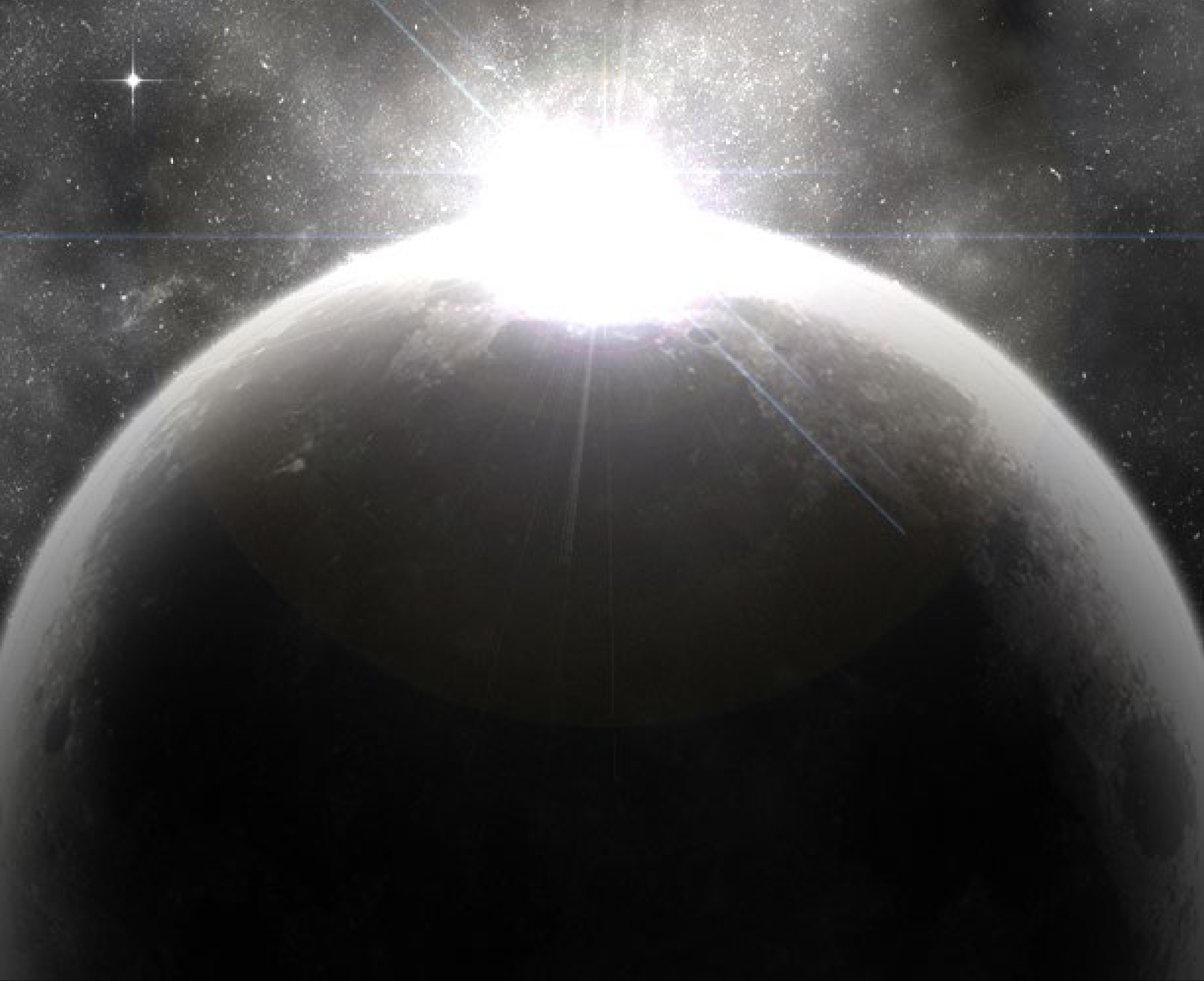
MICHIGAN TECHNOLOGICAL UNIVERSITY TECHNICAL PROPOSAL 2021

VOYAGER



Compliance Certificate

Michigan Technological University's 2020-2021 Concrete Canoe team hereby certifies that the design of *Voyage*r has been completed in compliance with the rules and regulations of the National Concrete canoe Competition. The eight registered participants are qualified, eligible student members, and national student members of ASCE. *Voyager* was completely designed within the current academic year of the competition. The team has read all of the Material Technical Data Sheets (MTDS) and Safety Data Sheets (SDS), and has planned to construct *Voyager* in methods conducive to a high degree of safety. The team acknowledges receipt of the Request for Information (RFI) Summary, and *Voyager* complies with responses thereof.

Registered Members of the 2020-2021 Michigan Tech Concrete Canoe Team

Lauren Bowling	11851359	Corbin Sullivan	12223833
Lauren Cole	11855298	Henry Summers	12224183
Kait Pascoe	11911054	Joey Switala	11865767
Steph Klaysmat	11927679	Jason Cinader	11866587

Voyager Dimensions

Total Length	20 Feet
Maximum Width	27.7 Inches
Maximum Depth	15.5 Inches
Average Thickness	3/8th Inch
Overall Weight	218 lbs

Properties of the Concrete Mixture and the Composite Material

Mixture	Unit Weight (pcf)		Strength (psi)				Air Content (%)
			Compressive		Tensile		
	Wet	Oven-Dry	14-Day	28-Day	14-Day	28-Day	
Structural	70.05	66.8	1480	1630	350	410	-10.1
Pigmented Finishing	66.05	65.5	510	580	220	250	4.7
Composite Flexural Strength: 1080 psi							

We certify that the aforementioned information is valid.

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Executive Summary

Michigan Technological University has been rooted in research and development since it was founded in 1885. A few of the most notable projects to date include 3-D printing prosthetic hands from recycled plastic for children in Nicaragua, implementing water treatment systems into villages in Ghana, and developing a COVID-19 test processing lab for the Michigan Tech students and community. In addition, Michigan Tech students successfully launched a microsatellite into space, funded by NASA, that serves as an imaging calibration target for ground-based observatories in 2019. Another satellite is planned for orbit in 2021 to study atmospheric clouds and gather hyper-local weather data; therefore, this year, the Michigan Tech Concrete Canoe Team was inspired by the innovative work done by our colleagues. The team drew on the tenacity that is required for space exploration, and applied it to the everchanging scholarly environment to have a successful 2020-2021 concrete canoe season.

Table 1. Properties of Voyager

Voyager (2021)	
Weight	218 Pounds
Colors	Black and Purple
Maximum Length	20 feet
Maximum Width	27.7 inches
Maximum Depth	15.5 inches
Average Thickness	3/8th inch
Primary Reinforcement	GlasGrid® 8511 SpiderLath 3/16-inch Steel Cable
Secondary Reinforcement	PVA-RFS400 Enduro Prime

Due to the COVID-19 pandemic, the team was allowed minimal use of campus facilities, changing the way that research and development was conducted, and the major goals set forth for the year. The team's ability to complete research largely transitioned to finding software to refine the data that the team already had from previous years. The major goals became enhancing statistical methods to confirm experimentally collected data, developing a hull with a higher travel velocity, decreasing the weight of the mix, and focusing on skill and knowledge transfer.

The team's adaptivity resulted from adjusting how it functioned while remote, from completing research and design with minimal lab access, to teaching along the way. The team dug deep and related this season to the un-predictableness that space brings, but continued to roll with the punches to produce a design that was favorable for conditions it will encounter.

Table 2. Properties of the 2020-2021 Concrete Mixture

Mixture	**Unit Weight (pcf)**		**Strength (psi)**				**Air Content (%)**
	Wet	Oven-Dry	Compressive		Tensile		
			14-Day	28-Day	14-Day	28-Day	
Structural	70.05	66.8	1480	1630	350	410	-10.1
Pigmented Finishing	66.05	65.5	510	580	220	250	4.7
Composite Flexural Strength: 1080 psi							

Introduction to the Project Team

ASCE Student Chapter Profile

Michigan Technological University is a public university nestled in the Keweenaw Peninsula of Michigan's Upper Peninsula. It boasts world class STEM majors and research programs, and is home for about 7,000 students. Michigan Tech's student ASCE chapter has 55 current members with 30 being registered national members; the student engagement with ASCE continues to grow each year. Monthly meetings are held in which faculty members, industry partners, and members of the UP ASCE chapter speak on a variety of topics. The chapter works alongside the graduate SEI chapter and jointly holds events during the school year.

Every year the chapter looks forward to community service projects that it participates in. The chapter regularly volunteers for the Adopt a Highway program; participates in stocking food pantries and raking leaves; shoveling snow for community members; and participates in the University's yearly Make a Difference Day. Make a Difference Day gives student organizations an opportunity to help the local community in a multitude of ways, this year, the student chapter's project was a beach and park clean up (Figure 1).

Michigan Tech's Concrete Canoe Team is composed of 15 members from a variety of majors, allowing the team to develop numerous solutions to any given problem. The team is led by a senior project manager and a junior project manager, which are supported by committee heads that specialize in mix design, hull design, reinforcement development, and other crucial aspects of the competition. These committees are composed of general members who are encouraged to learn new skills, with the goal of becoming committee heads themselves, to continue the program's success.

The Michigan Tech Concrete Canoe Team has competed in the North Central Student Conference since 1992 and most recently placed 10th in the 2019 national competition at Florida Institute of Technology.

Figure 1. ASCE members participating in Make a Difference Day.

Organizational Chart

Project Managers

Project Managers are responsible for keeping the team organized, on-track, and working toward their goals.

Lauren Bowling, Sr.

Lauren Cole, Sr.

Research & Development: Lauren Bowling, Sr.

Assisted By: Jason Cinader, Jr., Connor Dykehouse, Jr., Jacob Byron, Jr.

Responsible for the development and testing of mix designs, as well as reinforcement schemes and canoe aesthetics.

Academics: Kait Pascoe, So.

Assisted By: Lauren Bowling, Sr., Lauren Cole, Sr., Joey Switala, Sr., Henry Summers, So.

Presenters: Lauren Cole, Sr., Corbin Sullivan, Fr.

Responsible for structural analysis, hull design, design paper, presentation, and compliance.

Construction: Joey Switala, Sr.

Assisted By: Owen Green, Fr., Corbin Sullivan, Fr., Isodon Williams, Fr.

Responsible for casting day and all preparations, as well as stands, cross-section, and display construction.

Paddling: Lauren Cole, Sr. & Henry Summers, So.

Paddlers: Lauren Bowling Sr., Steph Klaysmat, Sr., Kait Pascoe, So., Colin Vander Beek, So, Sydney LaForest, Fr., Isodon Williams, Fr., Corbin Sullivan, Fr.,

Responsible for teaching, training, and preparing paddlers for competitions.

Technical Approach to the Overall Project

Hull Design

This year, the hull design committee's primary goal was to improve the travel velocity of the 2019-2020 hull. The 2019-2020 project, *Dozer*, was designed to improve stability while maintaining the speed and straight-line tracking of its predecessor, *Driftwood.* Due to the outbreak of COVID-19 in the spring of 2020, the hull design of *Dozer* was never properly tested by the paddling team, and therefore, the changes made to improve stability were never validated. This resulted in limited modifications to *Voyager's* hull this year and shifted the primary focus to improving the top speed of the canoe; improving top speed was the easiest way for new members to learn the hull design software, which was beneficial for fluid knowledge transfer throughout the team. Due to *Dozer*'s theoretical improved stability, the team's paddlers were comfortable in sacrificing some of this gained stability to allow for an increased top speed in *Voyager*'s theoretical design. The team's schedule allots time each year such that the paddlers can effectively test the proposed hull design in a wooden prototype; therefore, if the adjustments made prove to promote significant instability, the team can comfortably make modifications to *Voyager*'s hull.

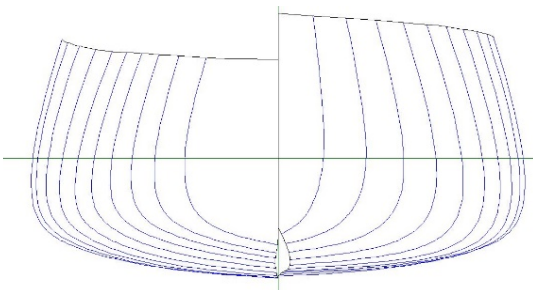


Figure 2. Diagram of Voyager's cross-section.

The major change made to *Voyager's* design was the shape of its hull. While *Dozer* utilized a shallow V-shaped cross section, *Voyager* was designed with a flat bottom cross section, which greatly improved the top speed of the canoe by sacrificing some stability (Figure 2). *Voyager* has an optimum speed of 6.035 knots, a substantial improvement over *Dozer,* which had an optimum speed of approximately 5.476 knots (Table 3). The heel angle at which the canoe would capsize is approximately 45 degrees, a decrease of 8 degrees from last year's design (Table 3). The team's paddlers are confident that the decreased stability would not be a problem in races, as this only significantly affects the turns of the race, and the paddlers are well experienced in turning due to practicing in a pool for the majority of the year.

Table 3. Hull Design Comparison between Dozer and Voyager

	Dozer	Voyager
Overall Length (ft)	20.000	20.000
Freeboard (in)	0.785	0.785
Block Coefficient	0.403	0.542
Prismatic Coefficient	0.590	0.628
Load Waterline (ft)	19.981	19.981
Optimum Speed (Knots)	5.476	6.035
Heel Angle Tipping Point (degrees)	53.000	45.000

Voyager is an excellent model for the standardized hull design for future concrete canoe competitions, as its slender hull and high-top speed allow the canoe to be extremely competitive, specifically in the long, straight sections of each race.

Structural Analysis

The goal of the structural analysis process was to provide the material development committees with an approximate value of the maximum stress that the canoe will experience. Structural analysis began with the derivation of cross-sectional X- and Y-coordinates from the final hull design.

The three load cases analyzed were the men's race, women's race, and co-ed race. In all loading cases, the weight of the canoe was theoretically determined through utilizing the density of the structural mix and the area of each cross section. The three racing scenarios were modeled using both sitting and kneeling paddlers, where the paddler's load distribution was calculated differently for each position. A conservative 150 pounds was assumed for a female paddler's weight and 200 pounds for the men; these assumptions were applied and all of the possible variations of kneeling and sitting paddlers were modeled. Buoyancy forces were modeled for all race cases and loading combinations and were determined through the amount of water the boat displaced. *Voyager* was found to experience the maximum stresses during a men's race, when both paddlers were kneeling. The calculated maximum compressive stress that the boat will experience is approximately 572 psi along its chines.

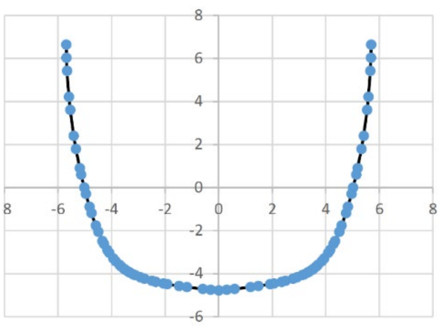


Figure 3. Example X- and Y-coordinates of a cross section.

Next, the structural analysis committee examined stresses attributed to punching shear from the paddlers. The load cases considered that a contact point resulted from both the kneeling and sitting positions. The maximum load case was determined to be a male paddler in a kneeling position with 63% of the paddler's 200-pound dynamic load being transferred through a single knee. Using a nominal thickness of 3/8th inch and a contact area of six by three inches, the maximum punching shear stress was calculated to be 33.3 psi.

As a result of this analysis, the structural analysis committee accomplished their goal of determining the maximum stress that the canoe would experience during racing, and the values were given to the research and development committee for their material testing and composite development.

Development and Testing

This year, the structural mix committee took a different approach to designing a mix that is both lightweight and structurally sound, compared to previous years, due to the current competition rules and the University's protocols regarding COVID-19. Minimal use of the lab was allowed throughout the fall semester, with restrictions placed on both the number of individuals allowed in the lab and times allowed in the lab; the ability to use the lab completely ceased later in the semester. Due to state government requirements to adopt remote learning, the team decided that it was best to proceed in developing a structural mix in a way that did not rely on physical testing of specimens and instead focused on statistical optimization modeling of the mix design.

The team's structural mix, *Moon Dust*, is an adaptation of Michigan Tech's 2019-2020 mix, *Backfill*. *Moon Dust* focused on specifically altering the aggregate type and quantity to meet 2021 competition requirements, as a majority of previously used aggregates in *Backfill* were classified as microspheres. To aid our mixing efforts of becoming more sustainable, the team implemented a statistical analysis software, Minitab, where it was utilized to statistically optimize the unit weight (pcf) of *Moon Dust* near that of water (62.4 pcf). *Moon Dust* is composed of crushed concrete, Elemix, and Haydite; all other components of the mix, such as the cement-to-water ratio, cementitious materials, and binders, remained of the same quantities as used in *Backfill*. Based on previous years' mix results, mixes containing higher percentages of Elemix were of lighter weight but lacked structural integrity. Mixes that contained lower amounts of Elemix and higher relative amounts of both crushed concrete and Haydite, were stronger but heavier. In order for Minitab to generate a design of experiments (DOE), that resulted in specific mixes to test, percent by volume limits and ranges were set for each aggregate, such that they complied with ASTM C330 standards and the competition's new aggregate restrictions (Table 4).

Table 4. Mixture DOE Design for Aggregates

Factors (X's)	Levels	Design: Mixture Single Total: 100	Responses (Y's)
Elemix (%)	10-40	Replicates: 1	Unit Weight (pcf)
Haydite (%)	20-50	Center Point: Yes	
Crushed Concrete (%)	20-65	# Runs: 13	

Through using data and knowledge from previous years, the Minitab runs were completed. With the goal of designing a lightweight structural mix, Minitab was used to predict a mix that had a target pcf of 63.0. This unit weight was chosen due to it being a relatively lighter mix compared to Michigan Tech's in the past, but one that is not unreasonable and close to the density of water. Minitab resulted with a mix that had a unit weight of 56.18 pcf and was comprised of 10% (by volume) Elemix, 37.50% Haydite, and 52.50% crushed concrete (Figure 4). It is important to note that although 63.0 pcf was targeted, the resultant mix had a predicted unit weight less than that; this is because Minitab analyzes trends in the provided data.

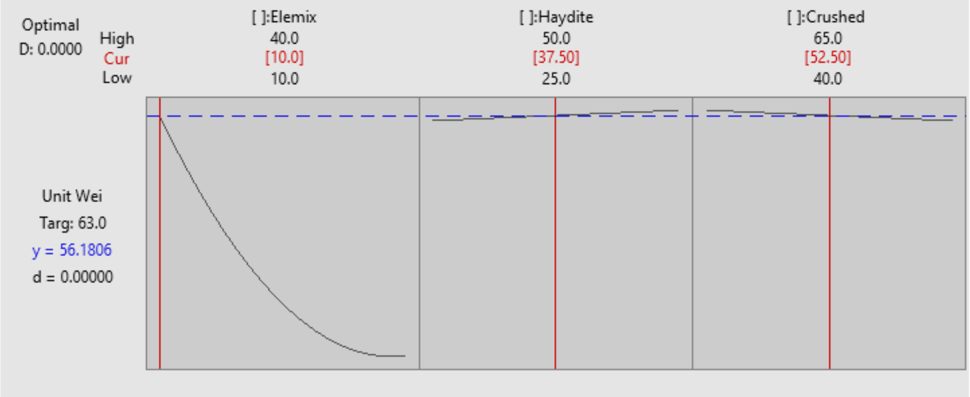


Figure 4. Resultant Minitab aggregate compositions for a mix with a target unit weight of 63.0 pcf.

The optimization of *Moon Dust* was seen as an experiment this year, as it faced little consequences in terms of materials and sustainability due to the modeling work that was completed. The decision to make this year's development more experimental for the team, was due to the absence of the requirement of a physical boat at this year's competition. In doing so, the team provided a new standard for which future concrete canoe teams at Michigan Tech can design a structural mix. The use of Minitab allowed the team to achieve a specific desired mix result, as well as reduce the number of mixes required to finalize the design. Utilizing Minitab also enabled the team to fix small issues within the development process experienced throughout previous years due to the team's traditional mix design program. In the past, mix mass-values were larger than expected for the given volume. After careful examination and guidance from staff at Michigan Tech, the mix committee decided to use bulk specific gravities in accordance with ASTM C29, rather than general specific gravities, to account for voids between individual particles (Table 5). With bulk specific gravities being lower in value compared to specific gravities, the mass calculated for the given volume decreased, equating to a more accurate representation of mass-to-volume ratio. Solving this issue cleared a path for the future Michigan Tech mixture committees, as the mix table is now more accurate.

Table 5. Properties of the Aggregates in the Final Concrete Mixture

Aggregate	Bulk Specific Gravity	Absorption (%)	Particle Size	% Retained in #200 Sieve
Haydite (Shale)	1.22	20	≤ 2.38 mm	100%
Elemix	0.042	5.5	≤ 2.38 mm	100%
Crushed Concrete	1.10		≤ 2.38 mm	100%

COVID-19 not only changed the scope of this year's concrete canoe competition, but also the outlook and goals of the mix committee. Instead of mixing weekly, which was the team's previous approach, the focus shifted to learning about how to design the optimum mix and fix small details within the development process that the team overlooked for years; this enabled this year's team to design a better mix. Much of the work completed by the mix committee this year was done to ensure knowledge transfer to future and current members. In years past, transferring knowledge involved new members creating mixes alongside the current members, and analyzing the results. While the analysis portion held true this year, the lack of batches physically produced as a result of the occupancy limits set forth in the lab, changed the knowledge transfer done. Therefore, during the spring semester, which is typically dedicated toward finishing mix development, it is important that the mix committee properly transfers the knowledge not done so in the fall.

Reinforcement

This year, the team decided not to expand on the testing and development of a new reinforcement scheme for multiple reasons. Focusing the limited access to the lab, in terms of time and space, on mixture development was decided to be more pertinent to the team, because they were confident in *Driftwood's* reinforcement scheme, which was also used in *Dozer*. Instead, the team used Minitab, to verify that this reinforcement scheme provided optimal strength, given the materials considered and tested for *Driftwood.* If Minitab gave similar results to those of the chosen scheme, the reinforcement selections and inclusion of Minitab would be verified.

The reinforcement design consisted of two different reinforcing meshes, GlasGrid® 8511 and SpiderLath. Three materials were considered for *Driftwood*, GlasGrid® 8511 (GG), SpiderLath (SL), and FG-050 (FG). Data was gathered from three-point bend tests in accordance to ASTM C1341 and testing was done in three steps. The first step was testing each reinforcement in its continuous state to obtain comparable strengths of each material; in this, beams were constructed with two layers of reinforcement, ensuring that all meshes were tested both on their own and in combination with the other two. The results from this general break were processed through Minitab as a mixture DOE, with a single total of two and the reinforcement levels varying from zero to two; a level of zero, one, or two corresponded to the number of layers of that reinforcement within the beam. The resulting contour plot (Figure 6) demonstrated that the greatest beam strength resulted from two SpiderLath layers. The contour plot indicated that the schemes with greatest strength, in decreasing order were, SL/SL, SL/GG, GG/GG, FG/GG, and SL/FG; this was the same conclusion that *Driftwood's* reinforcement committee came to as well. However, the *Driftwood* reinforcement committee chose to move forward with investigating the SL/SL, SL/GG, and FG/GG schemes. This was because in Michigan Tech's 2018 boat, *Backcountry*, the GG/GG scheme was used and was found to have both unfavorable weight contributions and workability; therefore, the GG/GG scheme was not considered for *Driftwood*.

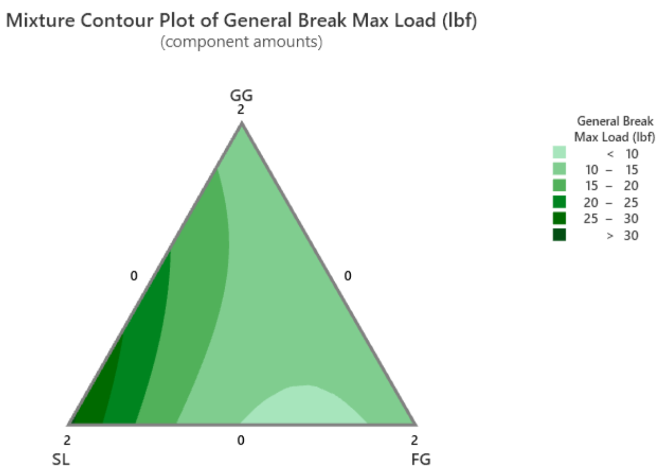


Figure 5. The Minitab generated contour plot for maximum load experienced by the beams in three-point bend, with GlasGrid® 8511 (GG), SpiderLath (SL), and FG-050 (FG) as factors. The darker contour lines correlate to a larger maximum load (lbf).

The second step of testing was evaluating the seam strength of all three reinforcing meshes via three-point bending. However, there were not enough tests conducted for *Driftwood* to make each seam and continuous reinforcement layer their own factor in Minitab; therefore, the data that Minitab evaluated for each scheme was a combination of data resulting from each reinforcement having a seam and a continuous layer. These beams were constructed such that when three-point bend tested, each beam only contained one seam, as their locations were staggered when constructing *Driftwood*. Nonetheless, this staggering caused the seam strength contour plot to inaccurately predict trends in the data and is a supporting reason to supplementally analyze the data by hand. The corresponding contour plot for the seams-break data (Figure 7) demonstrated that two layers GlasGrid® 8511 produced the beam with greatest strength. SL/GG and FG/GG had similar strengths, as a result of being located in the same contour line, and SL/SL had the weakest seam strength, which opposed the results of the general break.

Due to SpiderLath having the greatest continuous strength, but worst seam strength, *Driftwood's* reinforcement committee decided to implement a third step of scheme development, overlap-tests. It was of interest to determine if a critical overlap length between both sides of a SpiderLath seam existed, such that the seam would havecomparable strength to that of a

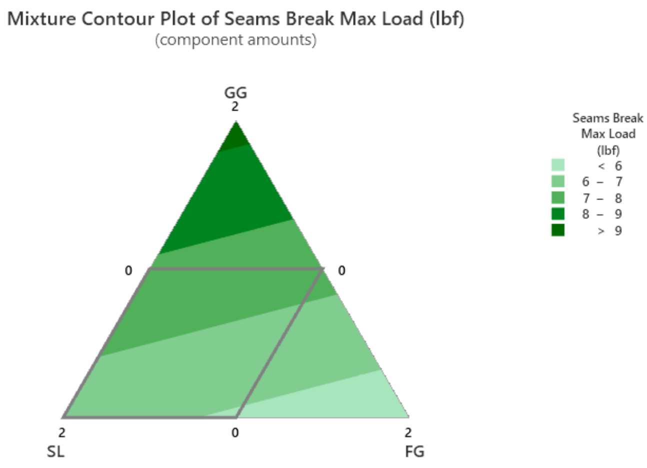


Figure 6. The Minitab generated contour plot for maximum load experienced by the seamed beams in three-point bend, with GlasGrid 8511® (GG), SpiderLath (SL), and FG-050 (FG) as factors. The darker contour lines correlate to a larger maximum load (lbf). All data outside of the grey box was extrapolated.

continuous layer of SpiderLath. Unfortunately, these results were unable to be analyzed through Minitab, as different concrete mixtures were used to construct the different sets of beams, meaning that data resulting from the three steps could not be compared directly, only their respective strength trends could be. This realization prompted the reinforcement committee to implement the use of the same mix when constructing various sets of beams in future years.

Through the analysis of the 2019 overlap-testing data, the reinforcement committee found that an overlap of 1.5 in on either side of a SpiderLath seam resulted in comparable strength to a continuous layer. Therefore, the final reinforcement scheme used in *Driftwood* and *Dozer* was a SL/GG layer scheme, with every SpiderLath seam having 1.5 in of overlap on each side. Integrating Minitab into the reinforcement committee's research and development process was successful, although it proved to both support and contradict decisions made by the 2019 reinforcement committee; this simply solidifies the importance of both quantitatively and qualitatively analyzing data.

The final aspect of *Voyager's* reinforcement scheme was not analyzed via Minitab, as it was implemented first in *Dozer*. A tension tie was placed in the gunnels of *Dozer*, with goals to mitigate torsional cracks from forming, as in the year before, these torsional cracks prompted *Driftwood*'s hull to break in two. For *Dozer*, there was a disproportionate placement of cable through the cross-section of the gunnels, which was sought to be addressed in the placement of cable tension ties in *Voyager*. A standard operating procedure was to be developed for placing the cables, however, due to competition not requiring a physical prototype, efforts were shifted to developing and integrating the Minitab model within structural mixture development. Nonetheless, the reinforcement committee planned on using the same cable within *Voyager's* gunnels, as its effectiveness was not able to be evaluated through a physical test on *Dozer*. Through the innovative use of Minitab within the reinforcement development process, the reinforcement committee is confident in the reinforcement scheme will lead to *Voyager's* success.

Proposed Construction

Once the hull design is complete, it will be used to order a high-density polystyrene concave mold that is fabricated into six sections; these six sections will be combined using plywood and screws. Once the mold is combined, several layers of epoxy will be to assist in the demolding process.

Troweling practices will be held on a weekly basis in an effort to integrate newly recruited members into the team, as well as continue knowledge transfer. These practices use previous years' molds to trowel and is an example of one of the team's environmentally sustainable aspects. At the practices, the team will use the finalized mix and reinforcement design to become comfortable and knowledgeable on how to properly trowel both the mix and interact with the layers of reinforcement; this will promote a timely and successful casting day.

The Quality Assurance and Quality Control (QC/QA) team will be crucial in ensuring that the troweled layers of concrete are consistent in depth, and will use 3-D printed depth gauges set to 1/8th, 2/8th, and 3/8th of an inch, to do so (Figure 8). A quality assurance measure taken prior to casting day is pre-mixing all of the mix batches, this allows the team to also save time during casting day and has increased consistency throughout batches.

Figure 7. QC/QA member measuring the depth of a concrete layer on casting day.

In previous years, innovation was centered around the efficiency of constructing the canoe on casting day. The most innovative method developed in recent years consisted of troweling the first layer of concrete approximately ⅓ of the way down the hull, followed by one team of individuals continuing to trowel down the canoe, while another team laid the first layer of reinforcement on that initial troweled section (Figure 9). Once the first layer of concrete is completely troweled, the process begins again at the bow and continues until all three layers of concrete are applied. Steel cables are then set into the gunnels, as a layer of reinforcement and concrete are troweled over it to secure the cable's position. This staggered method allows the canoe to be entirely cast in less than four hours, minimizing the possibility of cold joint occurrences. This technique will be used next season, when the research from *Voyager* comes to fruition in a full canoe deliverable

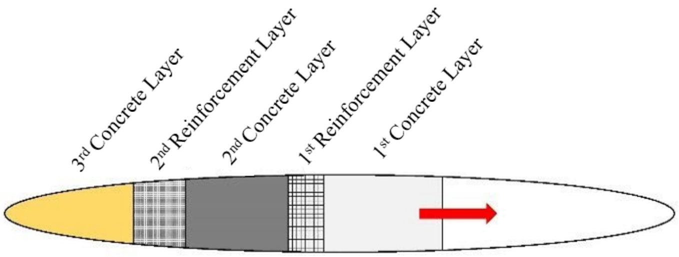


Figure 8. Innovative casting day technique that decreases the length of casting day and the probability of a cold joint occurrence.

Once the canoe is cast, the boat will be stored in a curing room built with a temporary structure to ensure that the temporary humidifiers placed within are able to generate the necessary curing environment. Humidifiers are used to ensure that the layers are properly bonded and to increase the compressive strength of the mix. During this curing process, ASTM C511 will be followed in general accordance, with the room being at 90% humidity and 70°F. Two weeks after casting and maintaining these curing conditions, the canoe have large enough compressive strength to begin the demolding process. The mold pieces will be carefully removed from the canoe's exterior, making it ready for the aesthetics committee to begin their work.

Approach to Safety

Due to the COVID-19 pandemic, the safety rules, regulations, and precautions for the 2020-2021 year were lengthened for all aspects of the project. Every year, each member of the team must complete assigned online safety training to be allowed in the lab and work on the canoe, such safety training includes general, electrical, and personal protective equipment (PPE). Before new members gain lab access, they must also complete an in-person lab safety walkthrough provided by the lab coordinator. With limited face-to-face contact and strict social distancing rules, this year proved a challenge in orchestrating the in-person walkthrough. It took longer than expected for new members to begin to work in the lab and therefore, initiate the knowledge transfer and construction process. Nonetheless, this delay was a demonstration to the new members of the importance and magnitude that the team holds safety to.

Along with the typical PPE required by the lab, such as safety glasses and closed-toed shoes, the team enforced that everyone must wear a mask and social distance from one another while working in the lab. The lab capacity was limited to a maximum of five people, which provided the team a new challenge this year, as most lab activities were done in bulk and within close quarters; however, the team persevered, much like the space industry, and overcame this disadvantage. Additionally, the weekly meetings and lab days, when applicable, were moved to an online format. It has been difficult to get new members into the lab in order to teach them the processes, but small groups have proven to be effective.

Paddling was another part of the competition preparation that required additional safety rules and regulations implemented. Although there is no paddling portion of the 2021 competition, it was important that the team be able to teach the new and less experienced paddlers the proper paddling techniques and strategies for future years. Therefore, paddling practices were not cancelled, but rather strict safety rules and regulations were put into place. At each practice, cleaning supplies were provided to clean the paddles in-between uses, and masks and social distancing were enforced. Additionally, each team member was responsible for monitoring their possible symptoms or exposure to the COVID-19 virus each day and for following measures to prevent the spread of COVID-19. Although this was new and challenging for the paddling team, these efforts will improve the team for the following years.

Approach to Project Quality and Management

Michigan Tech's team is led by two project managers (PM), a senior PM and a junior PM, who will ultimately lead the project the following year. The structure of the team consists of multiple committees and subcommittees that specialize in key components of the project. Committees are composed of general members that are taught the skills needed to contribute to their chosen committee, with the intention of having them lead a committee in the future and pass their knowledge to new members. At the end of the year, the team nominates and elects new committee heads to lead the organization the following year.

The organizational structure of the team is one way that knowledge is effectively shared through all levels of membership. A "Things Learned" document is updated throughout the entire project by each committee head. Through doing this each year, there are years' worth of documentation that team members can reference throughout the project when needed.

The main goal for the project managers this year was to work in conjunction with the committee heads to develop a schedule that allowed for feasible deadlines, without knowing the amount of lab access the team would have. A few contingency plans were made in the event that lab access was limited, and it eventually was. At the beginning of the fall semester, the schedule was developed from the outline of previous successful projects, with most of the research and development happening during the fall semester, while aesthetics and the competition display elements were planned to be completed in the spring semester. Due to the modifications of the rules and regulations caused by the ongoing COVID-19 pandemic, the team had to forego the majority of the schedule pertaining to the physical construction of a boat. While many critical points in the schedule were kept, such as finalizing the structural mix and reinforcement scheme, events like casting day and the entirety of the aesthetics work period were canceled to maintain the health and safety of the organization.

The major milestones for this year's project were hull design completion, mix design completion, and both the enhanced focus areas and technical paper completion. These activities were determined so that the critical path could be developed. Weekly meetings were held to update the team on the progress of each committee, as well as committees that required additional assistance that week; this open flow of communication allowed the team to devise a deliverable that we are proud of, in a time that made it difficult to do so. Overall, the team put in over 600-person hours' worth of work, and expects to put in an additional 200-person hours for mold construction, canoe construction, display, and additional project management hours (Figure 10).

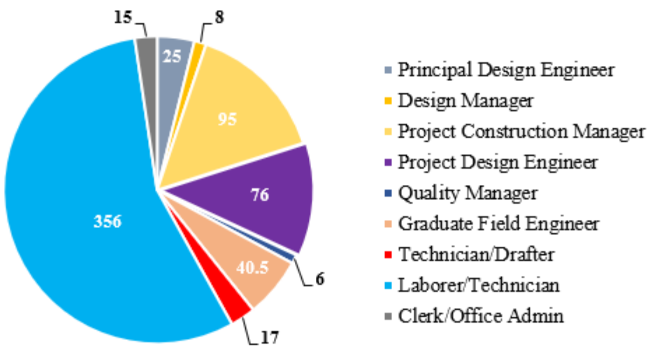


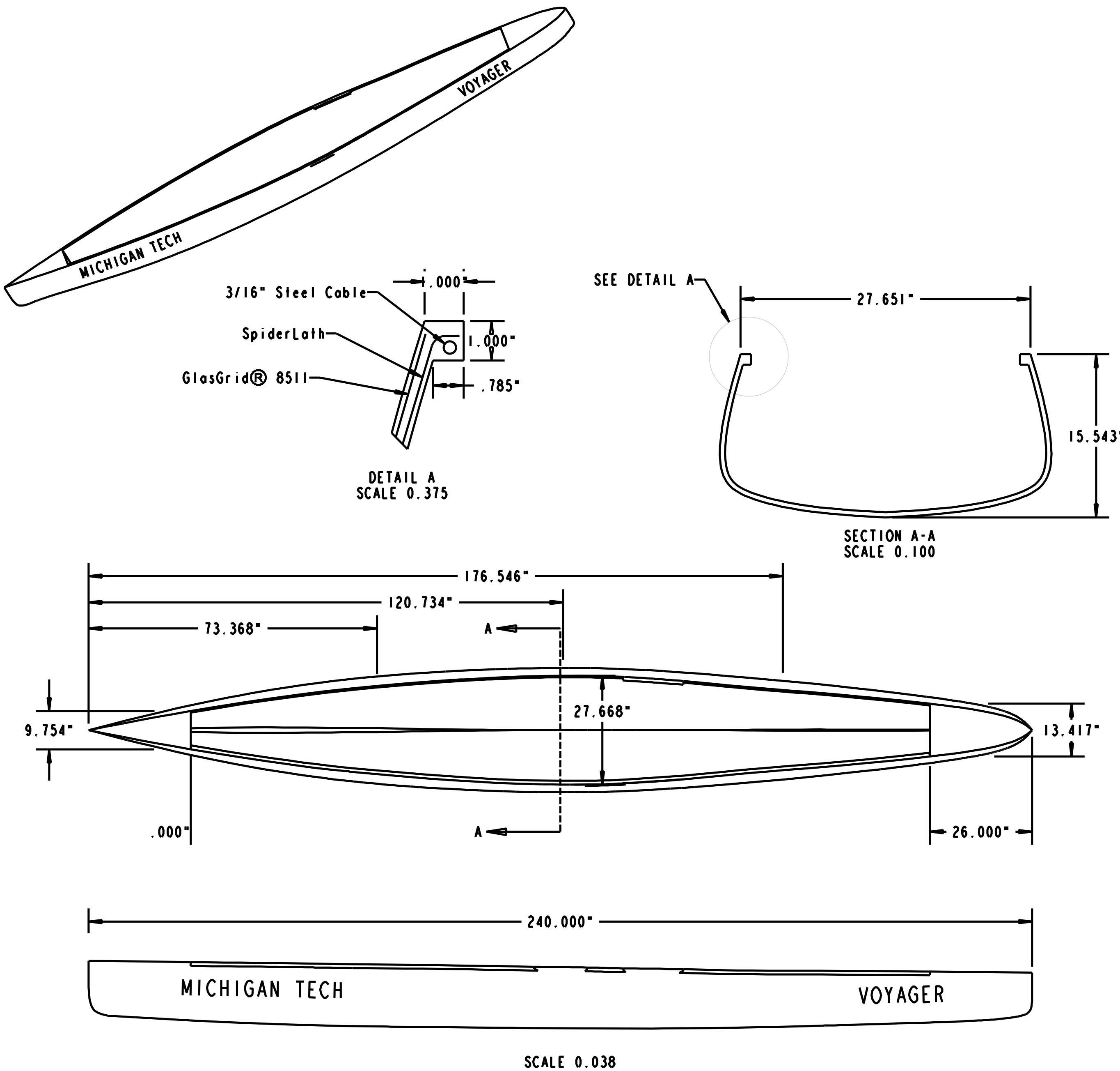
Figure 9. Person hour breakdown of 2021 competition season.

Making the best of it, this year the team took the opportunity to focus the budget on improvements to the team's infrastructure, since construction and mold budget allocations were not needed this year; these funds were dispersed to improve equipment and training practices. Specifically, funds were dedicated to the purchase of a new trailer for the paddling team, as the current one is nearing the end of its' life cycle. Additionally, the increased paddling budget allowed the team to increase their number of indoor pool practices. On the technical side, the hull design committee is researching new possible hull design software and laptops, as the current ones are more than 20-years old.

Approach to Sustainability

Michigan Tech Concrete Canoe Team's approach to sustainability this year was to be socially, economically, and environmentally sustainable in a safe manner. In an effort to be both environmentally and economically sustainable, the team planned on recycling the snow Houghton received into acceptable water to be used in the mix. The implementation of snow was an innovate use of a resource that Michigan Tech has an abundance of, since it is located in the Upper Peninsula of Michigan. Additionally, the outdoors is an optimal location for socially distanced activities and maintaining knowledge transfer, making this effort socially sustainable as well. Moreover, the lack of physical mixes produced this year reduced the amount of mix waste created. Although physical testing is important in typical competition years, the ability to use a software instead allowed the team to consume less materials, which lead to a more environmentally sustainable effort by the mix committee. The use of less materials also proved to be economically sustainable for the team, as this money was able to be put towards other team improvements or saved for following years, improving the team's longevity.

Another way the team was sustainable was knowledge transfer. Many of the team's members that have completed numerous seasons, are not returning after the spring 2021 semester, as they are graduated. Therefore, it was important that the team teach new members valuable information on the process of constructing a concrete canoe before then. This was a sustainable way of conducting knowledge transfer due to the fact that the team taught with current resources rather than waiting until the beginning of the next competition season to teach. If this delay were to happen, more resources and time would be used and possibly wasted in order to understand and complete the tasks that are completed each year.

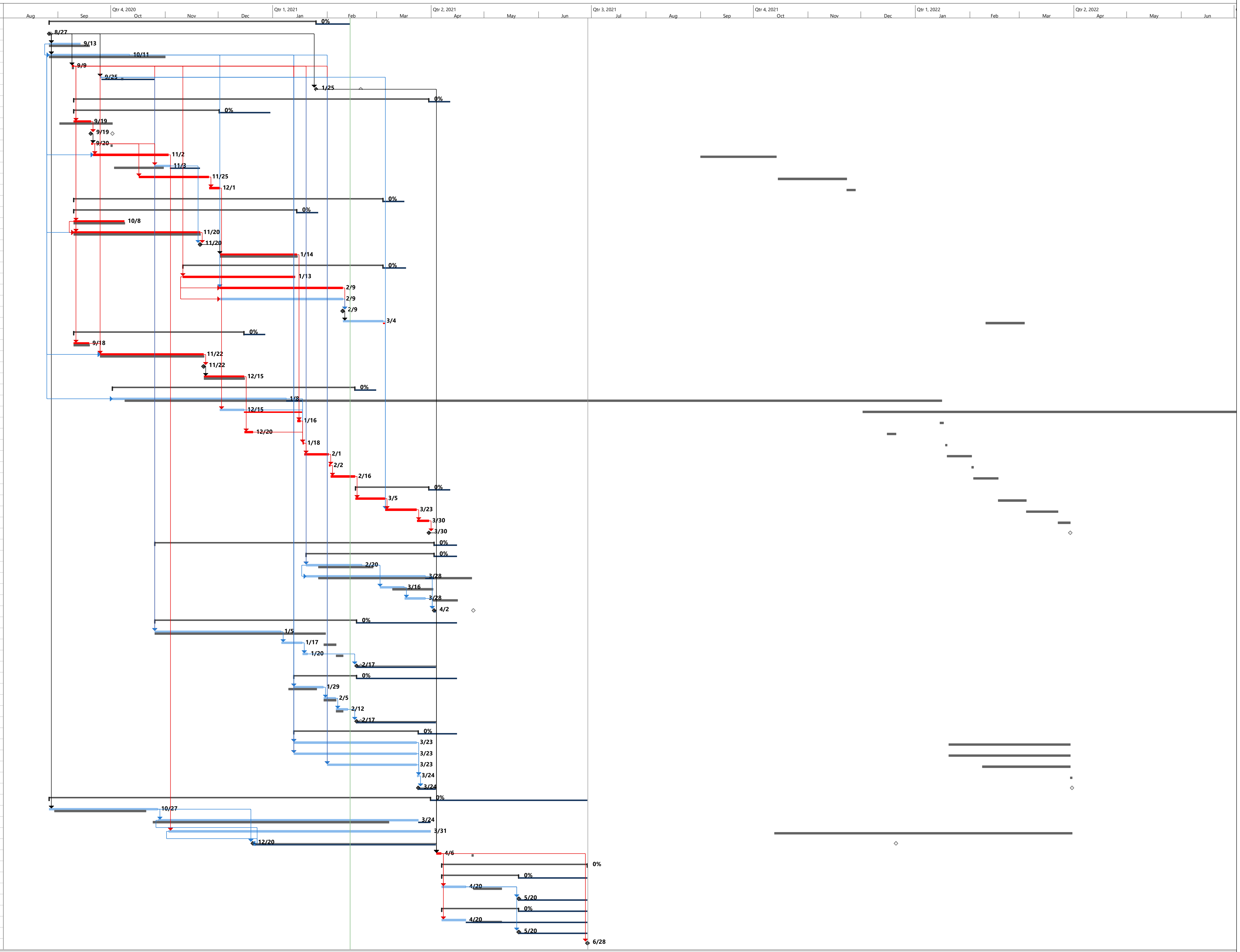


Michigan Technological University
1885

I.D.	DESCRIPTION	QTY
01	PORTLAND CEMENT	392.7 (LBS/YD^3)
02	BLAST FURNACE SLAG	162.3 (LBS/YD^3)
03	FLY ASH - CLASS C	233.7 (LBS/YD^3)
04	SILICA FUME	22.7 (LBS/YD^3)
05	PVA RFS400 (WHITE)	4.9 (LBS/YD^3)
06	ENDURO PRIME (FLEXIBLE)	7.3 (LBS/YD^3)
07	ELEMIX	31.9 (LBS/YD^3)
08	"B" HAYDITE	119.7 (LBS/YD^3)
09	CRUSHED CONCRETE	167.5 (LBS/YD^3)
10	WATER	432.0 (LBS/YD^3)
11	SUPERPLASTCISER	3.2 (LBS/YD^3)
12	3/16" STEEL CABLE	38.21 FT
13	SPIDERLATH	65.98 FT^2
14	GlasGrid® 8511	65.98 FT^2

CONSTRUCTION DRAWING	
DRAWN BY: HENRY SUMMERS	CHECKED BY: LAUREN BOWLING
DATE: 12/27/2020	SHEET: 1 OF 1
SCALE: VARIES	

ID	Task Mode	Task Name
1		**Project Management**
2		Start of Academic Year
3		Recruitment
4		Lab Safety Training
5		Rules Released & Reviewed
6		Theme Decision
7		ASCE Annual Report Submission
8		**Canoe Development**
9		**Hull Design**
10		Draft Hull Design
11		Final Hull Design Selection
12		Release Hull Dimensions
13		Prototype Construction
14		Structural Analysis
15		Foam Sized and CNC Milled
16		Mold Pick-up and Delivery
17		**Concrete Mix Design**
18		**Structural Mix**
19		Material Procurement for Testing (Structural)
20		Binder, Aggregate, and Fiber Testing
21		Final Structural Mix Selection
22		Final Structural Mix Material Procurement
23		**Finishing Mix**
24		Material Procurement for Testing (Finishing)
25		Finishing Mix Design & Testing
26		Application Technique Testing
27		Final Finishing Mix Selection
28		Final Finishing Mix Material Procurement
29		**Reinforcement**
30		Material Procurement for Testing
31		Reinforcement Testing
32		Final Reinforcement Selection
33		Final Reinforcement Material Procurement
34		**Canoe Construction**
35		Casting Practices
36		Mold Assembly
37		Pre-Batch Final Structural Mix
38		Pre-Cut Reinforcement
39		Concrete Placement
40		Initial Cure with Mold
41		Mold Removal
42		Final Curing
43		**Finishing & Aesthetics**
44		Sanding
45		Interior & Exterior Design
46		Sealing
47		Finishing Complete
48		**Communications**
49		**Technical Presentation**
50		Create Presentation
51		Presentation Practice
52		Professional Reviews
53		Final Revision
54		Presentation Complete
55		**Technical Proposal**
56		Proposal Outline & Draft
57		Professional Reviews
58		Final Revision
59		Technical Proposal Submission
60		**Material Technical Data Sheets Addendum**
61		MTDS Outline & Draft
62		Professional Reviews
63		Final Revision
64		MTDS Addendum Submission
65		**Final Product Display**
66		Table Top Display Design & Construction
67		Display Stands Design & Construction
68		Cross Section Design & Construction
69		Compliance Check
70		Final Product Display Complete
71		**Paddler Training**
72		Outdoor Paddling Practice
73		Indoor Paddling Practice
74		Prototype Testing
75		Selection of Competition Paddlers
76		North Central Student Conference
77		**National Competition**
78		**Technical Proposal**
79		Final Revision
80		Technical Proposal Submission
81		**Material Technical Data Sheets Addendum**
82		Final Revision
83		MTDS Addendum Submission
84		National Concrete Canoe Competition



Critical Progress | Split | Manual Task | Finish-only | Critical | Baseline | Baseline Milestone | Summary Progress | Manual Summary | External Tasks | Inactive Task | Inactive Summary | Slack
Task | Task Progress | Start-only | Duration-only | Critical Split | Baseline Split | Milestone | Summary | Project Summary | External Milestone | Inactive Milestone | Deadline

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Cover graphic and Organization Chart graphic designed by Jackson Bowling.

APPENDIX B: MIXTURE: STRUCTURAL, BACKFILL

CEMENTITIOUS MATERIALS				
Component	**Specific Gravity**	**Volume** ft^3	**Amount of CM** lb/yd^3	
Type 1 Portland Cement, ASTM C150	3.15	1.998	392.7	Total cm (includes c) __811.4__ lb/yd^3 c/cm ratio, by mass __0.484__
Blast Furnace Slag	2.99	0.87	162.3	
Fly Ash – Class C	2.65	1.413	233.7	
Silica Fume	2.22	0.164	22.7	

FIBERS				
Component	**Specific Gravity**	**Volume**	**Amount of Fibers** lb/yd^3	
PVA RFS400	1.3	0.06	4.9	Total Amount of Fibers __12.2__ lb/yd^3
Enduro Prime	0.91	0.129	7.3	

AGGREGATES (EXCLUDING MINERAL FILLERS PASSING NO. 200 SIEVE)							
Aggregates	**Expanded Glass (EG) or Cenosphere (C)**[1]	**Abs (%)**	SG_{OD}	SG_{SSD}	**Base Quantity, W**		**Volume,** $V_{agg,SSD}$ ft^3
					W_{OD} lb/yd^3	W_{SSD} lb/yd^3	
Elemix	No	0.055	0.042	0.044	6.58	6.94	2.51
Trinity Haydite (#8 Sieve)	No	0.122	1.17	1.313	152.27	170.85	2.09
RCA (#8 Sieve)	No	0.22	1.10	1.342	87.76	107.07	1.28

LIQUID ADMIXTURES					
Admixture	**lb/ US gal**	**Dosage (fl. oz / cwt)**	**% Solids**	**Amount of Water in Admixture**	
BASF GLENIUM 3030NS	9.009	6.00	0.2027	2.66 lb/yd^3	Total Water from Liquid Admixtures, $\sum w_{admx}$ __2.66__ lb/yd^3

SOLIDS (DYES, POWDERED ADMIXTURES, AND MINERAL FILLERS)				
Component	**Specific Gravity**	**Volume (ft^3)**	**Amount (lb/yd^3)**	
DCI Concrete Pigments – various colors	2.25	0.11	14.90	TOTAL SOLIDS. TOTAL ___14.90____ LB/YD3

WATER			
	Amount		**Volume** ft^3
Water, w, [$=\sum (w_{free} + w_{admx} + w_{batch})$]	w/c ratio, by mass __0.93__ w/cm ratio, by mass __0.45__	365.13	5.85
Total Free Water from All Aggregates, $\sum w_{free}$		-62.20	
Total Water from All Admixtures, $\sum w_{admx}$		2.66	
Batch Water, w_{batch}		424.68	

DENSITIES, AIR CONTENT, RATIOS, AND SLUMP						
Values for 1 cy of concrete	**cm**	**Fibers**	**Aggregate** (SSD)	**Solids,** S_{total}	**Water, w**	**Total**
Mass, M	811.4	12.2	287.39	68.88	378.80	$\sum M$: 1558.67 lb
Absolute Volume, V	4.45	0.189	16.26	3.84	6.80	$\sum V$: 31.54 ft^3
Theoretical Density, T, ($=\sum M / \sum V$)	55.27 lb/ft^3		**Air Content, Air,** [= (T – D)/T x 100%]			-3.37 %
Measured Density, D	57.13 lb/ft^3		**Air Content, Air,** [= (27 – ∑V))/27 x 100%]			-16.81 %
Total Aggregate Ratio[2] ($=V_{agg,SSD} / 27$)	46.4 %		**Slump, Slump flow, Spread** (as applicable)			0.5 in.
C330+RCA Ratio ($=V_{C330+RCA} / V_{agg,SSD}$)	46.9 %					

Cementitious Material

$Mass_{Portland} = 392.7lb$ $SG_{Portland} = 3.15$

$Mass_{BlastSlag} = 162.3lb$ $SG_{BlastSlag} = 2.99$

$Mass_{FlyAsh} = 233.7lb$ $SG_{FlyAsh} = 2.65$

$Mass_{SilicaFume} = 22.7lb$ $SG_{SilicaFume} = 2.22$

$$Volume_{Portland} = \frac{Mass_{Portland}}{SG_{Portland} \cdot 62.4 \frac{lb}{ft^3}} = 1.998 \cdot ft^3$$

$$Volume_{BlastSlag} = \frac{Mass_{BlastSlag}}{SG_{BlastSlag} \cdot 62.4 \frac{lb}{ft^3}} = 0.87 \cdot ft^3$$

$$Volume_{FlyAsh} = \frac{Mass_{FlyAsh}}{SG_{FlyAsh} \cdot 62.4 \frac{lb}{ft^3}} = 1.413 \cdot ft^3$$

$$Volume_{SilicaFume} = \frac{Mass_{SilicaFume}}{SG_{SilicaFume} \cdot 62.4 \frac{lb}{ft^3}} = 0.164 \cdot ft^3$$

$$\Sigma Mass_{CM} = Mass_{Portland} + Mass_{BlastSlag} + Mass_{FlyAsh} + Mass_{SilicaFume} = 811.4 \cdot lb$$

$$\Sigma Volume_{CM} = Volume_{Portland} + Volume_{BlastSlag} + Volume_{FlyAsh} + Volume_{SilicaFume} = 4.445 \cdot ft^3$$

$$C\_CM\_Ratio = \frac{Mass_{Portland}}{\Sigma Mass_{CM}} = 0.484$$

Fibers

$Mass_{RFS400} = 4.9lb$ $SG_{RFS400} = 1.3$

$Mass_{EnduroPrime} = 7.3lb$ $SG_{EnduroPrime} = 0.91$

$$Volume_{RFS400} = \frac{Mass_{RFS400}}{SG_{RFS400} \cdot 62.4 \frac{lb}{ft^3}} = 0.06 \cdot ft^3$$

$$Volume_{EnduroPrime} = \frac{Mass_{EnduroPrime}}{SG_{EnduroPrime} \cdot 62.4 \frac{lb}{ft^3}} = 0.129 \cdot ft^3$$

$$\Sigma Mass_{Fibers} = Mass_{RFS400} + Mass_{EnduroPrime} = 12.2 \cdot lb$$

$$\Sigma Volume_{Fibers} = Volume_{RFS400} + Volume_{EnduroPrime} = 0.189 \cdot ft^3$$

Aggregates

$MassOD_{Elemix} = 6.5823lb$ $\quad Abs_{Elemix} = 0.055$ $\quad SGOD_{Elemix} = 0.042$

$MassOD_{Haydite} = 152.2708lb$ $\quad Abs_{Haydite} = .122$ $\quad SGOD_{Haydite} = 1.17$

$MassOD_{RCA} = 87.7642lb$ $\quad Abs_{RCA} = .22$ $\quad SGOD_{RCA} = 1.10$

$MSSD_{Elemix} = Abs_{Elemix} \cdot MassOD_{Elemix} + MassOD_{Elemix} = 6.944 \cdot lb$

$MSSD_{Haydite} = Abs_{Haydite} \cdot MassOD_{Haydite} + MassOD_{Haydite} = 170.848 \cdot lb$

$MSSD_{RCA} = Abs_{RCA} \cdot MassOD_{RCA} + MassOD_{RCA} = 107.072 \cdot lb$

$SGSSD_{Elemix} = Abs_{Elemix} \cdot SGOD_{Elemix} + SGOD_{Elemix} = 0.044$

$SGSSD_{Haydite} = Abs_{Haydite} \cdot SGOD_{Haydite} + SGOD_{Haydite} = 1.313$

$SGSSD_{RCA} = Abs_{RCA} \cdot SGOD_{RCA} + SGOD_{RCA} = 1.342$

$$V_{Elemix} = \frac{MSSD_{Elemix}}{SGSSD_{Elemix} \cdot 62.4 \frac{lb}{ft^3}} = 2.512 \cdot ft^3$$

$$V_{Haydite} = \frac{MSSD_{Haydite}}{SGSSD_{Haydite} \cdot 62.4 \frac{lb}{ft^3}} = 2.086 \cdot ft^3$$

$$V_{RCA} = \frac{MSSD_{RCA}}{SGSSD_{RCA} \cdot 62.4 \frac{lb}{ft^3}} = 1.279 \cdot ft^3$$

$\Sigma MSSD_{non\_EG\_C\_aggs} = MSSD_{Elemix} + MSSD_{Haydite} + MSSD_{RCA} = 284.864 \cdot lb$

$\Sigma MassSSD_{aggs} = \Sigma MSSD_{non\_EG\_C\_aggs} = 284.864 \cdot lb$

$\Sigma Volume_{aggs} = V_{Elemix} + V_{Haydite} + V_{RCA} = 5.876 \cdot ft^3$

Admixtures

$Dosage_{BASF3030} = 6.00 \frac{fl\_oz}{100lb}$ $\%Solids_{BASF3030} = 0.2027$ $Density_{BASF3030} = 9.009 \frac{lb}{gal}$

$WC_{BASF3030} = 1 - \%Solids_{BASF3030} = 0.797$

$Water_{BASF3030} = Dosage_{BASF3030} \cdot 7.8930 \cdot 100lb \cdot WC_{BASF3030} \cdot Density_{BASF3030} = 2.658 \cdot lb$

$\Sigma Water_{admix} = Water_{BASF3030} = 2.658 \cdot lb$

Solids

$Mass_{DCIPigments} = 14.90lb$ $SGOD_{DCIPigments} = 2.25$

$$V_{DCIPigments} = \frac{Mass_{DCIPigments}}{SGOD_{DCIPigments} \cdot 62.4 \frac{lb}{ft^3}} = 0.106 \cdot ft^3$$

$\Sigma Mass_{solids} = Mass_{DCIPigments} = 14.9 \cdot lb$

$\Sigma Volume_{solids} = V_{DCIPigments} = 0.106 \cdot ft^3$

Free Water

$MC_{Elemix} = 0$

$MC_{Haydite} = 0.01$

$MC_{RCA} = 0.01$

$WF_{Elemix} = MassOD_{Elemix} \cdot (MC_{Elemix} - Abs_{Elemix}) = -0.362 \cdot lb$

$WF_{Haydite} = MassOD_{Haydite} \cdot (MC_{Haydite} - Abs_{Haydite}) = -17.054 \cdot lb$

$WF_{RCA} = MassOD_{RCA} \cdot (MC_{RCA} - Abs_{RCA}) = -18.43 \cdot lb$

$\Sigma WFree = WF_{Elemix} + WF_{Haydite} + WF_{RCA} = -35.847 \cdot lb$

Water

$W\_CM\_ratio = 0.45$

$W = W\_CM\_ratio \cdot \Sigma Mass_{CM} = 365.13 \cdot lb$

$W_{batch} = W - (\Sigma WFree + \Sigma Water_{admix}) = 398.319 \cdot lb$

$$Volume_{batch} = \frac{W}{62.4 \frac{lb}{ft^3}} = 5.851 \cdot ft^3$$

Concrete Analysis

$$\Sigma Masses = \Sigma Mass_{CM} + \Sigma Mass_{Fibers} + \Sigma MassSSD_{aggs} + \Sigma Mass_{solids} + W = 1.488 \times 10^{3} \cdot lb$$

$$\Sigma Volumes = \Sigma Volume_{CM} + \Sigma Volume_{Fibers} + \Sigma Volume_{aggs} + \Sigma Volume_{solids} + Volume_{batch} = 16.467 \cdot ft^{3}$$

$$Density_{Theor} = \frac{\Sigma Masses}{\Sigma Volumes} = 90.391 \cdot \frac{lb}{ft^{3}} \qquad Density_{Meas} = 70.05 \frac{lb}{ft^{3}}$$

$$Air\_Content\% = \frac{Density_{Theor} - Density_{Meas}}{Density_{Theor}} \cdot 100 = 22.503$$

Important Ratios

$$Water\_Cement\_Ratio = \frac{W}{Mass_{Portland}} = 0.93 \qquad Aggregate\_Ratio = \frac{\Sigma Volume_{aggs}}{27ft^{3}} = 0.218$$

$$Water\_CM\_Ratio = \frac{W}{\Sigma Mass_{CM}} = 0.45 \qquad EG\_C\_Ratio = \frac{V_{Elemix} + V_{Haydite} + V_{RCA}}{\Sigma Volume_{aggs}} = 1$$

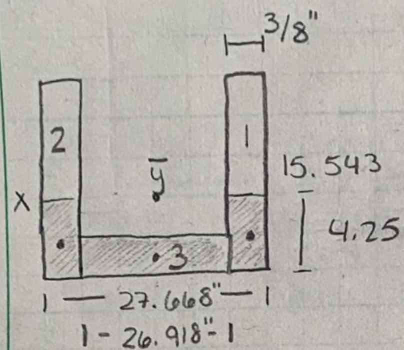
Appendix C

Summary Table

Product Name	Type	ASTM	Link
Lafarge - Portland Cement	Cement	C-150	https://www.lafargeholcim.us/our-solutions-and-products
Lafarge - Blast Furnace Slag	Cementitious Material	C-989	https://www.lafarge.ca/en/newcem
Lafarge - Class C Fly Ash	Cementitious Material	C-618	https://www.lafargeholcim.us/our-cement-solutions
NORCHEM - Undensified Silica Fume	Cementitious Material	C-1240	https://www.norchem.com/technical-data-sheet.html
NYCON - RFS400 PVA	Secondary Reinforcement	C-1116	https://nycon.com/collections/pva-fibers/products/rfs400
SIKA - ENDURO PRIME	Secondary Reinforcement	C-1116, C-1116M	https://fibermesh.com/wp-content/uploads/2018/04/FIB-EnduroPrime_ProdData_PCS1229E005_042019.pdf
GlasGrid® 8511	Reinforcement	C-338, D-276, D-5261, D-6637	https://www.tensarcorp.com/Search?query=8511%20msds
SpiderLath	Reinforcement	D-3775, D-1777, D-5035	https://spiderlath.com/installation/#testing
3/16" Steel Cable	Reinforcement	A-90, A-700, A-1023, B-139, D-3953 D-6039	https://www.fehr.com/img/product/description/Meets%20the%20performance%20requirements%20of%20Federal%20Specification%20RR-W-410.pdf
Trinity Haydite	Aggregate	C-330, C-331	www.stlohio.com

DOW Extruded Polystyrene Foam	Flotation	NONE	https://www.dupont.com/products/thermax-sheathing.html
Elemix	Aggregate	C-39, C-78, C-143, C-469, C-1611	https://www.cmdgroup.com/documents/FS/catalogs/SYNTHEON%20Inc%20-%20ELEMIX%20Brochure.PDF
Recycled Concrete Aggregate	Aggregate	C-128, C-136	https://docs.google.com/document/d/11puNym5EQQGIeLvAF9Bm86Gwx2OwclEdZ8f7k78iFd8/edit?usp=sharing
Direct Colors Concrete Pigments	Pigment	C-979	https://directcolors.com/concrete-pigment/
Distilled Water	Water	NONE	N/A
BASF Glenium 3030 NS	Superplasticizer	C-494, C-494M	https://www.master-builders-solutions.basf.us/en-us/products/concrete-admixtures/water-reducers/water-reducers-high-range/masterglenium-3030
Sealkrete Clear-Seal	Sealer	D-1640, D-3359B, D-3363, G-53	https://www.rustoleum.com/product-catalog/consumer-brands/seal-krete/horizontal-sealing/clear-seal
3M - Silhouette Glossy Permanent Vinyl Tape 471	Lettering Tape	D-3652, D-3759	https://www.3m.com/3M/en_US/company-us/all-3m-products/~/3M-Vinyl-Tape-471/?N=5002385+3293242769&preselect=3293786499&rt=rud

I, Q, C Calculations:



$$\bar{y} = \frac{\Sigma \tilde{y}_i A_i}{\Sigma A_i} \qquad \tau = \frac{VQ}{It} \qquad \sigma = \frac{Mc}{I}$$

Shape	$\tilde{y}_i$	A_i	$\tilde{y}_i A_i$
1	7.7715	5.83	45.3
2	7.7715	5.83	45.3
3	0.1875	10.09	1.892

$$\bar{y} = \frac{45.3 + 45.3 + 1.892}{2(5.83) + 10.09} = \boxed{4.25"}$$

$$Q = \Sigma y_i A_i$$

Shape	y_i	A_i	$y_i A_i$
1	2.125	1.59	3.379
2	2.125	1.59	3.379
3	4.0625	.10.09	41.007

$$\boxed{Q = 47.765}$$

$$I_x = \Sigma (I'_x + A d_x^2)$$

$$I_x = \frac{1}{12} b h^3$$

Shape

1 $\quad I'_{x_1} = \frac{1}{12}(0.375)(15.543)^3 + 0.375(15.543)\left(\frac{15.543}{2} - 4.25\right)^2$

2 $\quad$ "

3 $\quad I'_{x_3} = \frac{1}{12}(27.668)(0.375)^3 + 0.375(27.668)(4.25 - 0.1875)^2$

$$\boxed{I_x = 550.6 \text{ in}^4}$$

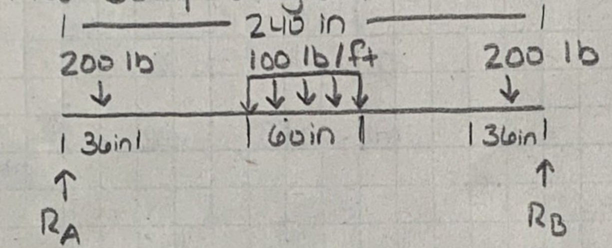
6.4.9.4.1

2 200 lb paddlers

Paddler Locations: $0.15(240) = 36$ in

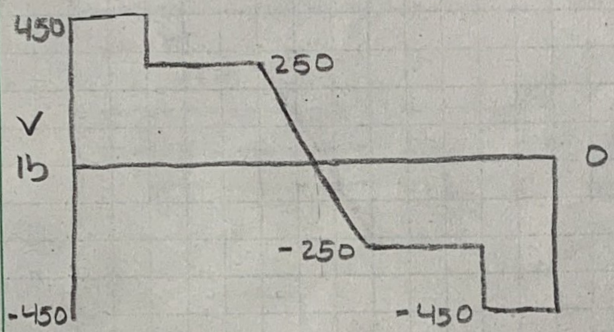
$0.85(240) = 204$ in

Free Body Diagram:

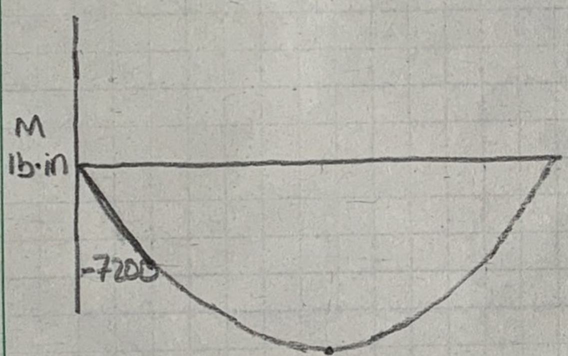


Assumptions:
- Canoe weighs 218 lb
- Material is homogeneous
- Cargo load is evenly distributed

$$R_A = R_B = \frac{2(200) + 100(5)}{2} = 450 \text{ lb}$$



$V = 0$ at 120 in



$M = -52800$ lb·in at 120 in

At maximum moment $V = 0$ lbf $\quad \tau = \frac{VQ}{It} = 0$ psi

$$\sigma = \frac{M_{max} c}{I} = \frac{52800(4.25)}{550.6} = 407.55 \text{ psi}$$

6.4.9.4.2

4 paddlers : 2 200 lb, 2 150 lb

Paddler Locations :

240 (0.15) = 36 in

240 (0.90) = 216 in

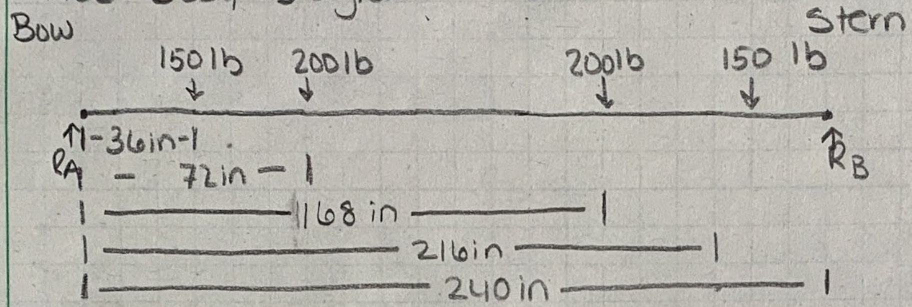
240 (0.30) = 72 in

240 (0.70) = 168 in

Assumptions :

- Material is homogeneous
- paddlers are in the correct locations
- paddlers are point loads

Free Body Diagram :

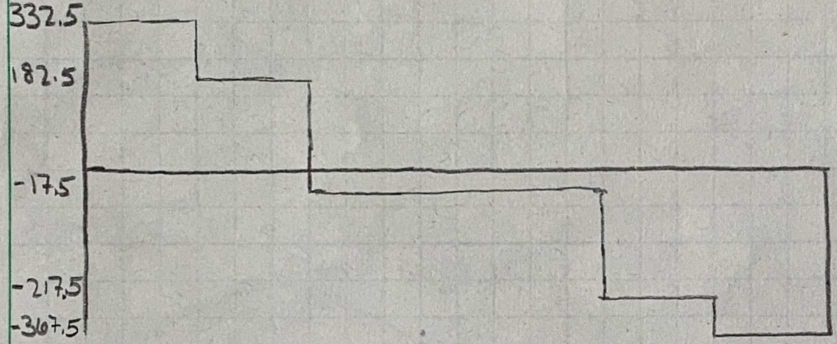


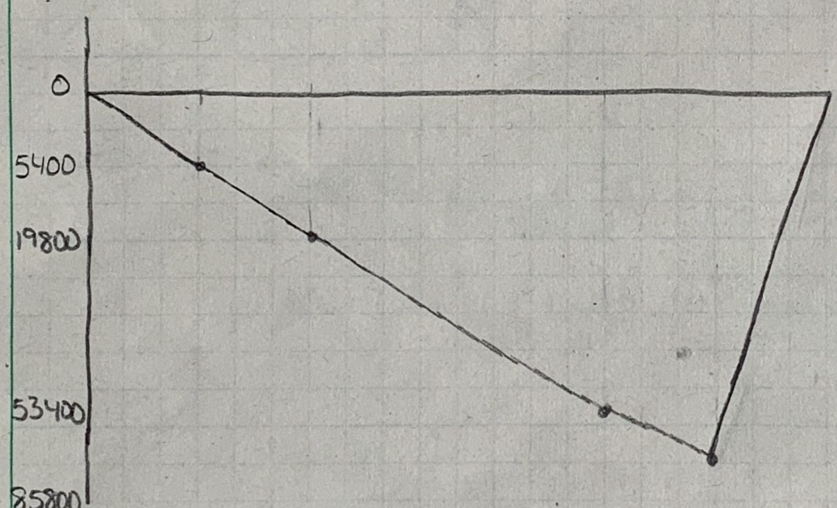
$\Sigma M = 0$

$= 85800 + R_B(240)$

$R_B = 367.5$ lb

$R_A = 332.5$ lb





$$\tau_{max} = \frac{6 V_{max}}{b t^3}\left(\frac{t^2}{4} - y_{max}^2\right)$$

- $t = 3/8$ in

$V_{max} = -367.5$

$b = 240$ in

$$\frac{367.5(47.765)}{550.6(0.375)} = 85.0158 \text{ psi} = \tau$$

$$\frac{88200(4.25)}{550.6} = 680.803 \text{ psi} = \sigma$$

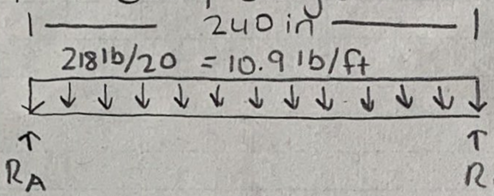
6.4.9.4.3

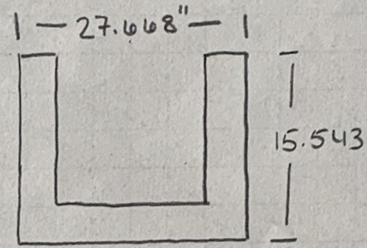
- Maximum beam of Canoe
- Bending moment that Cracking occurs
- Ultimate bending moment

Assumptions:

- Flat bottom Canoe
- Weight is a distributed load

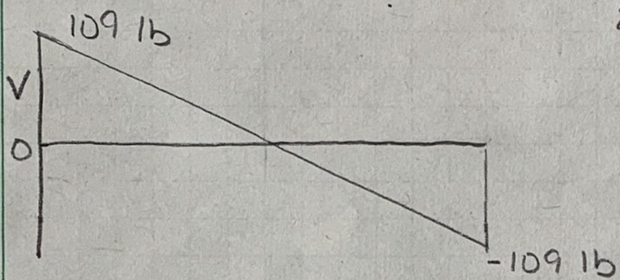
Free Body Diagram:



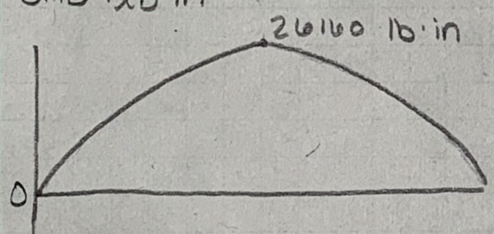


$\Sigma M = 0 = 120(218) + R_B(240)$

$R_B = R_A = 109$ lb



BMD: lb·in



Composite:

$1080 \text{ psi} = \dfrac{m(4.25)}{550.6} = \boxed{M_{UBM} = 139917 \text{ lb·in}}$

$410 \text{ psi} = \dfrac{m(4.25)}{550.6} = \boxed{M_{cracking} = 53116.7 \text{ lb·in}}$

Freeboard Calculations:

Assumptions:

1. Density of Water = 62 lb/ft^3 (ρ_w in Equation)
2. Waterplane Area of Canoe = 36.572 ft^2 (gathered from PROLINES 98) (A in Equation)
3. Height of Gunwales = 15.543 in (gathered from PROLINES 98) (h in Equation)
4. Weight of 1 Male Paddler = 240 lbs
5. Weight of 1 Female Paddler = 170 lbs
6. Unloaded Weight of Canoe = 218 lbs
7. Assumed Flat-Bottomed Canoe

Equation Used:

$$F_b = h - \frac{12 * w}{\rho_w * A}$$

Cases	Weight of the Canoe (w [lbs])	Submerged Depth of Canoe ($\frac{12*w}{\rho_w*A}$ [in])	Freeboard of Canoe (F_b [in])
Unloaded	218	1.15	14.39
	268	1.42	14.12
	318	1.68	13.86
	368	1.95	13.60
	418	2.21	13.33
	468	2.48	13.07
	518	2.74	12.80
Female Tandem	558	2.95	12.59
	568	3.01	12.54
	618	3.27	12.27
	668	3.54	12.01
Male Tandem	698	3.69	11.85
	718	3.80	11.74
	768	4.06	11.48
	818	4.33	11.21
	868	4.59	10.95
	918	4.86	10.68
	968	5.12	10.42
	1018	5.39	10.16
Four-Person Co-Ed	1038	5.49	10.05
	1068	5.65	9.89
	1118	5.92	9.63
	1168	6.18	9.36
	1218	6.45	9.10

Appendix E

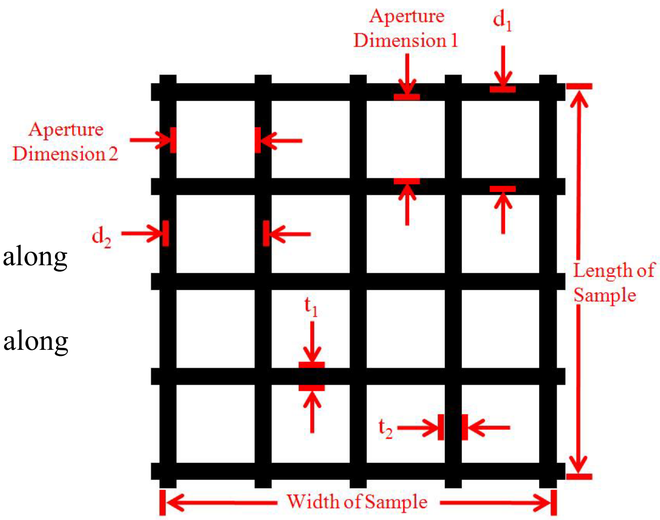
PERCENT OPEN AREA CALCULATIONS

Calculations per Exhibit 5

Samples: SpiderLath and GlasGrid®8511 Mesh

Given

$n_{1,SL} = 34$ Number of apertures along length
$n_{1,GG} = 9$ Number of apertures along width
$n_{2,SL} = 35$
$n_{2,GG} = 5$
$t_{1,SL} = 0.103$ in Average thickness of reinforcement along length
$t_{1,GG} = 0.262$ in
$t_{2,SL} = 0.051$ in Average thickness of reinforcement along width
$t_{2,GG} = 0.173$ in



Sample of Reinforcement

Aperture_Dimension_1_SL = 0.312 in
Aperture_Dimension_1 _GG= 0.737 in
Aperture_Dimension_2 _SL= 0.288 in
Aperture_Dimension_2 _GG= 0.808 in

d_1 = Aperture_Dimension_1 + 2*(t_1/2) $d_{1,SL} = 0.42$ in, $d_{1,GG} = 0.99$ in Average spacing of reinforcement (center-to-center) along the sample length

d_2 = Aperture_Dimension_2 + 2*(t_2/2) $d_{2,SL} = 0.34$ in, $d_{2,GG} = 0.98$ in Average spacing of reinforcement (center-to-center) along the sample width

Determine Solution Percent Open Area (POA) for the GlasGrid®8511 Mesh

$Length_{Sample} = n_1 * d_1$ $Length_{SL} = 14.09$ in
$Length_{GG} = 8.98$ in

$Width_{Sample} = n_2 * d_2$ $Width_{SL} = 11.85$ in
$Width_{GG} = 4.91$ in

$Area_{Open}$ = n_1*n_2*Aperture_Dimension_1*Aperture_Dimension_2 $Area_{Open,SL} = 106.76\ in^2$
$Area_{Open,GG} = 680\ in^2$

$Area_{Total} = Length_{Sample} * Width_{Sample}$ $Area_{Tota,SL} = 167.05\ in^2$
$Area_{Total,GG} = 1120\ in^2$

$POA = (Area_{Open}/Area_{Total})*100$
POA _SL= 63.9%
POA_GG = 60.7%

The POAs are greater than the 50% minimum required, demonstrating compliance.

HULL THICKNESS CALCULATIONS

Calculations per Exhibit 5

Annotation

T_G = 0.045 in Average thickness of first layer of reinforcement, GlasGrid®8511 Mesh

T_S = 0.050 in Average thickness of second layer of reinforcement, SpiderLath Mesh

T_H = 0.375 in Nominal thickness of the canoe hull

Determine that the reinforcement at any point in the canoe will not exceed 50% of the total hull thickness.

Solution

Within the canoe, a maximum of one layer of GlasGrid®8511 and two layers of SpiderLath were used along the bottom of the canoe.

$$\frac{T_G + 2T_S}{T_H} * 100 = 38.7$$

The two layers of reinforcement make up approximately 38.7% of the hull. This value is less than the maximum value of 50% outlined in Exhibit 5, demonstrating compliance.

GUNNEL CAP THICKNESS CALCULATIONS

Calculations per Exhibit 5

Annotation

T_S = 0.050 in Average thickness of the layer of reinforcement, SpiderLath Mesh

T_C = 0.1875 in Diameter of the steel cable

T_W = 1 in Nominal thickness of the gunwale cap

Determine that the reinforcement at any point in the canoe will not exceed 50% of the total hull thickness.

Solution

One layer of SpiderLath Mesh and the steel cable were used throughout the gunnel cap.

$$\frac{T_S + T_C}{T_W} * 100 = 23.75$$

The layer of reinforcement and cable make up approximately 23.75% of the gunnel cap. This value is less than the maximum value of 50% outlined in Exhibit 5, demonstrating compliance.

Appendix F- Bill of Materials

Bill of Materials	Cost
Lafarge Portland Cement C-150	$ 1.69
Blast Furnace Slag	$ 0.47
Class C Fly Ash	$ 0.65
NORCHEM Undensified Silica Fume	$ 1.37
NYCON RFS400 PVA	$ 0.71
SIKA ENDURO PRIME	$ 0.94
GlasGrid 8511	$ 7.89
SpiderLath	$ 7.89
3/16" Steel Cable	$ 1.36
Trinity Haydite	$ 0.56
DOW Extruded Polystyrene Foam	$ 42.50
Elemix	$ 7.35
Recycled Concrete Aggregate	$ 0.71
Direct Colors Concrete Pigments	$ 9.41
Distilled Water	$ 1.14
BASF Glenium 3030 NS	$ 0.45
Sealkrete Clear-Seal	$ 32.89
Silhouette Glossy Permanent Vinyl	$ 1.50
TOTAL COST PER CANOE	**$ 119.48**

Activity	Projected Total Person-Hours	Associated Cost
Project Management	18	$ 860.00
Hull Design	13	$ 325.00
Structural Analysis	30	$ 600.00
Mixture Design Development	40	$ 4,732.50
Mold Construction	32	$ 991.75
Canoe Construction	69	$ 1,819.75
Preparation of Technical Proposal	50	$ 1,000.00
Presentation	336	$ 6,720.00
Display	50	$ 1,550.00
Shipping Costs - Trailer	N/A	$ 100.00
TOTAL	$ 638.00	**$ 18,699.00**
TOTAL COST PER CANOE		**$ 119.48**
GRAND TOTAL		**$ 18,818.48**

Pre-Qualification Form (Page 1 of X)

Michigan Technological University

(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.	LB, RAS
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)	LB, RAS
The eligibility requirements of registered participants (Section 2.0 and Exhibit 3)	LB, RAS
The deadline for the submission of *Letter of Intent* and *Pre-Qualification Form* (uploaded to ASCE server) is October 16, 2020.	LB RAS
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.	LB, RAS
The last day to submit *Request for Information* (RFI) to the C4 is January 22, 2021.	LB, RAS
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.	LB, RAS
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.	LB, RAS
The submission date of *R. John Craig Presentation* for Conference Competition (uploading of presentation to ASCE server) is Friday, February 19, 2021.	LB, RAS
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.	LB, RAS
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.	LB, RAS

Lauren Bowling	10/10/2020	R. Andrew Swartz	10/13/2020
Team Captain	*(date)*	*ASCE Student Chapter Faculty Advisor*	*(date)*
Lauren Bowling		Raymond A. Swartz	
(signature)		*(signature)*	

Pre-Qualification Form (Page 2 of X)

Michgan Technological University

(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?

As of 10/10/2020, instructure is hybrid. After Thanksgiving Break, instructure is currently planned to remain hybrid.
As of 10/10/2020, it is planned to have access to a laboratory space throughout the semester, even if instructure changes remote or on-line.

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.

The team has a health and safety plan in place that centers around proper training for personal and proper use of personal protection equipment (PPE) in both the laboratory and paddling environment. Prior to being allowed into the on-campus laboratory space, members must complete assigned on-line safety training courses, which include general safety awareness, hazard communication, PPE equipment, the university chemical hygiene plan, and COVID-19 prevention. Member who complete the on-line portion of the training, must then complete a laboratory walk-through, where the laboratory supervisor familiarizes them with resources available to them, their current safety procedures, and potential hazards in their work area. There is also a minimal laboratory space dress code that anyone in the space must adhere too; pants, closed toed shoes, and safety goggles. Dusk masks, gloves, and hard hats are provided and used as needed. At paddling practices, all boats are equipped with enough life-vests for everyone in the boat and the team works alongside a former U.S. Coastguard to asses the weather conditions before practices.

COVID-19 now requires all meetings to be held on-line and restricts the number of personal in the laboratory space When meeting in-person, all personal are required to properly wear a mask and maintain social distance of 6-feet, in addition to any other safety requirements (such as safety glasses, hard hats, or life-jackets).

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 team's QC/QA plan consists of three separate sectors: schedule control, compliance control, and knowledge control. Schedule control consists of material procurement, communications, and budget. The focus of compliance control remains on documentation and technical review and within knowledge control, there is an emphasis is on training, recruitment, and knowledge transfer. The team has one QC/QA committee head that oversees the implementation of the various sectors, however, each committee head is also responsible to maintain knowledge transfer to less tenured members within their own areas of expertise.

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?

Yes, the team has reviewed the Department and University safety policies relevant to our work.

The core project team is made up of 32 number of people.

The anticipated canoe name and overall theme is – space.

The team plans to hone in on the perseverance demonstrated by the recent NASA Mars rover launch and the astronomical impacts that many Michigan Tech clubs are making on the Aerospace industry. The technical proposal, EFA report, and John Craig legacy competition submission are expected to reflect a "galaxy" aesthetic.

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

Yes--no Trademark or Copyright issues are expected.