KRAKEN

Michigan Technological University
Design Report 2022

Cover letter

Michigan Technological University's 2021-2022 Concrete Canoe team hereby certifies that the design and construction of *The Kraken* has been completed in compliance with the rules and regulations of the National Concrete Canoe Competition. The ten registered participants are qualified, eligible student members and national student members of ASCE. *The Kraken* was completely built 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 constructed *The Kraken* in methods conducive to a high degree of safety. The team acknowledges receipt of the Request for Information (RFI) Summary, and *The Kraken* complies with responses thereof.

Registered Members of the 2021-2022 Michigan Tech Concrete Canoe Team

Lauren Cole	11855298	Corbin Sullivan	10765493
Sydney LaForest	10775654	Jason Cinader	11000686
Henry Summers	10957008	Collin Vander Beek	11949737
Steph Klaysmat	11927679	Kait Pascoe	11911054

Kraken Dimensions

Total Length	20 Feet
Maximum Width	2 Feet
Maximum Depth	15.5 Inches
Average Thickness	3/8th Inch
Overall Weight	205 lbs

Properties of the Concrete Mixture and the Composite Material

Mixture	Unit Weight (pcf)		Strength (psi)				Air Content (%)
	Wet	Oven-Dry	Compressive		Tensile		
			14-Day	28-Day	14-Day	28-Day	
Structural	74.1	72.5	1798	1977	350	410	-24.6
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:

The waters surrounding the Keweenaw Peninsula are an important part of the culture at Michigan Tech. They provide beautiful scenery and profound mystery to the already charming part of the Upper Peninsula of Michigan. The Michigan Tech Concrete Canoe team was inspired by the depths of the waters surrounding the place students call home.

There are legends that come with the Great Lakes. In Lake Superior, near the Presque Isle River, there is a mythical tale telling of a glowing creature named Pressie. In one tale, a diver came across Pressie in an underwater cave, and in another, it was said that bystanders witnessed the beast snatch an unsuspecting deer trekking across Lake Superior's shores. Another being is shown in pictographs at the Lake Superior Provincial Park. These 500-year-old pictographs portray a water lynx and two giant serpents near a canoe. The Michigan Tech Concrete Canoe team wanted to create a boat design that would last the test of time along with the legends of the sea.

Table 1: Properties of *The Kraken*

The Kraken (2022)	
Weight	205 lbs
Colors	Black and Purple
Maximum Length	20 Feet
Maximum Width	2 Feet
Primary Reinforcement	SpiderLath
Secondary Reinforcement	GlasGrid 8511®

To complete the team's goal of creating a lasting design, the team researched and utilized aspects of last year's canoe data. This year, our primary goal was to improve the straight-line speed of the 2020/2021 hull design *Voyager*. *The Kraken* was designed to have a fast straight line speed while also allowing paddlers to more effortlessly lean into turns.The major change that was made in the latest design was the shape of the hull. While our past boat, *Voyager, utilized* a shallow flat bottom cross section, *The Kraken* was designed with a rounded bottom.

The team's mix committee worked diligently to create a mix that followed the rule changes in the

2022 competition. They ultimately decided to use a final structural mixture that does not comply with the rule requiring that 50% or more of the aggregate volume be composed of a combination of recycled concrete aggregate or ASTM C330 compliant aggregate. The two compliant aggregates we possessed and tested were recycled concrete aggregate and Haydite. These materials are significantly heavier than all of our other aggregates. Due to time constraints, it was not feasible to research, order, and then test alternative ASTM C330 compliant aggregates. The mixture committee has begun researching lightweight ASTM C330 compliant materials that can be incorporated into future years' mixtures. The team decided it was better to work on knowledge-transfer through the creation of a boat that floats but is noncompliant with this rule. This was not an easy decision, but it was in the best interest of the team's future success.

The team's reinforcement committee tested several different reinforcement combinations throughout the year. The reinforcement design consisted of two different reinforcing meshes: GlasGrid 8511® and SpiderLath. Three materials were considered for *The Kraken*: GlasGrid 8511® (GG), SpiderLath (SL), and FG050 (FG). Data was gathered from flexural bend tests in accordance with ASTM C1341. The committee tested each reinforcement in its continuous state, in order to obtain comparable strengths of each material. Beams were constructed with two layers of reinforcement, ensuring that all meshes were tested on their own and in combination with the other two.

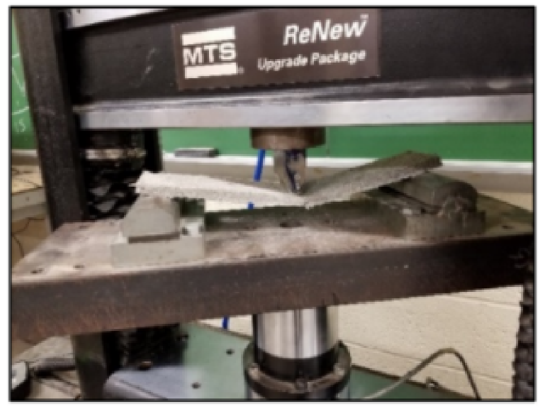

Figure 1: ASTM C1341 Flexural Bend Test

Table 2: Properties of the Concrete Mixture and the Composite Material

Mixture	Unit Weight (pcf)		Strength (psi)				Air Content (%)
	Wet	Oven-Dry	Compressive		Tensile		
			14-Day	28-Day	14-Day	28-Day	
Structural	74.1	72.5	1798	1977	350	410	-24.6
Pigmented Finishing	66.05	65.5	510	580	220	250	4.7
Composite Flexural Strength: 1080 psi							

Project Delivery Team:

ASCE Student Chapter Profile

Michigan Tech's chapter of ASCE exists to provide civil engineering students opportunities to develop their engineering skills and knowledge, a support network consisting of students and professors, and the chance to hear from professional engineers. The chapter currently holds about 50 members with 30 of those members being registered national members. The student engagement with ASCE continues to grow every year, while the executive board continues to find new ways to reach out to the student body and local community. Monthly meetings are held in which faculty members and industry partners speak on a variety of topics, including their experiences in the engineering field and advice for future civil engineers.

In addition to the monthly meetings held for members, Michigan Tech's chapter of ASCE enjoys being involved on campus and in the community. The chapter volunteers to clean up a section of highway 41 that runs through Houghton and the Upper Peninsula of Michigan three times a year. The chapter also takes part in volunteering for the annual university sponsored event called "Make a Difference Day," where members are assigned tasks to support the community such as raking leaves or cleaning windows. The chapter looks forward to finding new opportunities to support the community while continuing in its traditional ways.

Michigan Tech's Concrete Canoe team is composed of 23 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. These positions are supported by committee heads that specialize in mix design, hull design, reinforcement development, among other crucial aspects of 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.

Key Team Members/Organizational Chart

Project Managers:

Lauren Cole, Sr & Henry Summers, Jr

Committee	Committee Head	Roles
Reinforcement	Henry Summers, Jr	Research and development of a strong reinforcement that can be troweled over.
Paper	Kait Pascoe, Jr	Delegating, editing, and finalizing the team's final design paper.
Safety	Sydney LaForest, So	Providing safety training and managing safety throughout the year.
QC/QA	Owen Green, So	Training for troweling and depth gauge usage.
Structural Mix/Co-Construction	Connor Dykehouse, Jr	Research and development of a strong, lightweight, and workable structural mix.
Finishing Mix/Structural Analysis	Jacob Byron, Jr	Research and development of a strong, lightweight, and workable finishing mix.
Paddling	Colin VanderBeek, Jr	In charge of paddling practices and drills.
Mix Supervisor	Jason Cinader, Sr	Supervises mix process throughout the year.
Hull Design	Corbin Sullivan, So	Research and development of a fast and durable hull design in which the paddlers can succeed.

Additional Members: Steph Klaysmat, Sr., Alex Rogers, Sr., Isodon Williams, So., Patrick Mungcal, Fr., Jake Hazel, Fr., Sam Pendell, Fr., Suraiya Siddiqi, So., Brendan Hedge, Fr., Lydia Lamey, Fr., Sydney Streveler, Jr., Emma Strutz, Fr., Duffy Karstrom, So., and Luke Sturm, So.

Technical Approach to the Overall Project:

Approach to Design, Analysis, & Construction

The primary goals of the mixture committee this year included transferring knowledge to our young and inexperienced team, creating a mixture with high workability to account for the said inexperienced troweling team, and replenishing our material supply.

Recruiting new members to the mixture committee was a priority from the start of the year. It was determined that a hands-on approach would be the most efficient way for team members to become more involved and learn more about the mixture committee's work. General members of the club, not previously involved with the mix committee, were shown how to measure out, mix, and then properly fill concrete test cylinders (ASTM C192). Mixture committee heads held information sessions detailing how mixture designs were created and adjusted. Members were also shown how to operate the concrete compression machine. Our club began the year with two active members of the mixture committee and finished the year with eight now-qualified contributors.

It was identified early in the year that our supply of several materials used in our mixtures was depleted. Our club had not ordered materials in the past several years and replacing our supply was necessary this year in order to test multiple different mixture designs. Committee head members reached out to local concrete suppliers and university faculty members to identify how and where materials could be purchased. Some of the materials purchased throughout the year included Type I Portland Cement, Class C Fly Ash, Haydite, and two types of NYCON fibers.

This year's structural mix is an adaptation of Michigan Tech's 2019-2020 mix, *Backfill*. Individual concrete mixtures were tested at seven and fourteen day intervals for compressive strength (ASTM C39) and unit weight (ASTM C138). NYCON PVA RF4000 and NYCON PVA RFS400 fibers were used throughout testing in order to lessen the difficulty of troweling. Similarly, larger diameter microspheres such as Poraver 2-4 mm were not used. The binder blend from *Backfill* was used as a baseline. It was determined through testing that decreasing the amount of Fly Ash and increasing the amount of Silica Fume, both pozzolanic materials, improved the compression strength while also lowering the weight. Aggregate proportions became the focus due to the new competition rule stating that 50% or more of the total aggregate volume must be a combination of ASTM C330 compliant aggregates or recycled concrete aggregate. As we progressed through the year the unit weights of our mixes were consistently well above the unit weight of water (62.4 pounds per cubic foot). Table 3 ------ shows the mass in grams of the cylinders for our aggregate tiered tests and their respective unit weights. The tests highlighted in red were immediately disregarded, regardless of their unit weight, because they were considered too difficult to trowel.

Table #. Unit Weights

Aggregate Test Number	Cylinder Mass (grams)	Unit Weight (lb/ft^3)
A1	925.3	83.11
A2	855.5	76.84
A3	890.8	80.01
A4	926.1	83.18
A5	819.1	73.57
A6	781.0	70.15
A7	898.9	80.74
A8	764.2	68.64
A9	824.0	74.01
A10	830.3	74.58
A11	758.2	68.10
A12	810.3	72.78
A13	820.0	73.65

Previous Michigan Tech teams used a lightweight aggregate called Elemix due to its low specific gravity. It was identified at the beginning of the year that our current supply of Elemix would not be sufficient to construct an entire boat. The mixture committee looked into purchasing additional Elemix but the material is no longer commercially available. Our team's lack of an extremely lightweight material like Elemix contributed to our mixture designs having high unit weights.

With the unit weights of our mixtures too high, the mixture committee ultimately decided to use a final structural mixture that does not comply with the rule requiring 50% or more of the aggregate volume being composed of a combination of recycled concrete aggregate or ASTM C330 compliant aggregate. The two compliant aggregates we possessed and tested were recycled concrete aggregate and Haydite. These materials are significantly heavier than all of our other aggregates. Due to time constraints, it was not feasible to research, order, and then test alternative ASTM C330 compliant aggregates. Therefore, the mixture committee came to the conclusion that it would be more advantageous to our young and inexperienced team to design a mixture that is light enough to float, albeit being non-compliant, as opposed to using a mixture that is compliant but does not float. The mixture committee has already begun researching lightweight ASTM C330 compliant materials that can be incorporated into future years mixtures.

Figure 2 ----- shows the final structural mixture aggregate proportions by volume. Through a series of tiered tests, the six aggregate combination shown in the figure was found to have the best blend of high compression strength and low weight. As discussed above, the total volume of ASTM C330 compliant aggregates and recycled concrete aggregate is 17% and does not comply with the rule. Haydite was tested but ultimately not used in our final mix due to its high weight.

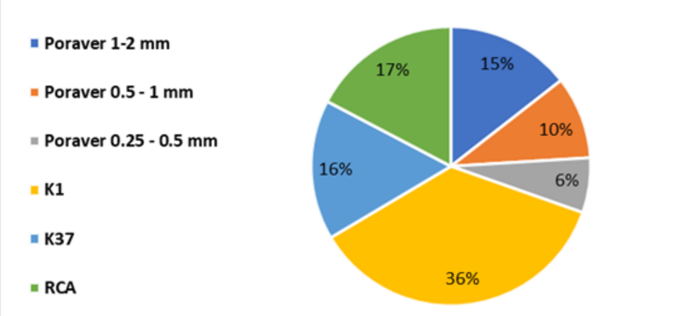

Figure #. Aggregate Proportions by Volume

Structural Analysis:

The goal of the Structural analysis committee was to create parameters and goals for the demands of the materials for the material development committee this year. To find the loads put onto the canoe the average weights of the men and women were calculated as 240 lbs for the men and 170 lbs for the women. To find the load placed on the canoe we divided the weight of the paddlers. In order to solve this issue, the location of the cracks was measured as 120 in from the front of the canoe on average. From there, a shear stress calculation was performed to figure out the maximum shear stress experienced by the canoe during races.

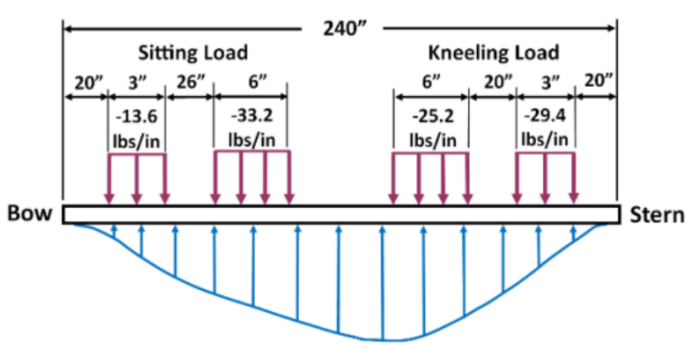

Figure 3- - - A buoyant force equal to the weight of the paddlers and canoe was also factored in. It was found that the maximum shear stress occurred during the men's sprint race and was 872 psi (tension) at the gunwales. An iterative excel sheet was used to calculate the moment of inertia for the applicable cross section in order to calculate this stress value. The maximum tensile stress of the canoe at the gunwales is 280 psi. In previous years we had put a steel cable into the gunwales in order to add tension to the canoe and help reduce the damage done by cracking. This year however we did not put the steel cable into the gunwales, as we were focusing on teaching core pieces of the project and not components that we were not confident in.

Reinforcement:

This year, the team decided not to expand on the testing and development of a new reinforcement scheme for multiple reasons. Instead, it was decided that focusing on the collection of data for all materials in the lab would be beneficial for the team as baseline data for future testing due to the limited transfer of knowledge that occurred over the past few years. Additionally, a second major goal of the reinforcement committee was to improve committee recruitment and retention in order to create a strong foundation of knowledge for future years.

The first step taken by the reinforcement committee was to take inventory of the lab to evaluate what materials were readily available to use in this year's canoe.The following four reinforcement meshes were considered for the design of *Kraken,* Panzer 15 (PA), FG050 (FG), GlasGrid 8511® (GG), and SpiderLath (SL). Data was collected from three-point bend testing in accordance with ASTM C1341. Each reinforcement mesh was tested in its continuous state, in order to obtain comparable strengths of each material. This was done using 14 in. x 3 in. beams constructed in wooden molds with two layers of reinforcement separated by ⅛ in. layers of concrete, ensuring that all meshes were tested on their own and in combination with the others. Due to the fact that the reinforcement testing was being done prior to the selection of a final mix design, all testing was done using a compliant concrete mix similar to those used in previous years as structural mixes. The results of this testing are summarized in Table YY.

In addition to mechanical testing, reinforcement schemes were also evaluated based on qualitative trowler feedback. Over the course of several mock-castings, the workability during troweling and bond quality of the reinforcement with the concrete was analyzed. Panzer 15 was removed from consideration following severe delamination in both the beam testing and mock-casts (Figure XX). Because the reinforcement was stored tightly wound up in rolls, reinforcement sections were pre-cut before casting and weights were placed on top of the sheets in order to ensure they were flat. This was a successful measure to prevent curling of the reinforcement during casting.

Figure 4: Delamination of a bend test beam containing Panzer 15 reinforcement.

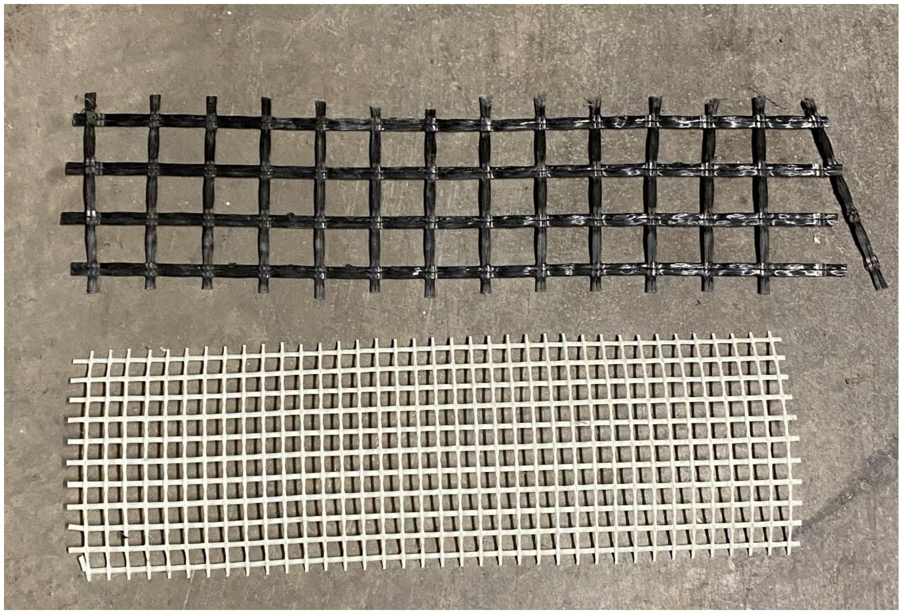

Figure 5: GlasGrid 8511 (top) and SpiderLath (bottom).

Table 4: Primary Reinforcement Specifications.

Reinforcement	Composite Flexural Strength (psi)	Weight (lb/ft^2)	Open Area (%)
GlasGrid 8511	234	0.08	60.7
SpiderLath	500	0.06	63.9
FG-50	225	0.08	62.1

The final reinforcement scheme was selected based on a combination of bend test data and qualitative analysis of the materials. GlasGrid 8511 and Spiderlath had superior flexural strengths when compared to the other materials, and were far more workable. Neither of these materials had substantial delamination during testing. The most favorable orientation to maximize flexural strength was an inner layer of SpiderLath with 1.5 in. overlap and an outer layer of GlasGrid 8511. This reinforcement scheme is very similar to the scheme that was used in the design of Driftwood. The reinforcement committee hopes to use the baseline data that was gathered to more efficiently further explore not only new meshes with improved properties, but also new methods to quantify other properties of the concrete-reinforcement interface.One such test method is a pullout test, which could be used to analyze the bond strength between the mix and reinforcement.

Approach to Project 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 next 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 passing down their knowledge to future members. At the end of the year the team nominates and elects new committee heads to lead the organization the following year.

The goal of the organizational structure is to promote knowledge transfer, and has worked well in previous years. The team ultimately fell short in these knowledge transfer efforts, as covid affected the ability for older previous members to teach younger members critical aspects of the research and design methods, along with team expectations. Luckily the team has years worth of documents called ‘things learned.’ This document breaks down each committee and what is believed could be improved upon from year to year.

The main goal for the Senior project manager this year was to work in conjunction with the committee heads to teach all aspects of the project to younger members. The majority of the committee heads were new to their position and were not well enough equipped to complete R&D in a manner that the team would in previous years. This year the team focused on filling gaps of knowledge for the success of future years products.

The year began with the development of the project schedule. 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, and aesthetics along with competition display elements being completed in the spring semester.

The major milestones for this year's project were hull design completion, mix design completion, along with EFA and technical paper submissions. These activities were determined so that the critical path could be developed. A couple critical path items that were determined were structural mix design completion, and reinforcement design completion.

Weekly meetings were held to update the team on where progress stood for each committee, as well as which committee’s may need additional assistance week to week. This open flow of communication allowed the team to come up with a deliverable we are proud of in a time that made it difficult to do so. Overall the team put in a little under 600 person hours worth of work, and expects to put in an additional 200 person hours for aesthetics, stands and display, presentation practices and miscellaneous project management tasks.

Approach to Quality Control/Quality Assurance (QC/QA)

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

Troweling practices were held on a bi-weekly basis in an effort to integrate newly recruited members into the team, as well as relearn the knowledge that was lost due to last year. These practices used previous years’ molds to trowel and is an example of one of the team’s environmentally sustainable aspects. At the practices, the team used different mix and reinforcement designs to become comfortable and knowledgeable on how to properly trowel different mix and reinforcement schemes as well as using prior years unused materials; this will promote a timely and successful casting day.

The Quality Assurance and Quality Control (QC/QA) team is crucial in ensuring that the troweled layers of concrete are consistent in depth, and used 3-D printed depth gauges set to 1/8th, 1/4th, and 3/8th of an inch. A quality assurance measure taken prior to casting day is pre-mixing all of the mix batches, this allowed the team to also save time during casting day and has increased consistency throughout batches.

In previous years, the first layer of concrete was approximately 1/3rd of the way down the length of 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. Once the first layer of concrete was completely troweled, the process began again at the bow and continued until all three layers of concrete were applied.

A layer of reinforcement and concrete are troweled into the gunwales. This staggered method aims for the canoe to be entirely cast in less than four hours, minimizing the possibility of cold joint occurrences. However, this process was fairly new to most team members as we did not have a complete casting day last year and many of the experienced team members from previous years have graduated. The team practiced troweling and checking the thickness with depth gauges, watched a video of the staggered troweling method from a previous year, and asked questions throughout practices and meetings in preparation for casting day. Completing the construction of *The Kraken* will help with knowledge-transfer for the newer members and will lead to future success.

Once the canoe was cast, the boat was stored in a curing room built with a temporary structure to ensure that the temporary humidifiers placed within were 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 was 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 had adequate compressive strength to begin the demolding process. The mold pieces were carefully removed from the canoe's exterior, making it ready for the aesthetics committee to begin their work.

Approach to Sustainability

Through the challenges of the COVID-19 Pandemic, creative breakthroughs have been necessary to make the world more sustainable. At Michigan Tech, the team's goal this year was to improve on our sustainability efforts from previous years while continuing to keep in mind the Triple Bottom Line: focusing on the environment, the economy, and society. Each of these three pillars play an important role in sustainable engineering.

Outside of building the canoe, the team has made efforts to use more sustainable practices. Masks have become a large portion of solid waste during the Covid-19 Pandemic. To help reduce this waste, the team was encouraged to purchase washable, reusable face masks. This largely cut down on some of the waste that was encountered from the previous year. Another form of waste the team wanted to reduce was atmospheric emissions such as CO_2 emissions. To help combat these, the team carpooled and/or walked to a destination more than driving themselves. For example, paddling practice requires a vehicle to get to, and the team decided to take the minimum amount of vehicles possible to the location.

In order to reduce solid waste, we had to be certain that the materials were correct before the construction of the canoe. We systematically tested different mixtures and layering to determine the best combination with the lowest number of trials. This created the strongest material with the least waste. Also, by carefully designing the hull using a 3D modeling software before printing, we reduced plastic waste.

Approach to Health & Safety

The Michigan Technological University Concrete Canoe Team cannot succeed without the prioritization of each member's health and safety; therefore, a safety plan is implemented into almost every aspect of operation. Each member of the team is required to complete an online safety training which educates members on the general safety of working in a lab and proper use of equipment and chemicals. In addition, members are required to tour the lab with the lab supervisor to learn about the provided tools, how to safely operate them, and become familiar with Michigan Tech's emergency protocols within the lab. In order to mitigate the risk of injury in the lab, members are required to wear the proper attire, such as long pants and closed toed shoes, in addition to safety glasses, gloves and a dust mask. There is also a designated space within the lab for eating and drinking. During paddling practice, canoes are supplied with the proper amount of life vests per person, and Michigan Tech's water activity safety standards are always followed. The team follows Michigan Tech's guidelines on COVID-19 procedures in all instances, such as at general meetings, paddling practice, and lab work.

Construction Drawings and Specs

Table 5: Hull Design Comparison

	Voyager	Kraken
Overall Length (ft)	20	20
Freeboard (in)	0.785	0.583
Block Coefficient	0.542	0.431
Prismatic Coefficient	0.628	0.538
Load Waterline (ft)	19.981	19.968
Optimum Speed (Knots)	6.035	6.77
Heel Angle Tipping Point (degrees)	45.000	50

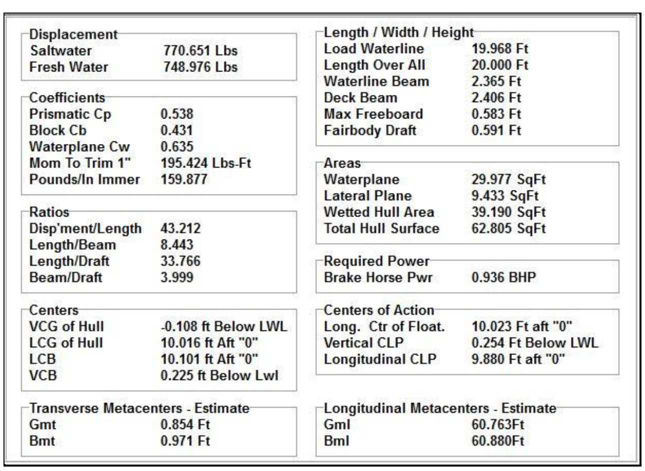

Figure 6: Hydrostatic Information

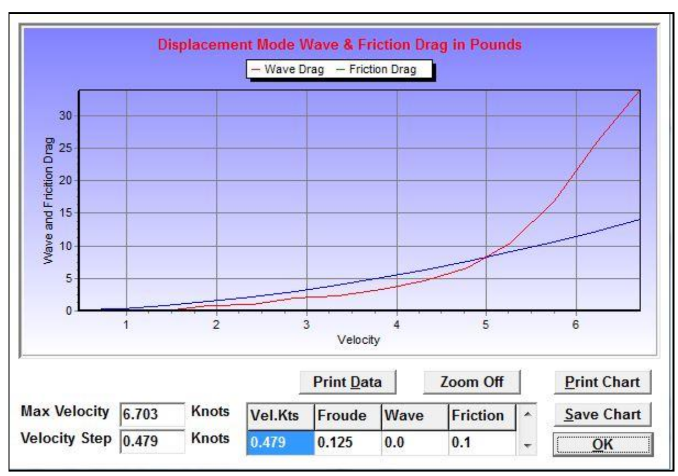

Figure 7: Drag and Friction Information

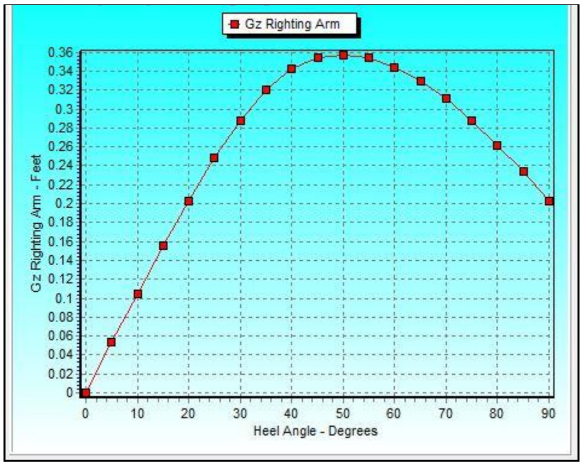

Figure 8: Stability Analysis in Feet and Pounds

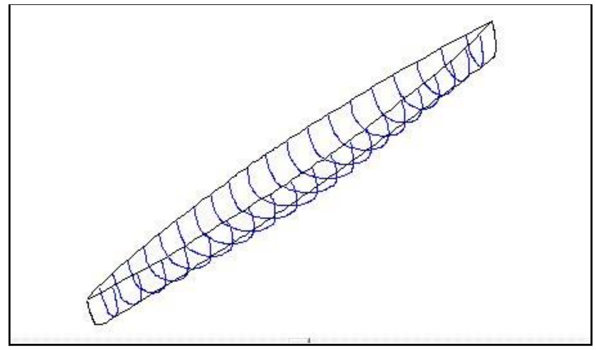

Figure 9: Isometric View of Hull Design

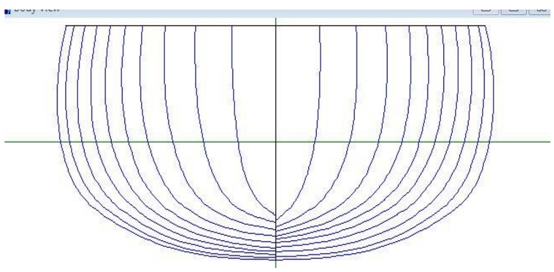

Figure 10: Front View of Hull Design

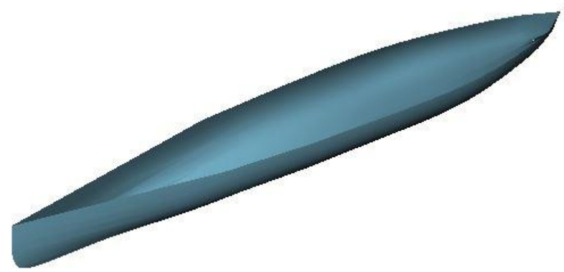

Figure 11: Rendering of Hull Design

Approach to Project Schedule

The schedule was developed from the outline of previously successful projects, with most of the research and development happening during the fall semester, and aesthetics along with competition display elements being completed in the spring semester. Some of the major milestones occurring during the length of the project include selection of the final structural mix, finishing mix, and reinforcement scheme, along with the completion of the technical proposal and presentation. These milestones, along with the completion of the final display elements, are crucial in providing a high-quality final product for competition.

This year, the Michigan Tech Concrete Canoe team has a dual critical path on the final schedule. This is due to the importance of the structural mix and reinforcement scheme development during the fall semester. The critical path continues with casting, curing, and applying the aesthetics to the canoe. These aspects must be completed on time in order for the project to continue without delay. One risk to the schedule included material procurement during the research and development phase. This risk was mitigated by having meetings with committee heads early on to determine quantities needed in order to successfully develop a mix with the desired qualities. Through this scheduling process, the Michigan Tech Concrete Canoe team was able to achieve their goals without any major delays in the project. There was a slight delay due to the manner in which the team was able to receive the mold for the canoe. The company that the team typically gets its mold was not able to provide one this year. Due to this, team members had to research and find a new company. Unfortunately, this company was farther away than past years, and team members had to make a trip to retrieve the mold. Because of this situation, casting day for the canoe was pushed back slightly. This is the reason for not being able to acquire 28-day strength testing.

Appendices:

Appendix A - Bibliography

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Appendix B - Mixture proportions and primary mix calcs

MIXTURE: STRUCTURAL

CEMENTITIOUS MATERIALS				
Component	*Specific Gravity*	*Volume ft³*	*Amount of CM lb/yd³*	
Type 1 Portland Cement, ASTM C150	3.15	1.888	371.0	Total cm (includes c) 766.6 lb/yd³ c/cm ratio, by mass 0.484
Blast Furnace Slag	2.99	0.822	153.3	
Fly Ash – Class C	2.65	0.185	30.7	
Silica Fume	2.22	1.527	211.6	

FIBERS				
Component	*Specific Gravity*	*Volume*	*Amount of Fibers lb/yd³*	
PVA RFS400	1.3	0.097	7.9	Total Amount of Fibers 13.2 lb/yd³
PVA RF4000	1.3	0.065	5.3	

AGGREGATES (EXCLUDING MINERAL FILLERS PASSING NO. 200 SIEVE)							
T	*ASTM C330 or RCA¹*	*Abs (%)*	*SG_{OD}*	*SG_{SSD}*	*Base Quantity, W*		*W3*
					W_{OD} lb/yd³	*W_{SSD} lb/yd³*	
Poraver 1-2 mm	No	20.0	0.39	0.468	58.507	70.208	2.404
Poraver 0.5-1 mm	No	25.0	0.47	0.588	46.806	58.508	1.595
Poraver 0.25-0.5 mm	No	30.0	0.59	0.767	39.005	50.707	1.059
RCA (#8 Sieve)	Yes	22.0	0.76	0.927	136.517	166.551	2.879
K1	No	0	0.125	0.125	46.806	46.806	6.001
K37	No	0	0.37	0.37	62.408	62.408	2.703

LIQUID ADMIXTURES					
Admixture	*lb/ US gal*	*Dosage (fl. oz / cwt)*	*% Solids*	*Amount of Water in Admixture (lb/yd³)*	
BASF GLENIUM 3030NS	9.009	20	20.27	8.85	Total Water from Liquid Admixtures, $\sum w_{admx}$ 8.55 lb/yd³

SOLIDS (DYES, POWDERED ADMIXTURES, AND MINERAL FILLERS)				
Component	*Specific Gravity*	*Volume (ft³)*	*Amount (lb/yd³)*	
K1	0.125	4.55	35.49	TOTAL SOLIDS. TOTAL 62.70 lb/yd³
K37	0.37	1.18	27.21	

WATER			
	Amount		*Volume ft³*
Water, w, [=$\sum (w_{free} - w_{admx} + w_{batch})$]	w/c ratio, by mass 0.98	361.8	6.7
Total Free Water from All Aggregates, $\sum w_{free}$		-63.7	
Total Water from All Admixtures, $\sum w_{admx}$	w/cm ratio, by mass 0.47	8.0	
Batch Water, w_{batch}		417.5	

DENSITIES, AIR CONTENT, RATIOS, AND SLUMP						
Values for 1 cy of concrete	*cm*	*Fibers*	*Aggregate (SSD)*	*Solids, S_{total}*	*Water, w*	*Total*
Mass, M	766.6	13.2	455.2	62.7	417.5	∑M: 1715.2 lb
Absolute Volume, V	4.42	0.16	16.64	5.73	6.70	∑V:33.65 ft³
Theoretical Density, T, (=∑M / ∑V)	50.97 lb/ft³		*Air Content, Air, [= (T – D)/T x 100%]*			-42.24 %
Measured Density, D	72.5 lb/ft³		*Air Content, Air, [= (27 – ∑V))/27 x 100%]*			-24.63 %
Total Aggregate Ratio² (=$V_{agg,SSD}$ / 27)	61.6 %		*Slump, Slump flow, Spread (as applicable)*			1.5 in.
C330+RCA Ratio (=$V_{C330+RCA}$ / $V_{agg,SSD}$)	17.3 %					

Appendix C - Structural and freeboard calcs

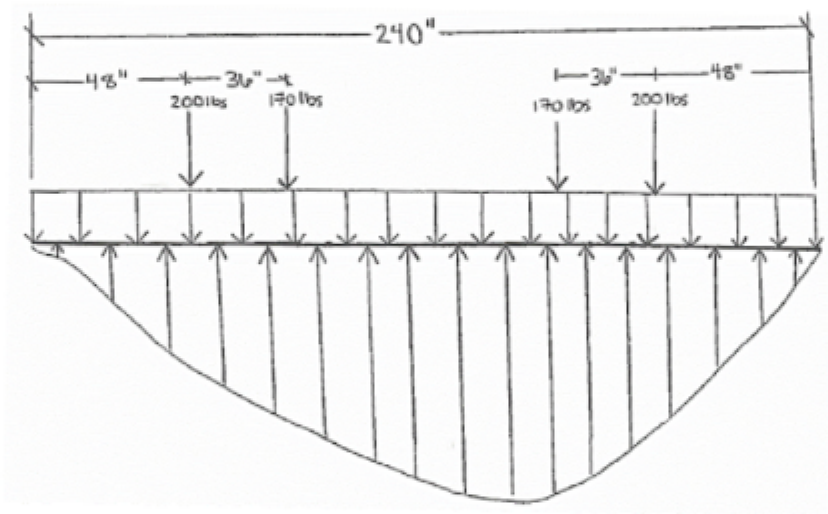


Figure 12: Free Body Diagram

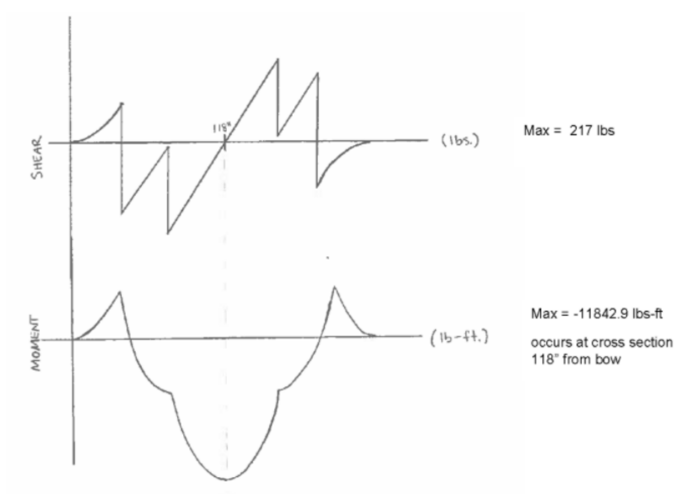


Figure 13: Shear and Bending Moment Diagrams

Appendix D - Hull / Reinforcement

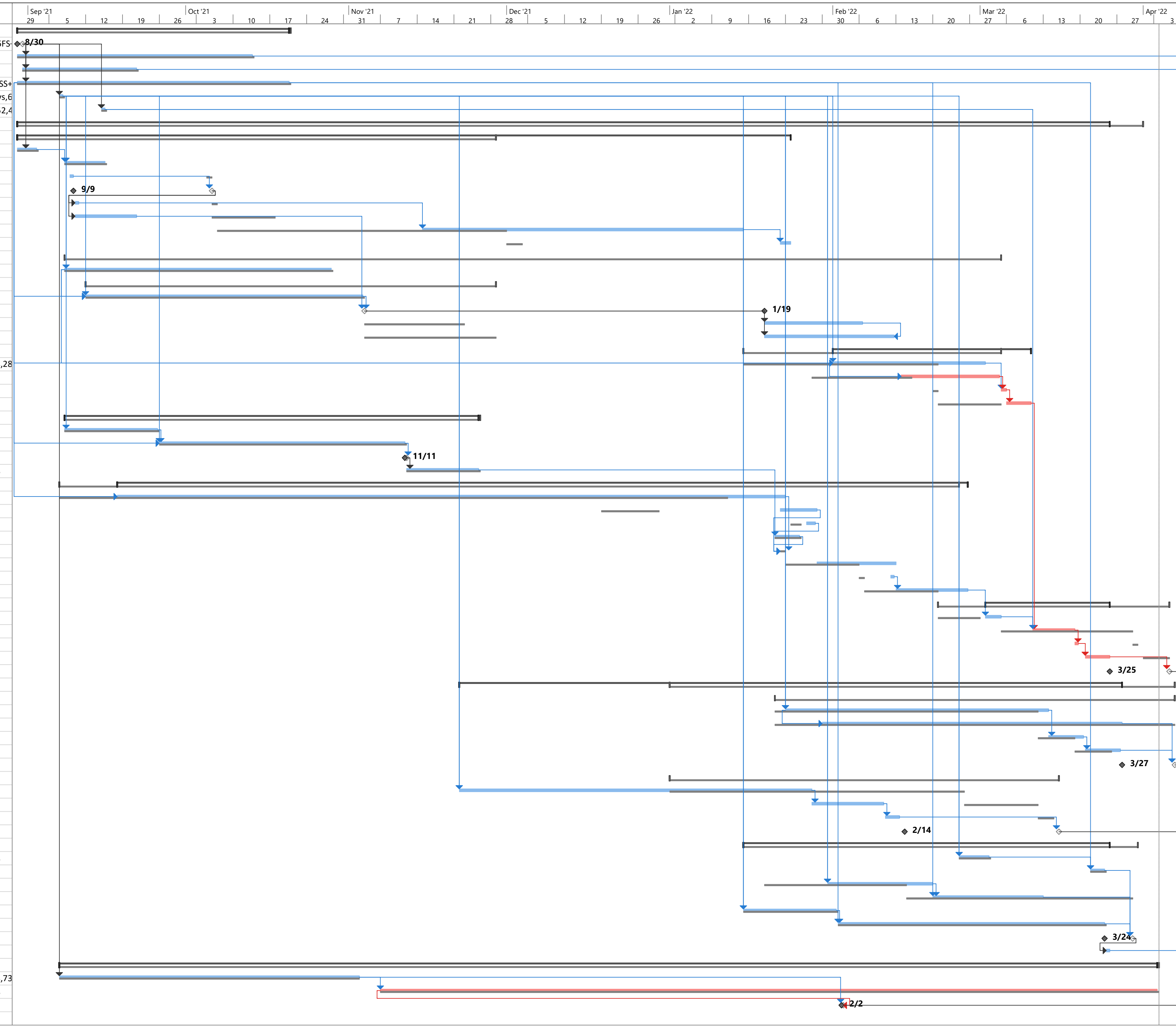
Hull Design

This year, our primary goal was to improve the straight line speed of the 2020/2021 hull design *Voyager*. The *Kraken* was designed to have a fast straight line speed and to be able to really lean while turning. Due to the outbreak of COVID-19 in the spring of 2020, the hull design of *Voyager* was never properly tested by our paddling team so, to improve the top speed and tipping point of the canoe, slight modifications were made to the design this year.

The major change that was made in this year's design, *Kraken*, was the shape of the hull. While *Voyager* utilized a shallow flat bottom cross section, *The Kraken* was designed with a rounded bottom. This design greatly improved the top speed of the canoe by creating less surface area which in turn causes less drag. *The Kraken* has an optimum speed of 6.77 knots, a substantial improvement over *Voyager,* which had an optimum speed of 6.035 knots. The heel angle at which the canoe will capsize is approximately 50 degrees, an increase of 5 degrees from last year's design.

The Kraken is an excellent model for the standardized hull design for future concrete canoe competitions. The slender hull with a high top speed allows the canoe to be very competitive, especially in the long, straight sections of each race. The paddlers this year were well experienced and put a large emphasis on turning exercises during practices. The simplicity of *The Kraken* design allows it to be easily duplicated. Teams can use either a male or female mold supplied by a CNC service. If a team does not have access to a CNC service, a mold could be shaped around full scale cross sections spaced out a foot apart.

ID	Task Name	Duration	Start	Finish	Baseline Start	Baseline Finish	Predecessors	Successors
1	**Project Management**	**52 days**	**Mon 8/30/21**	**Wed 10/20/21**	**Mon 8/30/21**	**Wed 10/20/21**		
2	Start of Academic Year	0 days	Mon 8/30/21	Mon 8/30/21	Mon 8/30/21	Mon 8/30/21		3,4FS+1 day,6FS-
3	Fundraising - Fall Newsletter	45 days	Mon 8/30/21	Wed 10/13/21	Mon 8/30/21	Wed 10/13/21	2	75
4	Recruitment	22 days	Tue 8/31/21	Tue 9/21/21	Tue 8/31/21	Tue 9/21/21	2FS+1 day	75
5	Lab Safety Training	52 days	Mon 8/30/21	Wed 10/20/21	Mon 8/30/21	Wed 10/20/21	2	21SS,32SS,36SS+
6	Rules Released & Reviewed	1 day	Tue 9/7/21	Tue 9/7/21	Tue 9/7/21	Tue 9/7/21	2FS+3 days	63FS+170 days,6
7	Theme Decision	1 day	Wed 9/15/21	Wed 9/15/21	Wed 9/15/21	Wed 9/15/21	2FS+15 days	58,63,65,67,52,4
8	**Canoe Development**	**208 days**	**Mon 8/30/21**	**Fri 3/25/22**	**Mon 8/30/21**	**Thu 3/31/22**		
9	**Hull Design**	**147 days**	**Mon 8/30/21**	**Sun 1/23/22**	**Mon 8/30/21**	**Sun 11/28/21**		
10	Hull Design Research	4 days	Mon 8/30/21	Thu 9/2/21	Mon 8/30/21	Thu 9/2/21	2	11
11	Draft Initial Hull Design	8 days	Wed 9/8/21	Wed 9/15/21	Wed 9/8/21	Wed 9/15/21	10,6	
12	Rework of Hull Design	1 day	Thu 9/9/21	Thu 9/9/21	Tue 10/5/21	Tue 10/5/21		13
13	Final Hull Design Selection	0 days	Thu 9/9/21	Thu 9/9/21	Tue 10/5/21	Tue 10/5/21	12	14,15
14	Release Hull Dimensions	1 day	Fri 9/10/21	Fri 9/10/21	Wed 10/6/21	Wed 10/6/21	13	16
15	Structural Analysis	12 days	Fri 9/10/21	Tue 9/21/21	Wed 10/6/21	Sun 10/17/21	13	22
16	Foam Sized and CNC Milled	61 days	Mon 11/15/21	Fri 1/14/22	Thu 10/7/21	Tue 11/30/21	14	17
17	Mold Pick-up and Delivery	2 days	Sat 1/22/22	Sun 1/23/22	Wed 12/1/21	Fri 12/3/21	16	
18	**Concrete Mix Design**	**178.13 days**	**Wed 9/8/21**	**Fri 3/4/22**	**Wed 9/8/21**	**Fri 3/4/22**		
19	Material Procurement for Testing	51 days	Wed 9/8/21	Thu 10/28/21	Wed 9/8/21	Thu 10/28/21	6	21SS,26SS
20	**Structural Mix**	**130.13 days**	**Sun 9/12/21**	**Wed 1/19/22**	**Sun 9/12/21**	**Sun 11/28/21**		
21	Binder, Aggregate, and Fiber Testing	53 days	Sun 9/12/21	Wed 11/3/21	Sun 9/12/21	Wed 11/3/21	6FS+4 days,19SS,5SS	22
22	Final Structural Mix Selection	0 days	Wed 1/19/22	Wed 1/19/22	Wed 11/3/21	Wed 11/3/21	15,21	24,23
23	Final Structural Mix Testing	19 days	Wed 1/19/22	Sun 2/6/22	Thu 11/4/21	Mon 11/22/21	22	24FF
24	Final Structural Mix Material Procurement	25 days	Wed 1/19/22	Sat 2/12/22	Thu 11/4/21	Sun 11/28/21	22,23FF	
25	**Finishing Mix**	**38 days**	**Tue 2/1/22**	**Thu 3/10/22**	**Sat 1/15/22**	**Fri 3/4/22**		
26	Finishing Mix Design & Testing	29 days	Tue 2/1/22	Tue 3/1/22	Sat 1/15/22	Sun 2/20/22	6FS+129 days,19SS,5SS	27SS+13 days,28
27	Application Technique Testing	19 days	Mon 2/14/22	Fri 3/4/22	Fri 1/28/22	Tue 2/15/22	26SS+13 days	28
28	Final Finishing Mix Selection	1 day	Sat 3/5/22	Sat 3/5/22	Sun 2/20/22	Sun 2/20/22	27,26	29
29	Final Finishing Mix Material Procurement	5 days	Sun 3/6/22	Thu 3/10/22	Mon 2/21/22	Fri 3/4/22	28	46
30	**Reinforcement**	**79 days**	**Wed 9/8/21**	**Thu 11/25/21**	**Wed 9/8/21**	**Thu 11/25/21**		
31	Material Procurement for Testing	18 days	Wed 9/8/21	Sat 9/25/21	Wed 9/8/21	Sat 9/25/21	6	32
32	Reinforcement Testing	47 days	Sun 9/26/21	Thu 11/11/21	Sun 9/26/21	Thu 11/11/21	6FS+18 days,31,5SS	33
33	Final Reinforcement Selection	0 days	Thu 11/11/21	Thu 11/11/21	Thu 11/11/21	Thu 11/11/21	32	34
34	Final Reinforcement Material Procurement	14 days	Fri 11/12/21	Thu 11/25/21	Fri 11/12/21	Thu 11/25/21	33	39FS+56 days
35	**Canoe Construction**	**162 days**	**Sat 9/18/21**	**Sat 2/26/22**	**Tue 9/7/21**	**Thu 2/24/22**		
36	Casting Practices	127 days	Sat 9/18/21	Sat 1/22/22	Tue 9/7/21	Tue 1/11/22	5SS+8 days	40
37	Mold Assembly	7 days	Sat 1/22/22	Fri 1/28/22	Sun 12/19/21	Wed 12/29/21		40
38	Pre-Batch Final Structural Mix	2 days	Thu 1/27/22	Fri 1/28/22	Mon 1/24/22	Tue 1/25/22		40
39	Pre-Cut Reinforcement	5 days	Fri 1/21/22	Tue 1/25/22	Fri 1/21/22	Tue 1/25/22	34FS+56 days	40
40	Concrete Placement	1.13 days	Sat 1/29/22	Sat 1/29/22	Sat 1/22/22	Sat 1/22/22	36,37,38,39	
41	Initial Cure with Mold	15 days	Sat 1/29/22	Sat 2/12/22	Sun 1/23/22	Sat 2/5/22		
42	Mold Removal	1 day	Sat 2/12/22	Sat 2/12/22	Sun 2/6/22	Sun 2/6/22		43
43	Final Curing	14 days	Sun 2/13/22	Sat 2/26/22	Mon 2/7/22	Sun 2/20/22	42	45
44	**Finishing & Aesthetics**	**24 days**	**Wed 3/2/22**	**Fri 3/25/22**	**Mon 2/21/22**	**Tue 4/5/22**		
45	Sanding	3 days	Wed 3/2/22	Fri 3/4/22	Mon 2/21/22	Mon 2/28/22	43	46
46	Interior & Exterior Design	8 days	Fri 3/11/22	Fri 3/18/22	Sat 3/5/22	Tue 3/29/22	45,29,7	47
47	Finish Aesthetic Design	1 day	Sat 3/19/22	Sat 3/19/22	Wed 3/30/22	Wed 3/30/22	46	48FS+1 day
48	Sealing	5 days	Mon 3/21/22	Fri 3/25/22	Fri 4/1/22	Tue 4/5/22	47FS+1 day	49
49	Finishing Complete	0 days	Fri 3/25/22	Fri 3/25/22	Tue 4/5/22	Tue 4/5/22	48	75FS+6 days
50	**Communications**	**126 days**	**Mon 11/22/21**	**Sun 3/27/22**	**Sat 1/1/22**	**Wed 4/6/22**		
51	**Technical Presentation**	**57.13 days**	**Sun 1/30/22**	**Sun 3/27/22**	**Fri 1/21/22**	**Wed 4/6/22**		
52	Create Presentation	50 days	Sun 1/23/22	Sun 3/13/22	Fri 1/21/22	Fri 3/11/22	6FS+135 days,7	54,53SS
53	Presentation Practice	57 days	Sun 1/30/22	Sun 3/27/22	Fri 1/21/22	Wed 4/6/22	52SS	56
54	Professional Reviews	7 days	Mon 3/14/22	Sun 3/20/22	Sat 3/12/22	Fri 3/18/22	52	55
55	Final Revision	7 days	Mon 3/21/22	Sun 3/27/22	Sat 3/19/22	Fri 3/25/22	54	56
56	Presentation Complete	0 days	Sun 3/27/22	Sun 3/27/22	Wed 4/6/22	Wed 4/6/22	55,53	75
57	**Design Paper**	**89.13 days**	**Mon 11/22/21**	**Fri 2/18/22**	**Sat 1/1/22**	**Tue 3/15/22**		
58	Paper Outline & Draft	67 days	Mon 11/22/21	Thu 1/27/22	Sat 1/1/22	Fri 2/25/22	6FS+50 days,7	59
59	Professional Reviews	14 days	Fri 1/28/22	Thu 2/10/22	Sat 2/26/22	Fri 3/11/22	58	60
60	Final Revision	3 days	Fri 2/11/22	Sun 2/13/22	Sat 3/12/22	Mon 3/14/22	59	61FS+1 day
61	Design Paper Submission	0 days	Mon 2/14/22	Mon 2/14/22	Tue 3/15/22	Tue 3/15/22	60FS+1 day	75
62	**Final Product Display**	**70 days**	**Sat 1/15/22**	**Fri 3/25/22**	**Sat 1/15/22**	**Wed 3/30/22**		
63	Cross Section Design	6 days	Fri 2/25/22	Wed 3/2/22	Fri 2/25/22	Wed 3/2/22	6FS+170 days,7	64FS+19 days
64	Cross Section Construction	3 days	Tue 3/22/22	Thu 3/24/22	Tue 3/22/22	Thu 3/24/22	63FS+19 days,5	69
65	Table Top Display Design	20 days	Mon 1/31/22	Sat 2/19/22	Wed 1/19/22	Mon 2/14/22	6FS+133 days,7	66
66	Table Top Display Construction	21 days	Sun 2/20/22	Sat 3/12/22	Tue 2/15/22	Tue 3/29/22	65,5	69
67	Display Stands Design	18 days	Sat 1/15/22	Tue 2/1/22	Sat 1/15/22	Tue 2/1/22	6FS+129 days,7	68
68	Display Stands Construction	51 days	Wed 2/2/22	Thu 3/24/22	Wed 2/2/22	Thu 3/24/22	67,5	69
69	Final Product Display Complete	0 days	Thu 3/24/22	Thu 3/24/22	Tue 3/29/22	Tue 3/29/22	64,66,68	70
70	Compliance Check	1 day	Fri 3/25/22	Fri 3/25/22	Wed 3/30/33	Wed 3/30/22	69	75
71	**Paddler Training**	**209 days**	**Tue 9/7/21**	**Sun 4/3/22**	**Tue 9/7/21**	**Sun 4/3/22**		
72	Outdoor Paddling Practice	57 days	Tue 9/7/21	Tue 11/2/21	Tue 9/7/21	Tue 11/2/21	2FS+2 days	74FS+90 days,73
73	Indoor Paddling Practice	148 days	Sun 11/7/21	Sun 4/3/22	Sun 11/7/21	Sun 4/3/22	72FS+2 days	74SF+88 days
74	Selection of Competition Paddlers	0 days	Wed 2/2/22	Wed 2/2/22	Wed 2/2/22	Wed 2/2/22	72FS+90 days,73SF+88 days	75
75	**North Central Student Conference**	3.13 days	Thu 3/31/22	Sat 4/2/22	Fri 4/8/22	Sun 4/10/22	3,4,49FS+6 days,56,61,70,74	



Michigan Technological University
Concrete Canoe
2018-2019 Preliminary Schedule

Baseline Milestone ◇ | Baseline Summary | Task | Milestone ◆ | Summary | Critical | Baseline

PERCENT OPEN AREA CALCULATIONS

Calculations per Exhibit 5

Sample: SpiderLath Mesh

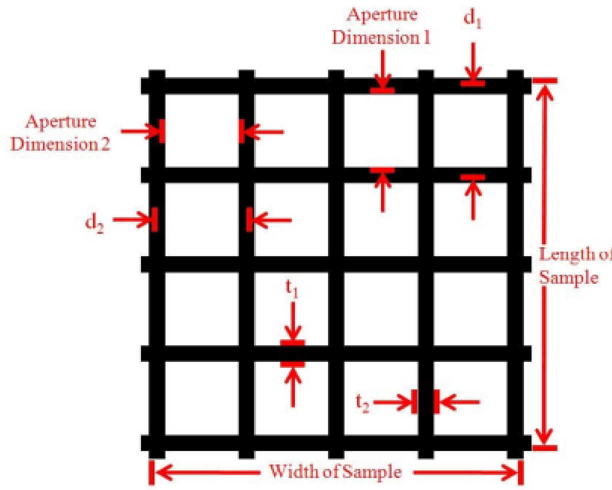
Given

$n_1 = 34$ Number of apertures along length

$n_2 = 35$ Number of apertures along width

$t_1 = 0.103$ in Average thickness of reinforcement along length

$t_2 = 0.051$ in Average thickness of reinforcement along width



Sample of Reinforcement

Aperture_Dimension_1 = 0.312 in

Aperture_Dimension_2 = 0.288 in

d_1 = Aperture_Dimension_1 + 2*(t_1/2) $d_1 = 0.42$ in Average spacing of reinforcement (center-to-center) along the sample length

d_2 = Aperture_Dimension_2 + 2*(t_2/2) $d_2 = 0.34$ in Average spacing of reinforcement (center-to-center) along the sample width

Determine Solution

Percent Open Area (POA) for the SpiderLath Mesh

$Length_{Sample} = n_1 * d_1$ $Width_{Sample} = n_2 * d_2$

$Length_{Sample} = 14.09$ in $Width_{Sample} = 11.85$ in

$Area_{Open} = n_1 * n_2$*Aperture_Dimension_1*Aperture_Dimension_2

$Area_{Total} = Length_{Sample} * Width_{Sample}$

$Area_{Open} = 106.76\ in^2$ $Area_{Total} = 167.05\ in^2$

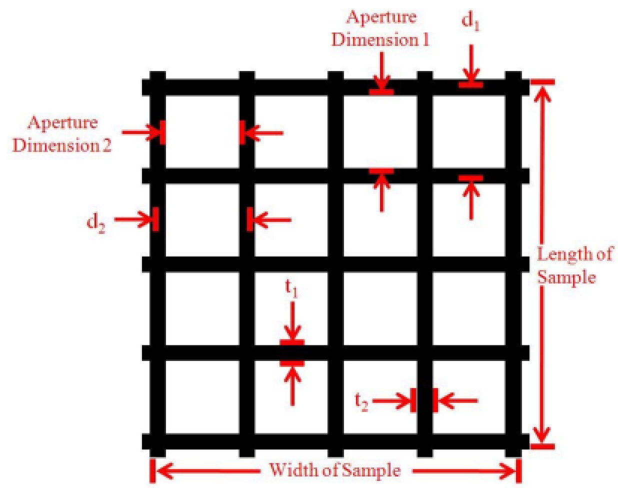
$POA = (Area_{Open}/Area_{Total})*100$ POA = 63.9%

The POA is greater than the 40% minimum required, demonstrating compliance.

PERCENT OPEN AREA CALCULATIONS

Calculations per Exhibit 5

Sample: GlasGrid 8511 Mesh



Sample of Reinforcement

Given

$n_1 = 9$ Number of apertures along length

$n_2 = 5$ Number of apertures along width

$t_1 = 0.262$ in Average thickness of reinforcement along length

$t_2 = 0.173$ in Average thickness of reinforcement along width

Aperture_Dimension_1 = 0.737 in

Aperture_Dimension_2 = 0.808 in

d_1 = Aperture_Dimension_1 + 2*(t_1/2) $d_1 = 0.99$ in — Average spacing of reinforcement (center-to-center) along the sample length

d_2 = Aperture_Dimension_2 + 2*(t_2/2) $d_2 = 0.98$ in — Average spacing of reinforcement (center-to-center) along the sample width

Determine Solution

Percent Open Area (POA) for the GlasGrid 8511 Mesh

$Length_{Sample} = n_1 * d_1$ $Width_{Sample} = n_2 * d_2$

$Length_{Sample} = 8.98$ in $Width_{Sample} = 4.91$ in

$Area_{Open} = n_1 * n_2 *$ Aperture_Dimension_1*Aperture_Dimension_2

$Area_{Total} = Length_{Sample} * Width_{Sample}$

$Area_{Open} = 680\ in^2$ $Area_{Total} = 1120\ in^2$

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

The POA is greater than the 40% minimum required, demonstrating compliance.

HULL THICKNESS CALCULATIONS

Calculations per Exhibit 5

Annotation

$T_1 = 0.045$ in — Average thickness of first layer of reinforcement, GlasGrid 8511 Mesh, measured in accordance with Section 4.3.1

$T_2 = 0.045$ in — Average thickness of second layer of reinforcement, GlasGrid 8511 Mesh, measured in accordance with Section 4.3.1

$T_h = 0.375$ 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 two layers of GlasGrid 8511 were used along the bottom of the canoe.

$$\frac{T_1 + T_2}{T_h} * 100 = \mathbf{24.0\%}$$

The two layers of reinforcement make up approximately 24.0% of the hull. This value is less than the maximum value of 50% outlined in section 4.3.1, demonstrating compliance.

GUNNEL CAP THICKNESS CALCULATIONS

Calculations per Section 4.3.1

Annotation

$T_1 = 0.045$ in — Average thickness of the layer of reinforcement, GlasGrid 8511 Mesh, measured in accordance with Section 4.3.1

$T_h = 1.375$ 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 GlasGrid 8511 Mesh was used throughout the gunnel cap.

$$\frac{T_1}{T_h} * 100 = 3.27\%$$

The layer of reinforcement makes up approximately 3.27% of the gunnel cap. This value is less than the maximum value of 50% outlined in section 4.3.1, demonstrating compliance.

Appendix E - Detailed fee estimate

Bill of Materials	Cost
Type 1 Portland Cement C-150	$54.29
Blast Furnace Slag	$16.70
Fly Ash - Class C	$2.36
NORCHEM Undensified Silica Fume	$359.90
NYCON PVA RF4000	$19.04
NYCON PVA RFS400	$38.75
Recycled Concrete Aggregate	$29.07
Poraver 1-2 mm	$56.20
Poraver 0.5-1 mm	$44.91
Poraver 0.25-0.5 mm	$37.34
K1	$44.50
K37	$51.38
Snow Water	$0.00
BASF Glenium 3030 NS	$49.62
Direct Colors concrete Pigments	$9.41
Sealkrete Clear-seal	$32.89
Silhouette Glossy Permanent Vinyl	$1.50
DOW Extruded Polystyrene Foam	$42.50
GlasGrid 8511	$70.50
SpiderLath	$63.00
TOTAL COST PER CANOE	$997.08

Activity	Projected Total Person-Hours	Associated Cost
Project Management	18	$860.00
Hull Design	20	$500.00
Structural Analysis	20	$400.00
Mixture Design Development	100	$3,093.13
Mold Construction	32	$991.75
Canoe Construction	69	$1,819.75
Preparation of Project Proposal	50	$1,000.00
Enhanced Focus Area Report	30	$600.00
Presentation	336	$6,720.00
Display	50	$1,550.00
Shipping Costs	N/A	$80.00
Total		$16,139.63
Total Cost Per Canoe		$997.08
Grand Total		$17136.71

Appendix F - Supporting docs

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
NYCON - RF4000 PVA	Secondary Reinforcement	C-1116	https://nycon.com/products/rf4000
GlasGrid® 8511	Reinforcement	C-338, D276, D5261, D6637	https://www.tensarcorp.com/Search?query=8511%20msds
SpiderLath	Reinforcement	D-3775, D-1777, D-5035	https://spiderlath.com/installation/#testing
DOW Extruded Polystyrene Foam	Flotation	None	https://www.dupont.com/products/thermax-sheathing.html
Recycled Concrete Aggregate	Aggregate	C-128, C136	https://docs.google.com/document/d/11puNym5EQQGIeLvAF9Bm86Gwx2OwclEdZ8f7k78iFd8/edit?usp=sharing
Snow Water	Water	NONE	N/A
Direct Colors Concrete Pigment	Pigment	C-979	https://directcolors.com/concrete-pigment/
BASF Glenium 3030 NS	Superplasticizer	C-494, C494M	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,	https://www.rustoleum.com/product-catalog/consumer-brands/seal-krete/horizontal-sealing/clear-seal

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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