1080.9	9.00	3.09
1223	9.86	2.23

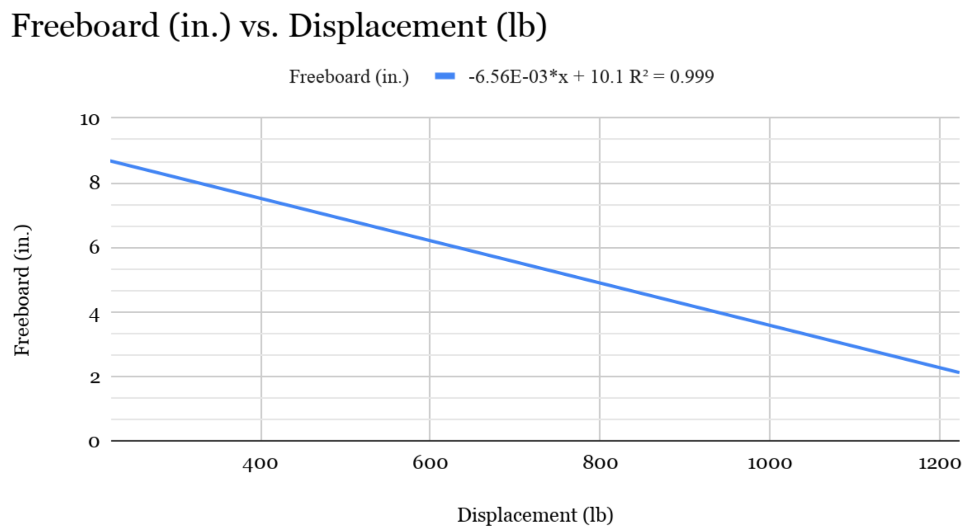

Figure D-8. Estimated Freeboard vs. Displacement.
$\text{Freeboard}(\Delta) = -6.56*10^{-3}*\Delta+10.1$ in.

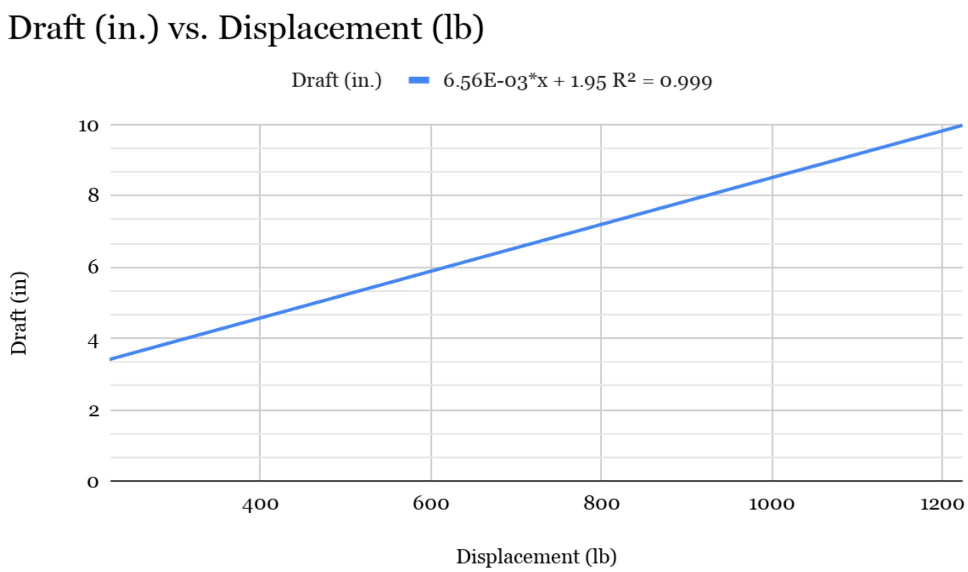

Figure D-9. Estimated Draft vs. Displacement.
$\text{Draft}(\Delta) = 6.56*10^{-3}*\Delta+1.95$ in.

Table D-2. Estimated Draft and Freeboard for Tandem Male, Tandem Female, and Co-Ed Load Cases.

Attribute	2 Male	2 Female	Co-Ed
Displacement (lb)	623	523	923
Draft (in.)	6.11	5.45	8.02
Freeboard (in.)	5.98	6.64	4.07

Appendix E – Hull Thickness/Reinforcement and Percent Open Area Calculations

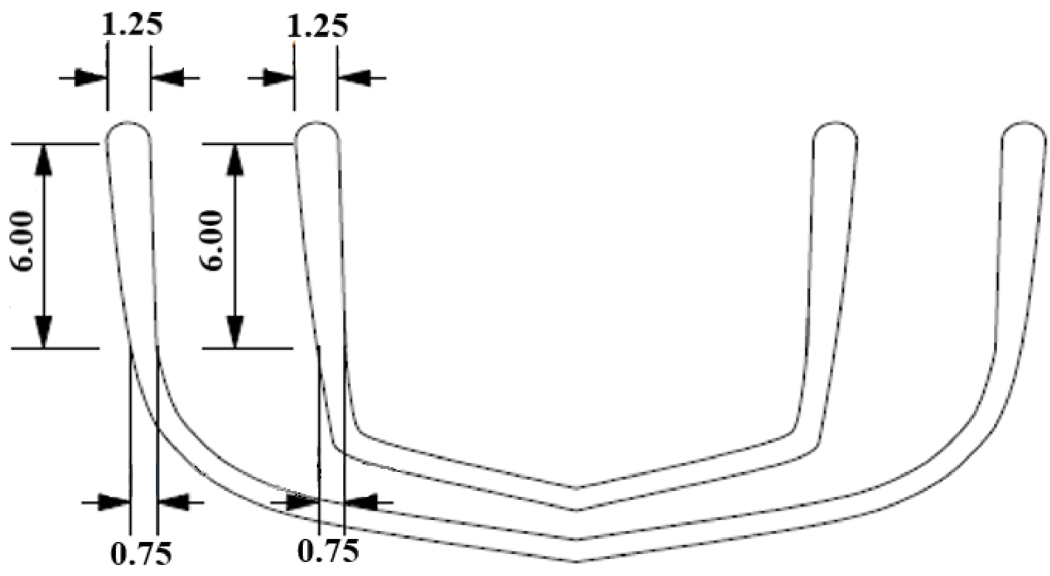

Figure E-1. Hull cross section thickness.

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 inches at the gunwales. These thicknesses are consistent along the entirety of the canoe. MCCT used a 1/16th 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 < 50% = Compliant

Percent Open Area:

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

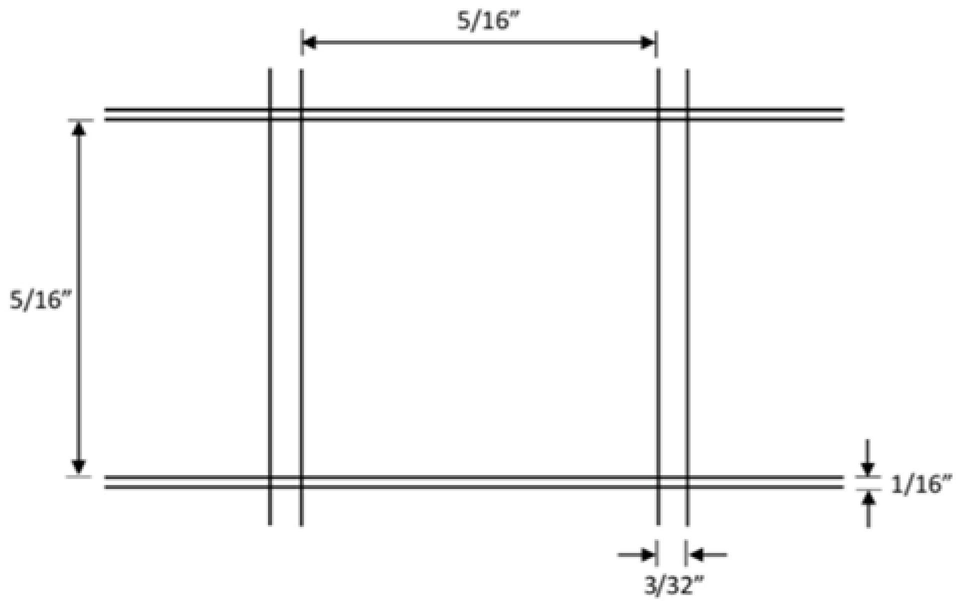

Figure E-2. Detailed view of the mesh reinforcement.

Number of apertures along sample width = 20
Number of apertures along sample length = 20

$$Open\ Area = 20 \times 20 \times \frac{5}{16} \times \frac{5}{16} = 39.06\ in.^2$$

$$Aperture\ Area\ \left(consider\ \frac{1}{2}\ of\ strand\ thickness\right)$$

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

$$L = \frac{5}{16}\ in. + \frac{1}{2}\left(2 \times \frac{1}{16}\ in.\right) = \frac{6}{16}\ in.$$

$$Width\ of\ Sample = 20 \times \frac{13}{32}\ in. = 8.13\ in.$$

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

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

$$Percent\ Open\ Area = \frac{39.06\ in.^2}{60.98\ in.^2} \times 100 = 49.3\% > 40\% = Compliant$$

Appendix F – Detailed Fee Estimate

Table 5. Labor costs.

Projected Total Manhours and Direct Labor Costs		
Position	**Raw Labor Rate (RLR)**	**Labor Hours (HRS)**
Project Management		
Design Manager	$45/hr	121
Laborer/Technician	$25/hr	604
Clerk/Office Admin	$15/hr	104
Hull Design		
Principal Design Engineer	$50/hr	86
Project Design Engineer	$35/hr	21
Technician/Drafter	$20/hr	31
Structural Analysis		
Principal Design Engineer	$50/hr	7
Project Design Engineer	$35/hr	17
Technician/Drafter	$20/hr	2
Mixture Design Development and Testing		
Principal Design Engineer	$50/hr	152
Project Design Engineer	$35/hr	112
Laborer/Technician	$25/hr	113
Mold Construction and Canoe Construction		
Project Construction Management	$40/hr	23
Laborer/Technician	$25/hr	54
Preparation of Technical Proposal		
Design Manager	$45/hr	54
Laborer/Technician	$25/hr	3
Preparation of Enhanced Focus Area		
Design Manager	$45/hr	27
Laborer/Technician	$25/hr	7
Preparation of Technical Presentation		
Design Manager	$45/hr	25
Laborer/Technician	$25/hr	18
TOTAL		
Direct Labor $DL = [\Sigma(RLR * HRS)] * (1.50 + 1.30) * (1.18)$		**$167,942.32**

Table 6. Canoe Material Costs.

Costs to Produce One Canoe				
Material	**Total Used**	**Unit Cost ($)**	**Source & Notes**	**Material Cost (MC) ($)**
Federal White Portland Cement Type I	14.0 lb	0.07	From Engineering News-Record	0.98
CTS Komponent ®	7.3 lb	0.07	Based on portland cement price	0.51
VCAS™-160 White Pozzolans	25.1 lb	0.46	From Blendhouse	11.55
Phoenix Fly Ash Class C Pozzolan	27.4 lb	0.02	From PennState College of Engineering	0.55
NewCem ® GGBFS Grade 120	11.3 lb	2.53	From eBay	28.59
NYCON-PVA RMS702 6mm	0.3 lb	7.60	From NYCON	2.28
NYCON-PVA RECS15 8mm	0.3 lb	7.60	From NYCON	2.28
NYCON-PVA RECS100 12mm	0.3 lb	7.60	From NYCON	2.28
"AX" Haydite	55.44 lb	0.006	From Engineering News-Record	0.33
Norlite Fines	39.96 lb	0.006	From Engineering News-Record	0.24
Buildex Expanded Shale	12.2 lb	0.006	From Engineering News-Record	0.07
CityMix EPS	3.72 lb	3.63	From Trinic LLC.	13.50
Water Reducer ADVA® Cast 555	1.1 lb	18.51	From concretematters.co.uk	20.36
Darex® II Air Entrainer	1.6 lb	25.09	From EMI SUPPLY INC	40.14
Fiberglass Mesh	80 ft^2	0.60	From SpiderLath	48
Water	38.1 lb	0.003	From City of Ann Arbor, Michigan	0.11
Foam Caps	15 ft^3	3.11*10	From UNIVERSAL FOAM PRODUCTS; multiplied by 10 to account for machining costs	466.5
SILRES BS 6920	16 lb	2.71	From eBay	43.36
Vinyl Lettering	56 letters	1.2	From Vinyl Wall Expressions	67.2
TOTAL				
Expenses $\boldsymbol{E = (\Sigma MC + \Sigma DE) * (1.10)}$			**$823.71**	

Table 7. Mold and shipping costs.

Mold Construction Lump Sum Fee	**$3,110.00**
Shipping Cost Roundtrip to Platteville, WI from Ann Arbor, MI	**$1,253.00**

Appendix G – Supporting Documentation

Pre-Qualification Form (Page 1 of 3)

_________________University of Michigan__________________________________

(school name)

We acknowledge that we have read the 2021 ASCE 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 Conference and Society-wide Final Competitions as outlined in Section 2.0 and Exhibit 3.	__JC_WH_
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 (Exhibit 3)	__JC__WH_
The eligibility requirements of registered participants (Section 2.0 and Exhibit 3)	__JC__WH_
The deadline for the submission of *Letter of Intent* and *Pre-Qualification Form* (uploaded to ASCE server) is October 22, 2020.	__JC__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, 2021.	__JC__WH_
The last day to submit *Request for Information* (RFI) to the C4 is January 22, 2021.	__JC__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.	__JC__WH_
The submission date of *Technical Proposal* and *Enhanced Focus Area Report* for Conference Competition (uploading of digital copies to ASCE server) is Friday, February 19, 2021.	__JC__WH_
The submission date of *R. John Craig Presentation* for Conference Competition (uploading of presentation to ASCE server) is Friday, February 19, 2021.	__JC__WH_
The submission date of *three (3) Peer Reviews* to the respective teams' folders (uploading of digital copies to ASCE server) is Friday, March 12, 2021.	__JC__WH_
The submission date of *Technical Proposal* and *Enhanced Focus Area Report* for Society-wide Final Competition (uploading of digital copies to ASCE server and mailed hard copies to ASCE Headquarters) is Thursday, May 20, 2021.	__JC__WH_

Jacob Cieply	10/14/20	Will Hansen	10/14/20
Team Captain	*(date)*	*ASCE Student Chapter Faculty Advisor*	*(date)*
[signature]		Will Hansen	
(signature)		*(signature)*	

Pre-Qualification Form (Page 2 of 3)

__________________________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 2020-21 classroom instruction (in-person, remote, hybrid)? What is anticipated after Thanksgiving 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 hybrid format; many are fully online, some are only in-person, and some are hybrid. The university is expected to continue in this format until at least May 2021. The team has limited access to laboratory spaces and facilities. The team has some access to sites to mix and test concrete, but there are severe restrictions on the number of attendees and accessible hours that make it impractical to conduct most of our business in-person.

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, 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 team meets with fewer people at a time, practices social distancing, and wears masks and other PPE as appropriate. Some activities, such as casting the canoe and paddling indoors, are rendered impractical by COVID-19.

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 quality assurance program consists of the quality control officer. This person is responsible for monitoring whether the rest of the team is following ASCE's official request for proposals. Each team lead is also responsible for reading their own portion of the rules. If the leads are ever confused by the guidelines, the quality control officer is the person to confirm this. This system works well because each subteam knows individually what they have to follow, while also having a leader who will be there if they have any problems. The next quality control officer is then voted in at the end of the school year through an election. The previous quality control officer leaves them with guidelines for how to operate for the coming year.

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). Note: teams may re-use past themes.*

We anticipate the theme to be "Michigan Salad" and our canoe name to be "Rowmaine". We intend to connect our theme to our university's approach to sustainability as well as Michigan agriculture.

Pre-Qualification Form (Page 3 of 3)

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

Yes. No trademark or copyright issues are anticipated.

The core project team is made up of __36__ number of people.

RFP Addendum No.1
Correction to Submission Date

4.2.1 Letter of Intent & Pre-Qualification Forms

Teams shall submit a *Letter of Intent* along with their *Pre-Qualification Forms* which acknowledges receipt of the Request for Proposal solicitation and shall provide a synopsis of their understating of the project. The letter must be signed by at least one (1) team captain and ASCE Student Chapter Faculty Advisor. The phone number and email address for both the team captain and faculty advisor shall be provided.

The Pre-Qualification Forms (see ***Exhibit 4***) are required to be completed and signed off by each team including initialing off on each line item and providing signatures from the team's team captain and the ASCE Student Chapter Faculty Advisor. Adobe PDF versions of the *Letter of Intent* and *Pre-Qualification Forms* are to be uploaded to the team's respective folder **no later than 5:00 pm [Eastern] Friday, October 16, 2020.** ***Late submissions and documents missing any of the required signatures, initials, and email addresses will be considered non-responsive and subject to deduction.***

Correction

Pursuant to RFI No. 6, Subject: Conflicting Submission Dates, issued 9/16/20

Adobe PDF versions of the *Letter of Intent* and *Pre-Qualification Forms* are to be uploaded to the team's respective folder **no later than 5:00 pm [Eastern] Thursday, October 22, 2020.**

*We acknowledge that we are in receipt of **Addendum No. 1 – Change to Submission Date** to the 2021 ASCE Concrete Canoe Competition Request for Proposal. We also acknowledge that this form shall be submitted under Appendix G – Supporting Documentation (Section 6.4.9.7 of the RFP).*

Jacob Cieply ____________________ 02/15/2021

Team Captain (print name) *(date)*

[signature]

(signature)

Will Hansen ____________________ 02/15/2021

ASCE Student Chapter Faculty Advisor (print name) *(date)*

Will Hansen

(signature)