UNIVERSITY OF MICHIGAN

LOCOBOATIVE PROJECT PROPOSAL

CONCRETE CANOE 2024

Date: February 16, 2024

To: Committee on Concrete Canoe Competitions

Subject: Response to *Request for Proposal* – 2024 Project Proposal, *LOCOBOATIVE*

Dear Committee on Concrete Canoe Competitions,

The Michigan Concrete Canoe Team (MCCT) is pleased to present this proposal in response to the 2023-2024 *Request for Proposal* (RFP). The proposed hull design, concrete mixture design, reinforcement scheme, and construction of the prototype canoe have been performed in full compliance with the specifications outlined in the *Request for Proposal*. Material Technical Data Sheets (MTDS) and Safety Data Sheets (SDS) have been reviewed by the team for completeness and compliance [1].

MCCT acknowledges receipt of the *Request for Information* (RFI) Summary and that our submissions comply with the responses provided. Additionally, the anticipated registered participants are qualified student members and Society Student Members of ASCE and meet all eligibility requirements (including names and ASCE Society Member ID Numbers). All text generation AI/NLP algorithm uses are properly cited within the respective document [1].

University of Michigan:

ASCE Student Chapter Faculty Advisor:
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F. Estéfan T. Garcia

Estéfan Garcia
Date: 2/15/24

Team Captain:
Vivian Kim
vivkim@umich.edu
(248) 881-7358

Vivian Kim

Vivian Kim
Date: 2/15/24

Table of Registered Participants:

Name	ASCE ID Number
Lauren Battle	12380860
Kate Ceccacci	12270597
Spence Cottrell	12448307
Mary Fouani	12422508
Vivian Kim	12272824
Greg Koontz	12441072
Thomas Lei	12348802
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Ben Routhier	12269463
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UNIVERSITY OF MICHIGAN
CONCRETE CANOE 2024
LOCOBOATIVE

EXPECTED COST OF PRODUCTION: $1,312,000 FOR 100 CANOES

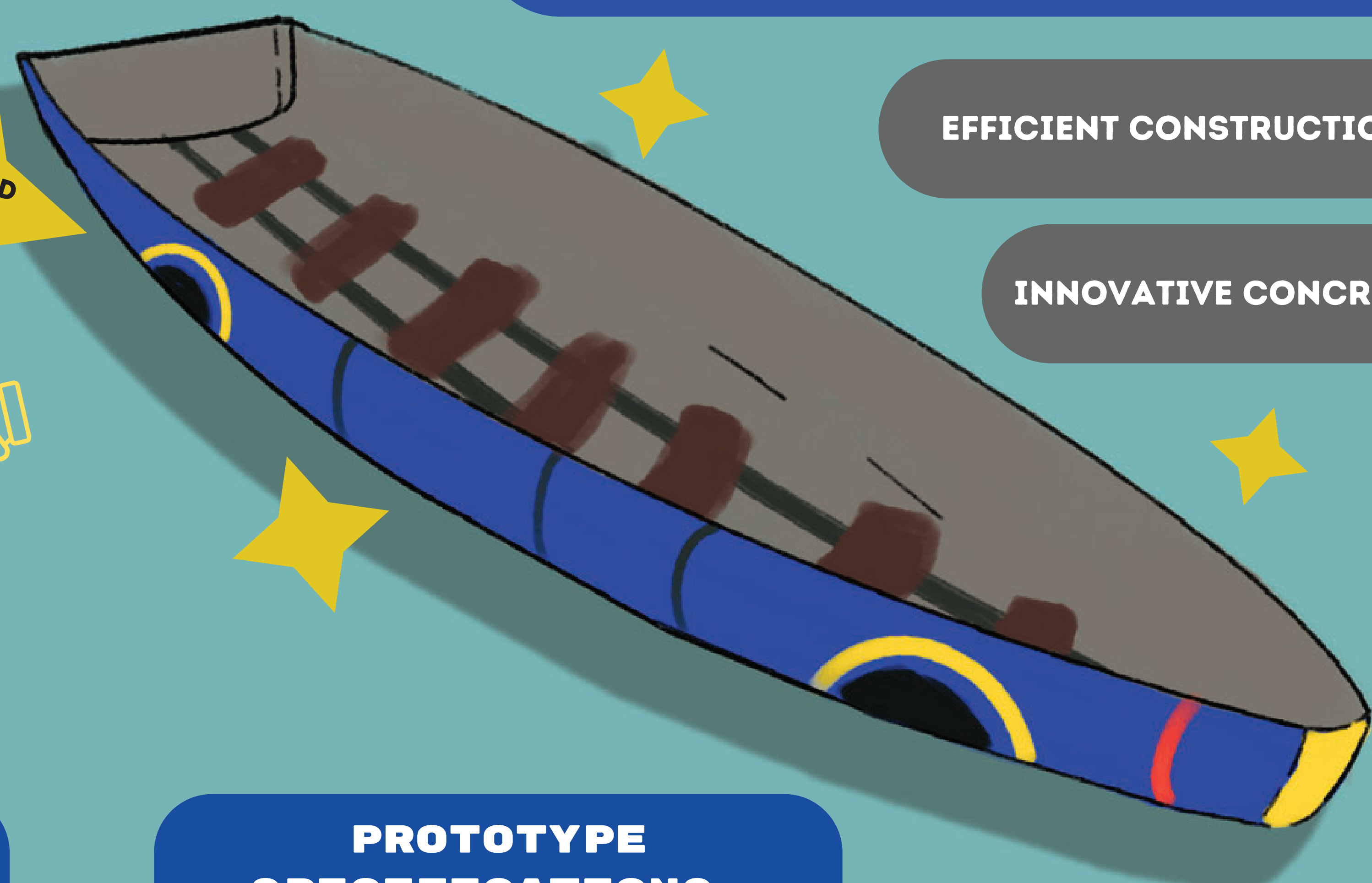
ASCE STUDENT CHAPTER PROFILE:

FOUNDED IN 1923

NETWORKING EVENTS:
CHICAGO TRIP TO MEET ALUMNI AND TAKE SITE TOURS

COMMUNITY EVENTS:
SOCIAL EVENTS AND VOLUNTEERING

CAREER EVENTS:
CAREER FAIR AND WEEKLY COMPANY LUNCHEONS



INNOVATIVE FEATURES THAT PROVIDE EXTERNAL VALUE:

- EFFICIENT CONSTRUCTION PROCESS THAT SAVES TIME AND MONEY!
- INNOVATIVE CONCRETE MIX THAT IS LIGHTWEIGHT AND STRONG!
- ONLY 210 LBS FOR EASE OF TRANSPORT!
- STABLE DESIGN THAT IS EASY TO PADDLE!
- LARGE CAPACITY FOR PEOPLE AND CARGO!

MIX SPECIFICATIONS:

- WET (PLASTIC) UNIT WEIGHT: 56.1 LB/FT3
- OVEN-DRY UNIT WEIGHT: 55 LB/FT3
- SLUMP: 0 IN
- AIR CONTENT:
  - MEASURED: 6.5%
  - CALCULATED: 8.1%
- COMPRESSIVE STRENGTH (28-DAY): 1500 PSI
- TENSILE STRENGTH (28-DAY): 360 PSI

PROTOTYPE SPECIFICATIONS:

- LENGTH: 218 IN
- WIDTH: 40 IN
- DEPTH: 15 IN
- THICKNESS: 0.6 IN
- WEIGHT: 210 LBS
- COMPOSITE FLEXURAL STRENGTH (28-DAY): 290 PSI
- ALL REINFORCEMENT UTILIZED: SPIDERLATH FIBERGLASS MESH, PVA FIBERS (¼, ⅓, ½ IN)
- FLOTATION UTILIZED: N/A

MEETING THE CLIENT NEEDS IN ONE OPTIMIZED DESIGN:

- MANEUVERABLE HULL CONFIGURATION
- DURABLE YET LIGHTWEIGHT CONCRETE STRUCTURE
- STREAMLINED CONSTRUCTION FOR EFFICIENT PRODUCTION

ORGANIZATIONAL CHART

FACULTY ADVISOR
WILL HANSEN
ACTS AS A LIAISON TO THE CIVIL AND ENVIRONMENTAL ENGINEERING DEPARTMENT AND OFFERS PROFESSIONAL INPUT ON CONCRETE DESIGN AND TESTING

ASCE ADVISOR
ESTÉFAN GARCIA
ACTS AS A LIAISON TO THE AMERICAN SOCIETY OF CIVIL ENGINEERS

TEAM CAPTAIN

VIVIAN KIM (SR)
CAPTAIN
SETS THE PROJECT SCHEDULE, KEEPS SUBTEAMS ON TRACK, AND FACILITATES INTERNAL AND EXTERNAL COMMUNICATION

TEAM CAPTAIN

BEN ROUTHIER (SR.)
MIX DESIGN LEAD
DIRECTS THE DESIGN AND TESTING OF CONCRETE MIXTURES

MOLD MANUFACTURING REPRESENTATIVE
MATT PARENTEAU
COMMUNICATES LOGISTICS FOR MILLING A MOLD OF THE DESIGNED SHAPE

WORKSPACE DIRECTOR AND MANAGER
CHRIS GORDON AND CASEY DIXON
MANAGE SHARED WORKSPACE, ADVISE ON SAFE PRACTICES, AND CONDUCT SAFETY TRAINING

PATRICK WHITE (SR)
HULL DESIGN LEAD
DIRECTS THE DESIGN, AND STRUCTURAL CAPACITY ANALYSIS OF THE HULL

LEONARDO UDELL (SR.)
AESTHETICS LEAD
DIRECTS THE DESIGN OF CANOE AESTHETICS AND DISPLAY TO CONVEY THE THEME

JENNA BONELLO (SR.)
QUALITY ASSURANCE LEAD
OVERSEES THE CONSTRUCTION AND FINISHING OF THE MOLD AND CANOE

BRAEDON URZUA (JR.)
RISK MANAGER
ENSURES THE TEAM FOLLOWS ALL REQUIREMENTS OUTLINED IN THE REQUEST FOR PROPOSALS

SONG KIM (SO.)
MIX DESIGN ASSISTANT
SUPPORTS THE MIX DESIGN LEAD TO IMPROVE THE EFFICIENCY OF MIX DESIGN MEETINGS

LAUREN BATTLE (JR.)
MIX, PADDLING
MADIE CZAJKA (SR.)
MIX
SPENCE COTTRELL (SO.)
PADDLING
MARY FOUANI (SO.)
MIX, PADDLING
DYLAN GOTTHEIM (SR.)
MIX
WILLIAM HARRIS (FR.)
MIX
TYLER KLINKMAN (SO.)
MIX
GREG KOONTZ (SO.)
HULL, PADDLING
THOMAS LEI (SO.)
HULL
PARKER NEWELL (FR.)
HULL, MIX

BRIAN RUND (SR.)
INVENTORY LEAD
MONITORS MATERIAL QUANTITIES AND COORDINATES MATERIAL ACQUISITION

GAURI JERE (JR.)
CONSTRUCTION LEAD
CONSTRUCTS THE PRODUCT DISPLAY AND CANOE STANDS

KARINA OTTEN (SR.)
TECH SUBMISSIONS LEAD
ORGANIZES THE WRITING OF THE PROJECT PROPOSAL AND OTHER WRITTEN DELIVERABLES

SARAH KUEPERS (SO.)
SAFETY LEAD
OVERSEES COMPLIANCE WITH WORKSPACE SAFETY PROTOCOL

KATE CECCACCI (SR.)
PADDLING LEAD
COORDINATES TEAM WORKOUTS AND PADDLING PRACTICES FOR THE PROTOTYPE DEMONSTRATION

JULIEN NYBERG (SR.)
HULL
ARNUV PERI (JR.)
MIX
JADE REDMOND (SO.)
HULL, MIX
ADNA MOHAMED SAED (SO.)
MIX
CARTER SANDSTROM (SR.)
HULL, MIX
LUKE SNUDDEN (SR.)
MIX
KOBY STEWART (JR.)
MIX
LILI SZALAI (SO.)
MIX
XANTHE THOMAS (SR.)
MIX
MATTHEW WU (FR.)
MIX

EMILY BARKES (JR.)
TREASURER
MANAGES THE TEAM'S INTERNAL FINANCES AND SETS THE PROJECT BUDGET

NICHOLAS SAID (SR.)
BUSINESS LEAD
MANAGES THE TEAM'S EXTERNAL FINANCES AND COORDINATES SPONSOR RELATIONS

KAITLYN APRILL (SO.)
SECRETARY
COORDINATES TEAM RECRUITMENT, PROMOTION, LOGISTICS, AND INTERNAL COMMUNICATIONS

Project Management

Project Scope

Inspired by Ann Arbor's own Huron River and the railroad tracks that run along its banks, the Michigan Concrete Canoe Team (MCCT) presents a train-themed canoe, *LOCOBOATIVE*, as a model for the 100 concrete canoes the Committee on Concrete Canoe Competitions is requesting construction proposals. MCCT prioritized constructability and usability to develop a canoe to service regional transportation needs. The canoe design underwent rigorous research and iteration to arrive at a high-quality, reliable project proposal.

The first phase of the proposal development consisted of research on materials, hull designs, and construction methods. The team tested various concrete mixes and selected the mix with the highest strength. The materials were selected to be consistent with the RFP as well as MCCT's goals for a lightweight but strong canoe. MCCT utilized a convergent design approach to develop a hull design that prioritized stability, structural capacity, and turning ability. MCCT chose a female mold to promote ease of demolding and mold reusability during mass production.

The second phase of the proposal development involved the construction and finishing of the prototype canoe. The canoe was constructed using a chasing method where subsequent layers were placed before previous ones were finished to avoid cold joints. After construction, the canoe underwent a 28-day cure. MCCT finished the canoe by sanding, staining, and adding aesthetic details.

Health and Safety

Member safety was a top priority for MCCT. To use the team workspace, members completed online and in-person safety training. The online course outlined hazardous waste management as well as fire and severe weather protocol. The in-person training taught members to use the workspace's tools safely. Respirator and Structures Lab training certified members to work with hazardous materials and test concrete cylinders for compression and tensile strength. While in the workspace, members were required to wear appropriate attire including long pants, closed-toed shoes, and safety glasses. Disposable gloves and half-facepiece respirators were also worn when necessary.

MCCT elected a Safety Lead, who attended weekly safety meetings run by the workspace facility and reported back to the team any pertinent information. They ensured that standards provided by the Occupational Safety and Health Administration, the University of Michigan, and the Environmental Health and Safety Department were met.

Project Management Plan

MCCT recognizes that a complicated project requires a cohesive, well-organized team. As such, the project management scheme emphasized the member-chosen values of Inclusivity, Collaboration, Excellence, Respect, and Education. This culture was incorporated throughout the project scope to create a positive and productive working environment.

The project budget was set to account for the costs of physical materials and attending the Regional Symposium. Fundraising was subsequently planned to meet these budget requirements. Symposium registration, travel, and lodging were included in the financial planning for the year to make the project an inclusive experience for all team members.

The project schedule was created to respect team members' busy schedules. Casting Day was scheduled for early January when students had fewer obligations as the new semester began. Building backward from Casting Day, the Mix Design and Hull Design schedules were developed. The Inventory Lead tracked concrete materials and ordered materials for Casting Day far in advance to prevent long lead times from impacting the schedule. For Hull Design, frequent communication with the mold manufacturer promoted an on-time mold delivery. Looking forward from Casting Day, canoe curing, finishing, and aesthetics were mapped out to complete the product prototype.

Release agent testing was built into the first half of the schedule to determine a method for efficient mold removal, a key benefit for mass production. Resources from the Mix Design subteam were allocated for release agent testing. MCCT also scheduled concrete placement practice sessions to educate new members on placing and smoothing concrete to develop a well-finished canoe exhibiting the excellence MCCT aspires to reach.

Major milestone activities were determined from the main deliverables of each subteam. Milestones included selecting a theme, selecting a hull design, selecting a mix design, Casting Day, selecting paddlers, and submitting the Project Proposal. MCCT collaboratively accomplished these milestones. For example, the Hull Design Lead presented the hull design options to the entire team to receive input for the final design. This practice kept the team informed and encouraged cross-subteam collaboration.

Critical path activities, shown in red in the Project Schedule on page 6, were determined from the longest path of consecutive tasks where a delay in one task would delay the start of the next. Critical path tasks included the hull design process, mold preparation, canoe construction and finishing, Regional Symposium attendance, and Society-wide Competition attendance. A two-week buffer was built into the critical path to absorb unexpected delays. Setbacks in mold manufacturing, preparation, and removal posed the most risk to the schedule. These risks were managed with extensive communication with the mold manufacturer as well as release agent testing and concrete placement practice.

An event not accounted for in the Preliminary Project Delivery Schedule was the moving of MCCT's workspace in November, but this was accommodated by adjusting the timeline of the concrete placement practice sessions. The shared workspace that the team operates in underwent substantial rearrangement, resulting in MCCT moving to a different area in the facility. Usual work was suspended for a week to move and consolidate materials.

Quality Assurance and Quality Control

MCCT utilized quality assurance and quality control throughout the testing and prototype construction processes to ensure that the final product met the standards required by the RFP. Quality assurance (QA) was defined as the processes used in production, while quality control (QC) was the measures in place to ensure all requirements were met[2]. Several key team members ensured quality assurance and quality control.

The QA Lead instructed members on properly making cylinders according to ASTM C31 so that all test specimens yielded the most accurate tensile and compressive strength values[3]. To ensure consistent concrete placement during construction, the QA Lead painted two 3/10-in lines on nails to verify the thickness of each layer of concrete. Additionally, cardboard wrapped in tape was used to manage the slump of the canoe's gunwales as the concrete set. These devices helped maintain consistent thickness throughout the canoe. The team also practiced the placement and layering of concrete on a spare mold form to ensure members would be experienced in the construction process prior to Casting Day.

MCCT used QC to verify that all deliverables met the required standards and specifications. The team elected a Risk Manager who worked with all subteam to cross-check that all deliverables were consistent with the RFP. Having a team member dedicated solely to this purpose reduced the risk of a subteam overlooking or violating any of the RFP guidelines. The team also elected a Technical Submissions Lead to organize the writing of the Project Proposal and implement a comprehensive editing process with multiple rounds of revisions from MCCT members and alumni.

Research and Development Cost

To achieve the desired concrete properties, the team devoted \$545 in materials and 174 hours to make fourteen unique test mixes. The primary goals of this research were to maximize tensile strength and concrete smoothness while maintaining a low density. Additionally, the team tested the effects of soaked aggregates and pigment on the strength of the structural concrete.

MCCT dedicated an additional \$64.32 in research and development for the testing of three release agents and \$42.87 for concrete placement practice to reduce canoe manufacturing costs. This investment is expected to result in fewer labor hours spent sanding and finishing the canoe and thus a net positive impact on the project budget due to saved labor costs.

MCCT also accrued 22 hours in outside consultation to refine and solidify deliverables. MCCT consulted alumni to review the Project Proposal and Technical Presentation for professionalism and clarity. For the structural analysis of the canoe, the Hull Design subteam conferred with structural professors to validate the approach.

Research and Development Fee Schedule

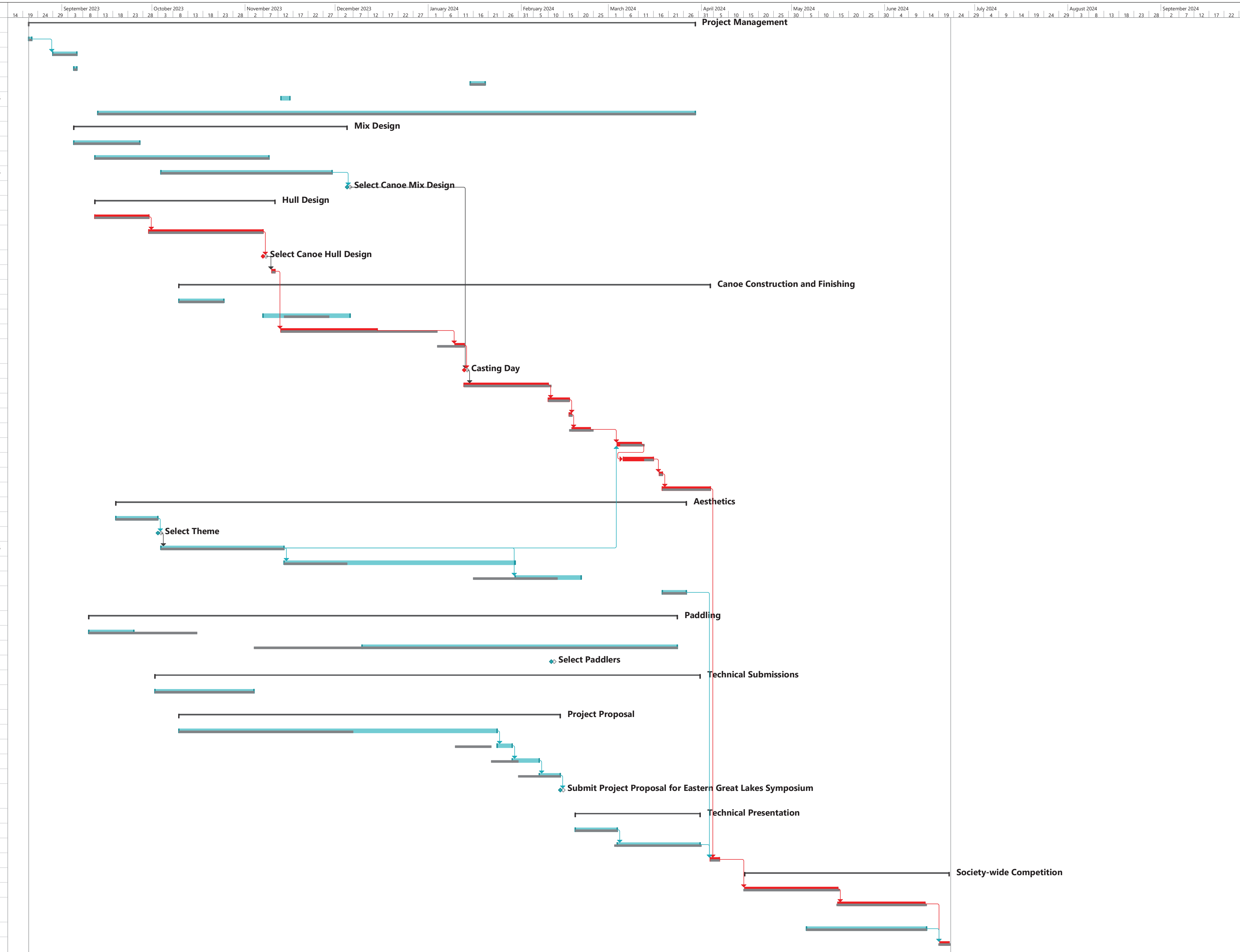
Project Total Hours	
Work Scope	Hours
Project Management	188
Hull Design	170
Structural Analysis	60
Mix Design & Testing	174
Mold Construction	27
Canoe Construction	23
Project Proposal Preparation	125
Presentation Preparation	65
Display Preparation	30
Total	**862**

R&D Labor Costs				
Role	RLR	DEC	HRS	Extended
Principal Design Engineer	$ 50.00	1.5	144	$ 10,800.00
Design Manager	$ 45.00	1.5	16	$ 1,080.00
Project Construction Manager	$ 40.00	1.5	90	$ 5,400.00
Construction Superintendent	$ 40.00	1.5	43	$ 2,580.00
Project Design Engineer (P.E.)	$ 35.00	1.5		$ -
Quality Manager	$ 35.00	1.5	39	$ 2,047.50
Graduate Field Engineer (EIT)	$ 25.00	1.5		$ -
Technician/Drafter	$ 25.00	1.5		$ -
Laborer	$ 25.00	1.5	447	$ 16,762.50
Clerk/Office Admin	$ 20.00	1.5	83	$ 2,490.00
Labor Subtotal			862	$ 41,160.00
Profit Multiplier (P)			18%	$ 7,408.80
R&D Direct Labor Total (DL)				**$ 48,568.80**

R&D Expenses			Cost
Materials / Other Cost			
Concrete Supplies			$ 544.48
Mixing Supplies			$ 69.72
Release Agent Testing Supplies			$ 64.32
Concrete Placement Practice Suppli			$ 42.87
Paddling Supplies			$ 408.20
Aesthetics Display/Presentation Costs			
Display Materials			$ 40.00
Stands			$ 30.00
Construction Wood			$ 35.00
Shipping / Travel Costs for Competition			
Vehicle / Fuel			$ 1,300.00
Accommodations			$ 1,900.00
Outside Consultants	HRS	$/HR	Extended
	22	200	$ 4,400.00
Expenses Subtotal			$ 8,834.59
Markup (M)	10%		$ 883.46
R&D Expenses (E)			**$ 9,718.05**

DL Total	$ 48,568.80
Expenses Total	$ 9,718.05
R&D Total Cost	**$ 58,286.85**

ID	Task Name	Baseline Start	Baseline Finish	Start	Finish
1	**Project Management**	**Mon 8/21/23**	**Fri 3/29/24**	**Mon 8/21/23**	**Fri 3/29/24**
2	First Eboard Planning Meeting	Mon 8/21/23	Mon 8/21/23	Mon 8/21/23	Mon 8/21/23
3	Fall Recruitment	Tue 8/29/23	Tue 9/5/23	Tue 8/29/23	Tue 9/5/23
4	2024 RFP Issued	Tue 9/5/23	Tue 9/5/23	Tue 9/5/23	Tue 9/5/23
5	Winter Recruitment	Mon 1/15/24	Fri 1/19/24	Mon 1/15/24	Fri 1/19/24
6	Project Workspace Moving	NA	NA	Mon 11/13/23	Wed 11/15/23
7	Fundraising	Wed 9/13/23	Fri 3/29/24	Wed 9/13/23	Fri 3/29/24
8	**Mix Design**	**Tue 9/5/23**	**Tue 12/5/23**	**Tue 9/5/23**	**Tue 12/5/23**
9	Inventory and Order Materials	Tue 9/5/23	Tue 9/26/23	Tue 9/5/23	Tue 9/26/23
10	Mix Design Testing	Tue 9/12/23	Wed 11/8/23	Tue 9/12/23	Wed 11/8/23
11	Strength Testing	Wed 10/4/23	Wed 11/29/23	Wed 10/4/23	Wed 11/29/23
12	Select Canoe Mix Design	Tue 12/5/23	Tue 12/5/23	Tue 12/5/23	Tue 12/5/23
13	**Hull Design**	**Tue 9/12/23**	**Fri 11/10/23**	**Tue 9/12/23**	**Fri 11/10/23**
14	Hull Design Education	Tue 9/12/23	Fri 9/29/23	Tue 9/12/23	Fri 9/29/23
15	Hull Design Analysis of Alternatives and Structural Calculations	Sat 9/30/23	Mon 11/6/23	Sat 9/30/23	Mon 11/6/23
16	Select Canoe Hull Design	Tue 11/7/23	Tue 11/7/23	Tue 11/7/23	Tue 11/7/23
17	Finalize and Submit Canoe Mold File	Fri 11/10/23	Fri 11/10/23	Fri 11/10/23	Fri 11/10/23
18	**Canoe Construction and Finishing**	**Tue 10/10/23**	**Wed 4/3/24**	**Tue 10/10/23**	**Wed 4/3/24**
19	Release Agent Testing	Tue 10/10/23	Tue 10/24/23	Tue 10/10/23	Tue 10/24/23
20	Practice Cross Sections	Tue 11/14/23	Tue 11/28/23	Tue 11/7/23	Tue 12/5/23
21	Mill Mold	Mon 11/13/23	Wed 1/3/24	Mon 11/13/23	Thu 12/14/23
22	Assemble Mold and Apply Release Agent	Thu 1/4/24	Fri 1/12/24	Wed 1/10/24	Fri 1/12/24
23	Casting Day	Sat 1/13/24	Sat 1/13/24	Sat 1/13/24	Sat 1/13/24
24	Curing	Sat 1/13/24	Sat 2/10/24	Sat 1/13/24	Fri 2/9/24
25	Sanding Inside of Canoe	Sat 2/10/24	Fri 2/16/24	Sat 2/10/24	Fri 2/16/24
26	Demolding	Sat 2/17/24	Sat 2/17/24	Sat 2/17/24	Sat 2/17/24
27	Sanding Outside of Canoe	Sat 2/17/24	Sat 2/24/24	Sun 2/18/24	Fri 2/23/24
28	Apply Aesthetic Elements	Tue 3/5/24	Tue 3/12/24	Mon 3/4/24	Mon 3/11/24
29	Apply Sealer	Wed 3/13/24	Fri 3/15/24	Wed 3/6/24	Fri 3/15/24
30	Apply Lettering	Mon 3/18/24	Mon 3/18/24	Mon 3/18/24	Mon 3/18/24
31	Buffer	Tue 3/19/24	Wed 4/3/24	Tue 3/19/24	Wed 4/3/24
32	**Aesthetics**	**Tue 9/19/23**	**Tue 3/26/24**	**Tue 9/19/23**	**Tue 3/26/24**
33	Theme Brainstorming	Tue 9/19/23	Mon 10/2/23	Tue 9/19/23	Mon 10/2/23
34	Select Theme	Tue 10/3/23	Tue 10/3/23	Tue 10/3/23	Tue 10/3/23
35	Canoe, Stands, and Display Design	Wed 10/4/23	Mon 11/13/23	Wed 10/4/23	Mon 11/13/23
36	Display Construction	Tue 11/14/23	Mon 12/4/23	Tue 11/14/23	Mon 1/29/24
37	Stand Construction	Tue 1/16/24	Mon 2/12/24	Tue 1/30/24	Tue 2/20/24
38	Cross Section Construction and Finishing	Tue 3/19/24	Tue 3/26/24	Tue 3/19/24	Tue 3/26/24
39	**Paddling**	**Sun 9/10/23**	**Sat 3/23/24**	**Sun 9/10/23**	**Sat 3/23/24**
40	Outdoor Paddling Practice	Sun 9/10/23	Sun 10/15/23	Sun 9/10/23	Sun 9/24/23
41	Indoor Paddling Practice	Sat 11/4/23	Sat 3/23/24	Sun 12/10/23	Sat 3/23/24
42	Select Paddlers	Sun 2/11/24	Sun 2/11/24	Sun 2/11/24	Sun 2/11/24
43	**Technical Submissions**	**Mon 10/2/23**	**Sun 3/31/24**	**Mon 10/2/23**	**Sun 3/31/24**
44	Letter of Intent, Prequalification Forms, and Draft Schedule	Mon 10/2/23	Fri 11/3/23	Mon 10/2/23	Fri 11/3/23
45	**Project Proposal**	**Tue 10/10/23**	**Wed 2/14/24**	**Tue 10/10/23**	**Wed 2/14/24**
46	Draft Project Proposal	Tue 10/10/23	Wed 12/6/23	Tue 10/10/23	Tue 1/23/24
47	Internal Project Proposal Edits	Wed 1/10/24	Sun 1/21/24	Wed 1/24/24	Sun 1/28/24
48	External Project Proposal Edits	Mon 1/22/24	Tue 1/30/24	Mon 1/29/24	Tue 2/6/24
49	Format Project Proposal	Wed 1/31/24	Tue 2/13/24	Wed 2/7/24	Tue 2/13/24
50	Submit Project Proposal for Eastern Great Lakes Symposium	Wed 2/14/24	Wed 2/14/24	Wed 2/14/24	Wed 2/14/24
51	**Technical Presentation**	**Mon 2/19/24**	**Sun 3/31/24**	**Mon 2/19/24**	**Sun 3/31/24**
52	Make Presentation	Mon 2/19/24	Sun 3/3/24	Mon 2/19/24	Sun 3/3/24
53	Practice Presentation	Sun 3/3/24	Sun 3/31/24	Sun 3/3/24	Sun 3/31/24
54	**Eastern Great Lakes Symposium**	**Thu 4/4/24**	**Sat 4/6/24**	**Thu 4/4/24**	**Sat 4/6/24**
55	**Society-wide Competition**	**Mon 4/15/24**	**Sat 6/22/24**	**Mon 4/15/24**	**Sat 6/22/24**
56	Edit Technical Proposal	Mon 4/15/24	Thu 5/16/24	Mon 4/15/24	Thu 5/16/24
57	Edit and Practice Technical Presentation	Thu 5/16/24	Fri 6/14/24	Thu 5/16/24	Fri 6/14/24
58	Outdoor Paddling Practice	Mon 5/6/24	Fri 6/14/24	Mon 5/6/24	Fri 6/14/24
59	2024 ASCE Concrete Canoe Competition	Wed 6/19/24	Sat 6/22/24	Wed 6/19/24	Sat 6/22/24



Project: Michigan Concrete Canoe Team
2024 Canoe LOCOBOATIVE
Date: Thu 2/8/24

Baseline Milestone ◇ Category Summary Task Milestone Critical Path Task Baseline

Technical Design and Construction Support

Hull Design
The main objective for *LOCOBOATIVE* was to improve race performance. The Hull Design subteam achieved this by prioritizing stability and turning ability in their design, based on recommendations from the Paddling subteam after the 2023 regional competition. Throughout the hull design process, the subteam ensured all members understood the methods used to select the final hull form and how to properly use the design and analysis software. The collaborative design process and analyses of alternatives resulted in *LOCOBOATIVE* being 218 inches long, 40 inches wide, and 15 inches deep.

Using survey data from the Paddling subteam, the Hull Design subteam developed relative priorities for the performance metrics of the hull. Speed, stability, and turning ability were assigned relative priorities shown in Table 1 to emphasize stability and turning ability in the design. The Hull Design subteam elected to use a low length-to-beam ratio and a hull form with a flat back to increase stability and maneuverability.

Table 1. Relative Priorities of Hull Performance Metrics

Performance Metric	Relative Priority
Speed	0.2
Stability	0.4
Turning Ability	0.4

The Hull Design subteam used Orca3D, a plugin for Rhino, to design the hull form. The prioritized characteristics–speed, stability, and turning ability–were quantified using results from Orca3D analysis tools[4]:

Canoe speed is influenced by the resistance of the canoe in water. The total resistance is a combination of wave-making resistance and viscous resistance. Orca3D was used to perform a Holtrop analysis to estimate the resistance of the canoe in water, and this resistance was used to estimate the relative speed of the hull design. Hull forms with lower resistance values were prioritized in the selection of the final hull form to improve speed.

Stability was quantified through an equally weighted combination of offset load freeboard, the distance from the top of the canoe to the surface of the water when a load is applied to the side, and roll resonant gain, the amount the rolling of the canoe is amplified. These values were determined by the hydrostatics analysis tool in Orca3D. The hull geometries with higher offset load freeboard values and lower roll resonant gain values were prioritized in the selection of the final hull form to improve stability.

Turning ability was quantified using two equally weighted metrics. The first is the length-to-beam ratio, which captures the relationship between stability and turning ability, and the second is the canoe length, which affects yaw inertia. A low length-to-beam ratio and a shorter overall length improved the turning ability of the canoe.

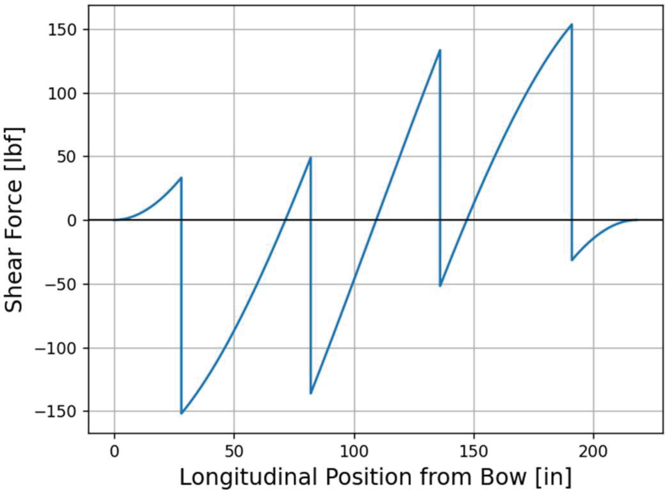
Structural Analysis
The Hull Design subteam performed longitudinal analysis, punching shear analysis, and failure envelope analysis in accordance with the RFP. For the purpose of structural analysis, the weight of the canoe was estimated to be 210 lbs.

Longitudinal Analysis
After considering the tandem case and co-ed load cases, MCCT determined the critical load case to be the co-ed case as it had the lowest structural margins. Paddlers were treated as point loads of 185 lbs. each according to ISO standard 12217-3[5]. Paddlers were placed at 28, 82, 136, and 191 inches from the bow.

Critical section properties were computed using Orca3D. The moment of inertia (I_x) was 779.7 in^2. The extreme fiber distances were 4.57 in from neutral axis to keel (C_c) and 10.43 in from neutral axis to gunwale (C_t). MCCT modeled the distributed weight and buoyancy forces as second-degree polynomials.

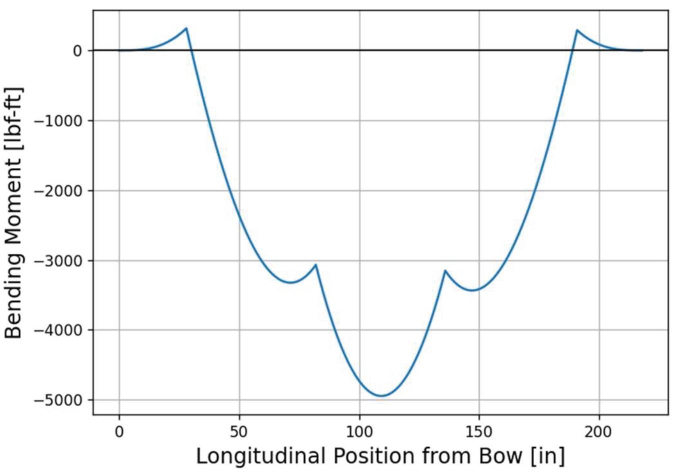
Shear and bending moment diagrams were created for the critical load case. The shear diagram was created by imposing boundary conditions, integrating the buoyancy and weight forces, and adding the point loads. The maximum positive or negative shear force was 152 lbf, located at 28 and 191 inches from the bow, shown in Figure 1.

Figure 1. Shear Force vs. Longitudinal Position



The bending moment was computed by taking the integral of the shear force. The maximum bending moment was -4949 lbf-ft, located at 109 inches from the bow, shown in Figure 2.

Figure 2. Bending Moment vs. Longitudinal Position



MCCT opted for a probabilistic approach rather than a factor of safety to account for the inherent variability of concrete mixing, concrete placement, and loads. This approach is further discussed in the *Improvements* section. The maximum bending moment was used in the calculation of the probability of failures.

Punching Shear Analysis[6]

The critical area for punching shear was determined to be a concentrated load at the knee of a paddler at the bottom of the boat. The punching shear stress was calculated at the paddler knee using Equation 1 in accordance with ACI 318-05[7]. The shear force, V_u was the weight of a paddler (185 lbs.), d was the distance from compression surface to tensile reinforcement (0.3 in), and b_o, the punch perimeter was 13.2 in, calculated with as a square with side length of (3 in + d). The punching shear stress was 46.7 psi.

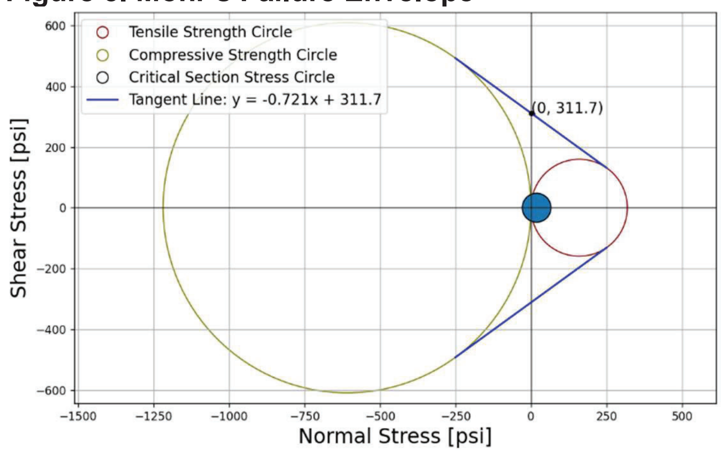
$$\tau_{punch} = \frac{V_0}{b_0 d} \qquad \textbf{(Eq. 1)}$$

The punching shear stress and the bending moment provided different perspectives regarding structural integrity. The punching shear quantified the internal reaction to the concentrated load of the paddler while the bending moment quantified the distribution of loads along the canoe. They both represented the internal reactions to loads being applied to the canoe. The Hull Design subteam used the results of the punching shear and bending moment calculations to help guide design decisions, such as thickness of the boat, which greatly affected punching shear.

Failure Envelope Analysis

The tensile, compressive, and critical section stress circles were drawn in accordance with the Structural Calculations Webinar[8]. Figure 3 shows that the critical section loads were well within the capacity of MCCT's hull and mix design.

Figure 3. Mohr's Failure Envelope

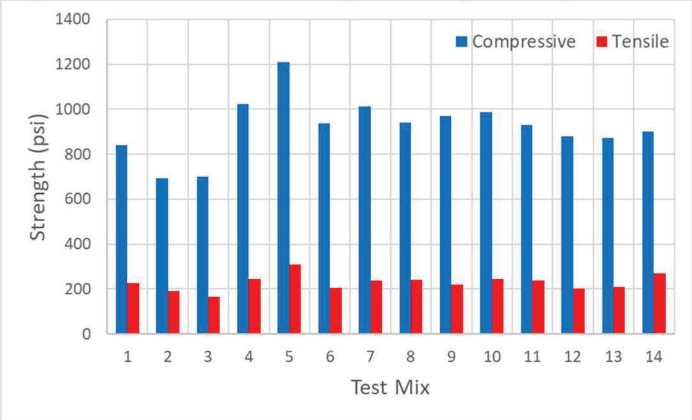


MCCT performed the longitudinal analysis, punching shear analysis, and failure envelope analysis according to the RFP[1]. The team used these calculations to help guide decisions during the hull selection process.

Mix Design

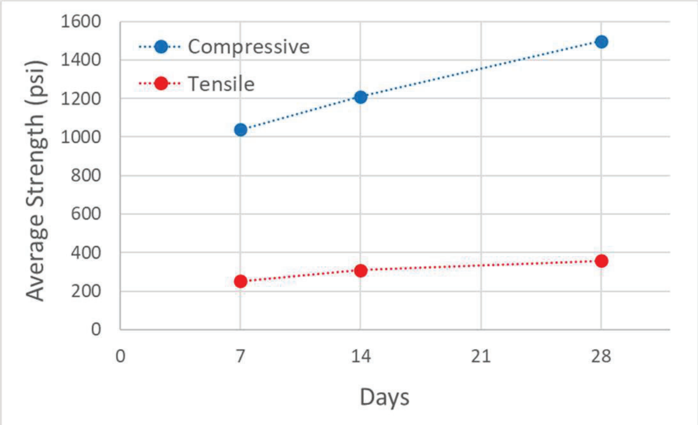
The primary goal of the Mix Design subteam was to create a concrete mix yielding a high level of design freedom. This was done by creating a smooth concrete for aesthetic purposes while maintaining low density and high tensile strength for hull design purposes. The smooth concrete will reduce sanding time and friction. Additionally, to minimize supply chain complications during mass production of the canoe, the materials in the mix were required to be reasonable to obtain. The team tested 14 unique concrete mixes and ultimately decided to use mix 5 for the final structural concrete due to its high strength, as shown below in Figure 4.

Figure 4. Test Mix Average 14-Day Strength



Tensile and Compressive tests were performed on 7, 14, and 28-day cylinders of the chosen structural mix. The resulting strength increase over time data can be seen below in Figure 5.

Figure 5. Structural Concrete Strength Curves



The proportions of the cementitious materials used in the final structural mix was an effective design, proved through past years' success[6,9]. Multiple mixes were tested that modified the cementitious material content, but the previous mix proportions were found to be the most effective.

The team used a selection of five cementitious materials to achieve the desired physical properties and reduce environmental impact. The pozzolanic materials GGBFS 100[10], Class C Fly Ash[11] and VCAS 160[12] were used in place of a large portion of the Portland Cement[13]. As pre-existing industrial byproducts, these alternative cementitious materials helped to reduce the environmental impact of canoe production, especially at large production volumes. Additionally, Class C Fly Ash and VCAS 160 have significantly lower densities than Portland Cement. Lastly, type K cement, Komponent[14], was used to reduce shrinkage cracking for improved tensile strength.

With no aggregate gradation requirements, the team had great flexibility in aggregate mix design. The ideal physical properties were achieved with a mix of microspheres consisting of K37 glass bubbles[15], SG-300 Extendospheres[16], and Poraver expanded glass[17] (sizes 0.25-0.5, 0.5-1, and 2-4 mm). Each of these materials has a lower density than water, so the concrete density is below that of water. Additionally, the small particle size of K37 and SG-300 created a smooth and very workable concrete. The aggregate properties are shown below in Table 2.

Table 2. Aggregate Properties

Aggregate	Composition	Specific Gravity	Absorption (%)	Particle Size (mm)
Poraver 2-4	Glass Microsphere	0.34	23	2.0 - 4.0
Poraver 0.5-1		0.50	18	0.5 - 1.0
Poraver 0.25-0.5		0.70	21	0.25 - 0.5
SG-300	Cenosphere	0.76	1	0.01 - 0.30
K37		0.37	1	0.02 - 0.08

The team made test mixes with aggregates soaked for 24 hours before mixing but found that this reduced tensile strength without offering any significant benefits due to the low water absorption by the cenospheres. Thus, the team opted not to presoak aggregates to obtain more accurate water requirement predictions. This resulted in reduced preparation time and more consistent concrete workability between mixes, aiding in the proposed mass production of concrete canoes.

The structural mix contains two admixtures, an air entrainer and a high-range water reducer, to decrease concrete density and improve workability, respectively. To prevent cracking and maintain tensile strength, the structural mix also incorporated polyvinyl alcohol (PVA) fibers as secondary reinforcement[18,19,20]. The fiber distribution consists of equal weights of 1⁄4-in, 1⁄3-in, and 1⁄2-in length fibers. The high workability of the concrete from the small aggregates enabled the team to use more fibers than in previous formulations, resulting in a high tensile strength. As primary reinforcement, a layer of SpiderLath fiberglass mesh[21] was incorporated between layers of concrete during canoe construction.

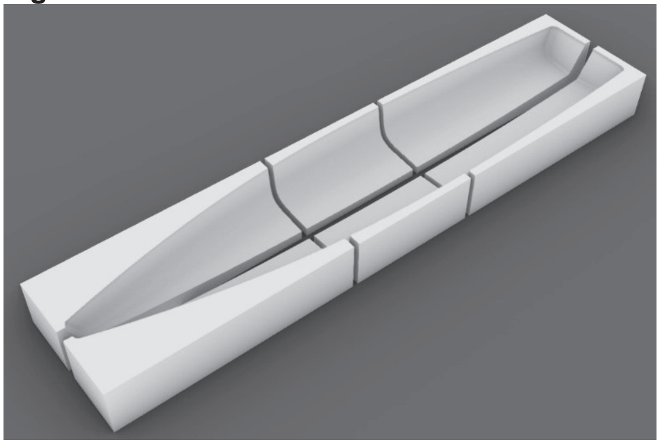
The team used a similar second mix to construct pigmented canoe outlays. Standard Portland cement was replaced with White Portland Cement[22] for more effective pigmentation of the concrete. Additionally, the finishing mix contains no fibers to increase workability for outlay construction.

Construction Process

Form Material Selection and Construction

To facilitate demolding, the canoe mold was designed in six sections, as shown in Figure 6. The smaller sections are easier to remove from the canoe than one or two large pieces. The mold supplier milled the mold sections from their 3-lb polystyrene foam stock. The team then wrapped each of the six pieces individually with Tuck Tape[23], the chosen release agent, to prevent the concrete from adhering to the mold. The pieces were set in place and held together with one piece of packing tape to connect each section on the inside of the mold. Ratchet straps were then wrapped around the outside of the mold to also hold the pieces together while being easily removable prior to demolding.

Figure 6. *LOCOBOATIVE* Mold in Six Sections



Placement of Concrete and Reinforcement

The placement of concrete in the mold began at the stern and worked towards the bow using a chasing method to prevent cold joints. Concrete was placed in a 3/10-in layer, verified by the painted nails, working from the keel line to the gunwales as placement moved along the length of the mold. When practicing concrete placement, the team noticed pitting from the concrete surface not being flush with the female mold. To reduce this and prevent voids, glass bottles were rolled on the surface of each layer to press the concrete onto the mold, as shown in Figure 7.

Figure 7. Glass Bottles Smoothing Concrete and Painted Nails Verifying Thickness

As the first layer progressed down the length of the canoe, sections of fiberglass mesh reinforcement were placed on top of the concrete. Each subsequent section of mesh overlapped by two inches. The second 3/10-in layer of concrete was placed using the same process as the first, and additional attention was placed on working the concrete into the mesh reinforcement to ensure that the two layers of concrete bonded together. Mesh reinforcement extended from gunwale to gunwale for the aft two-thirds of the canoe because this was where the reinforcement was deemed structurally necessary given the placement of the paddlers. Trowels were used along the surface of the completed canoe and especially at the tops of the gunwales, where they were used to flatten and smooth the concrete.

Curing

To create an insulated and controlled environment during the 28-day cure, MCCT covered the canoe in layers of damp burlap, plastic sheeting, and a concrete-curing blanket. The damp burlap provided a source of moisture, the plastic sheeting sealed in the moisture and prevented evaporation, and the curing blanket helped to maintain the temperature of the concrete. The temperature and humidity were monitored daily and the burlap was re-wet as needed to ensure constant curing conditions and maintain free water on the canoe's surface.

Form Removal and Canoe Finishing

The finishing process included sanding the interior, exterior, and gunwales. The team began by wet sanding the inside of the canoe with sandpaper of increasing grit density. Wet sanding reduced the amount of dust kick-up, resulting in a cleaner and safer finishing process. After the inside of the canoe was smooth, the team demolded the canoe by individually removing each of the six foam pieces. Implementing Tuck Tape this year as a release agent reduced the time and effort the team spent demolding and created a smoother concrete surface, requiring less sanding efforts. This allowed the mold pieces to be removed intact and reused for transporting the canoe and the display cross-section. After demolding, MCCT sanded the gunwales. Finally, the canoe was coated in two thin layers of clear, siloxane-based sealer.

Aesthetics

Focusing on the theme of steam engine trains, the Aesthetics subteam designed elements for the exterior of the canoe to mimic an 1873 Torch Lake steam train with University of Michigan colors. Two layers of blue stain were applied to the exterior of the canoe while leaving space for the use of yellow and red stain. For the interior of the canoe, the team used outlays of gray and brown to mimic railroad tracks.

Production Proposal

Value

LOCOBOATIVE's lightweight and functional design makes it an inclusive option for regional transportation. The 0.6-inch thickness and the low density of the innovative concrete mix result in an overall weight of 210 lbs. This design requires less effort from paddlers to propel and increases *LOCOBOATIVE*'s capabilities for speed and maneuverability. In addition to its low density, the concrete mix is also strong, providing the necessary durability for the canoe to withstand the rigors of regular use and extending its lifecycle and usage. The 40-inch width can accommodate a variety of passengers and cargo while offering a stable vehicle to comfortably traverse waterways.

MCCT's construction process saves on time and cost. The Tuck Tape release agent used between the mold and the concrete creates a smooth concrete surface, therefore reducing the labor hours required to sand the canoe to the desired smoothness. Tuck Tape is also an affordable and readily available material, making this construction process suitable for mass production. The female mold allows the concrete to shrink away from the mold as it cures and thereby facilitates the demolding process. These production choices allow the mold pieces to be removed quickly and intact so they can be reused. This saves costs during mass production since fewer molds would need to be manufactured.

The unique and aesthetic design of *LOCOBOATIVE* makes it both a desirable and valuable product. The creativity of the team and the connection that it has to the City of Ann Arbor and the University of Michigan add another layer of novelty to this specialty-designed canoe. A canoe of this caliber and quality will attract more consumers and increase the desirability of the product.

Sustainability

MCCT focused on the pillar of economic sustainability and stability to ensure success for the team. This year, the team ended with a budget surplus from last year as a result of excellent financial management and continuous upkeep of sponsor relationships. Therefore, a variety of capital improvement projects were conducted to safeguard the economic status of future teams. The canoe trailer underwent a thorough check-up and repair to address several issues. A new practice canoe was purchased to replace the previous boat which had leaks that could no longer be repaired. These investments most importantly will protect the team's physical and economic safety in the present and future.

MCCT also upheld the pillar of social sustainability by focusing on member engagement and team unity with the team's core value of inclusivity. The team believed that creating a positive, welcoming culture was just as important as the technical aspects of the project. MCCT expanded the team's social committee efforts to plan team bonding events outside of regular meetings, in order to foster a supportive and inclusive team culture. Events such as movie nights and friendly competitions with other project teams strengthened the team community and helped engage new members. Two executive board members also volunteered to check-in with new members to ensure they were being included and making meaningful contributions. Keeping new members engaged and in the loop will ensure that the team has a strong future and aid in the knowledge transition process.

Improvements

MCCT opted for a reliability-based structural design approach, because an appropriate safety factor for this unusual application was difficult to find. Literature-supported safety factors generally are applicable only to concrete in structural applications or steel in hydrostatic loading. Concrete in *LOCOBOATIVE* will be subjected to hydrostatic loading conditions. Given the design and application, it would be dishonest and unsafe to use a safety factor that only accounted for either the material or the loading condition.

Reliability-based structural design takes into account the variation and uncertainties present in the construction, materials, and applied loads to determine a probability of failure. By considering these factors, the team can better inform its design decisions. In contrast, deterministic methods, which rely on safety factors, do not explicitly address the inherent variation, offering a simpler, but less nuanced approach to structural design.

Utilizing a reliability-based structural design approach, MCCT's analysis focuses on characterizing the hull's capacity and demand. Capacity was modeled as a function of concrete strength and hull geometry. Subsequently, demand was modeled as a function of the loading conditions during the tandem and coed races. MCCT then compared the capacity against the demand on the hull to find the probability of failure. The capacity and demand were modeled as normal distributions. The coefficient of variation for the capacity was obtained through experiments involving the strength of the concrete and the variability of concrete placement. The coefficient of variation for the demand was taken from Hughes, Ship Structural Design. These normal distributions help account for the inherent variability present in *LOCOBOATIVE*, such as varied material properties, human error in the placement of concrete, and potential variation in load cases. MCCT then ran a Monte-Carlo Simulation to account for the variation mentioned above, to give us the probability of failure.

MCCT developed a Python script that took in various parameters to calculate the shear stress and bending moment and produced the associated graphs for both, and calculated the probability of failure of each potential hull geometry. The integrated structural analysis and reliability scripts enabled MCCT to accurately consider the structural reliability of many hull geometries during the design process.

Overall, this approach led to a more precise hull selection process and safely reduced hull weight due to a better understanding of margins. The reliability-based structural approach increased the safety of mass production, and resulted in a lighter canoe that is easier to transport.

Manufacturing Cost Estimate

The total cost for manufacturing 100 *LOCOBOATIVE*-style canoes is estimated to be $1,311,844. This includes $711.28 in mold fabrication costs per canoe. The total cost of manufacturing one mold is $7,112.76, including the mold fabrication labor costs and foam provided to MCCT by the team's external supplier as well as the tuck tape and ratchet straps applied to the mold. Curing plastic was also accounted for under mold fabrication expenses because the sturdy plastic can be reused as many times as the mold before replacement. Ten uses of a single mold is a reasonable estimate based on MCCT's practice concrete placement experience.

The canoe fabrication expenses include the costs of the materials used during Casting Day and canoe finishing, totaling $1,318.11. This includes $248.88 in PPE such as gloves for concrete placement and respirators for concrete mixing. Curing burlap was accounted for under canoe fabrication expenses because the wet burlap is unsuitable to be reused after curing one canoe and needs to be replaced.

The canoe fabrication labor costs were totaled from MCCT's Casting Day hours and expected finishing hours to be $11,089.05. However, this cost is a conservative estimate for the total labor cost associated with the production of 100 canoes because productivity increases as the construction process is repeated and laborers gain experience[24]. Thus, the total cost of manufacturing 100 canoes is likely to be less than the reported $1.3 million.

Manufacturing Fee Schedule

Permanent Material Costs - Per Canoe					
Material	QTY	Unit	Cost/Unit	Cost	Source
Portland Cement, Type I	19.35	lb	$ 0.18	$ 3.48	Holcim
Portland Cement (White), Type I	2.58	lb	$ 0.39	$ 1.01	Lehigh White Cement
GGBFS 100	16.32	lb	$ 0.02	$ 0.33	Holcim
Komponent	11.39	lb	$ 0.04	$ 0.46	CTS Cement
VCAS	39.27	lb	$ 1.24	$ 48.69	Vitro Minerals
Fly Ash, Type C	25.84	lb	$ 0.20	$ 5.17	Holcim
Poraver 2-4 mm	12.07	lb	$ 1.20	$ 14.48	Poraver
Poraver 0.5-1 mm	18.02	lb	$ 1.20	$ 21.62	Poraver
Poraver 0.25-0.5 mm	24.48	lb	$ 1.20	$ 29.38	Poraver
SG-300	15.13	lb	$ 0.18	$ 2.72	Sphere One
K37	23.29	lb	$ 7.59	$ 176.77	3M
PVA Fibers, 1/4 in	0.87	lb	$ 14.40	$ 12.53	Fishstone Concrete
PVA Fibers, 1/3 in	0.87	lb	$ 14.40	$ 12.53	Fishstone Concrete
PVA Fibers, 1/2 in	0.87	lb	$ 14.40	$ 12.53	Fishstone Concrete
Water Reducer	3.20	lb	$ 18.51	$ 59.16	GCP Applied Technologies
Air Entrainer	2.35	lb	$ 25.09	$ 58.86	GCP Applied Technologies
Pigment	0.34	lb	$ 7.59	$ 2.58	Direct Colors
Water	6.36	gal	$ 0.01	$ 0.06	City of Ann Arbor
Mesh Reinforcement	48.00	sqft	$ 0.69	$ 33.12	SpiderLath
Sealer	16.00	lb	$ 2.71	$ 43.36	Wacker
Stain	0.40	gal	$ 415.92	$ 166.37	Sika
Vinyl	3.00	yds	$4.10	$ 12.30	Oracal
Permanent Material Costs per Canoe (MC)				**$ 717.51**	

Canoe Fabrication Labor Costs - Per Canoe				
Role	RLR	DEC	HRS	Extended
Principal Design Engineer	$ 50.00	1.5	9	$ 675.00
Design Manager	$ 45.00	1.5	4	$ 270.00
Project Construction Manager	$ 40.00	1.5	15	$ 900.00
Construction Superintendent	$ 40.00	1.5	13	$ 780.00
Project Design Engineer (P.E.)	$ 35.00	1.5		$ -
Quality Manager	$ 35.00	1.5	5	$ 262.50
Graduate Field Engineer (EIT)	$ 25.00	1.5		$ -
Technician/Drafter	$ 25.00	1.5		$ -
Laborer	$ 25.00	1.5	168	$ 6,300.00
Clerk/Office Admin	$ 20.00	1.5	7	$ 210.00
Labor Subtotal			221	$ 9,397.50
Profit Multiplier (P)			18%	$ 1,691.55
Canoe Fabrication Direct Labor Total (DL)				**$ 11,089.05**

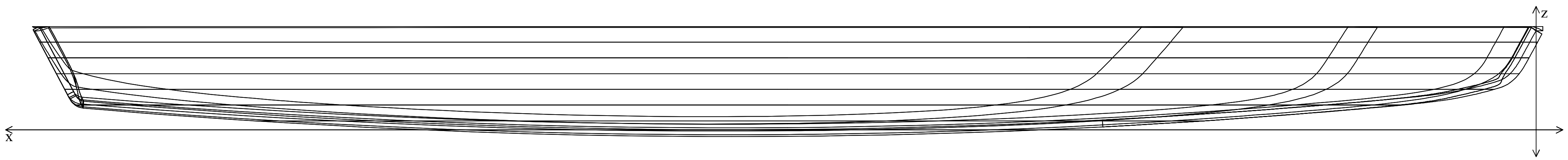
Canoe Fabrication Expenses - Per Canoe	
Description	Cost
Material Costs Per Canoe (MC) - Above	$ 717.51
Mixing Supplies	$ 113.74
PPE	$ 248.88
Quality Assurance Devices	$ 12.56
Curing Burlap	$ 84.65
Sandpaper	$ 20.94
Expenses Subtotal	$ 1,198.28
Markup (M) 10%	$ 119.83
Canoe Fabrication Expenses	**$ 1,318.11**
Mold Fabrication Costs per Canoe	**$ 711.28**
Total Canoe Fabrication Expenses (E)	**$ 2,029.38**

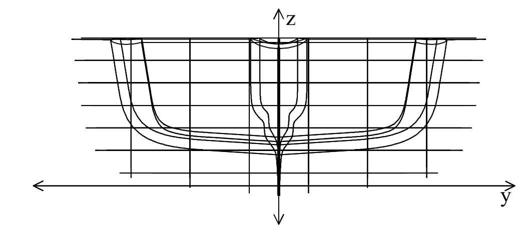
Total Cost Per Canoe	
Labor (DL)	$ 11,089.05
Expenses (E)	$ 2,029.38
Total	**$ 13,118.43**

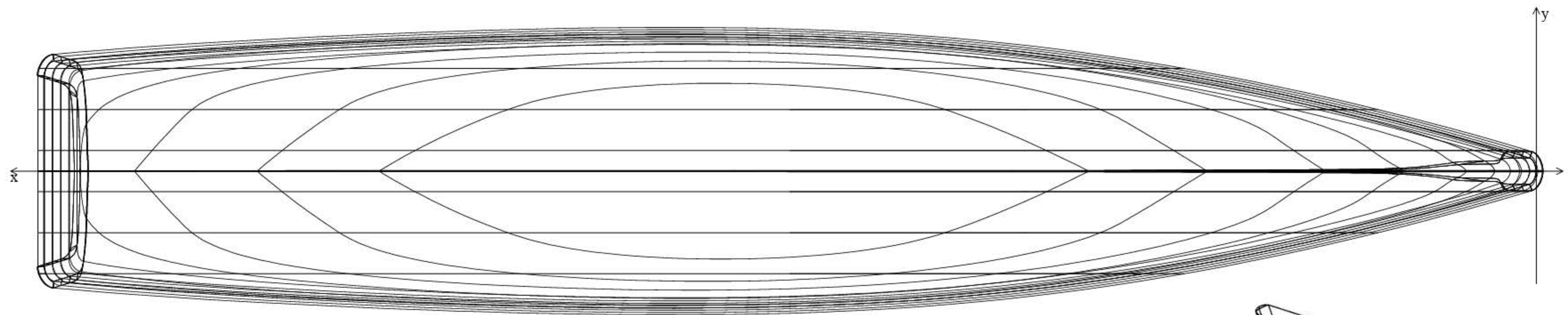
Mold Fabrication Labor Costs				
Role	RLR	DEC	HRS	Extended
Principal Design Engineer	$ 50.00	1.5	8	$ 600.00
Design Manager	$ 45.00	1.5		$ -
Project Construction Manager	$ 40.00	1.5		$ -
Construction Superintendent	$ 40.00	1.5	14	$ 840.00
Project Design Engineer (P.E.)	$ 35.00	1.5		$ -
Quality Manager	$ 35.00	1.5	6	$ 315.00
Graduate Field Engineer (EIT)	$ 25.00	1.5		$ -
Technician/Drafter	$ 25.00	1.5	6	$ 225.00
Laborer	$ 25.00	1.5	28	$ 1,050.00
Clerk/Office Admin	$ 20.00	1.5	2	$ 60.00
Labor Subtotal			64	$ 3,090.00
Profit Multiplier (P)			18%	$ 556.20
Mold Fabrication Direct Labor Total (DL)				**$ 3,646.20**

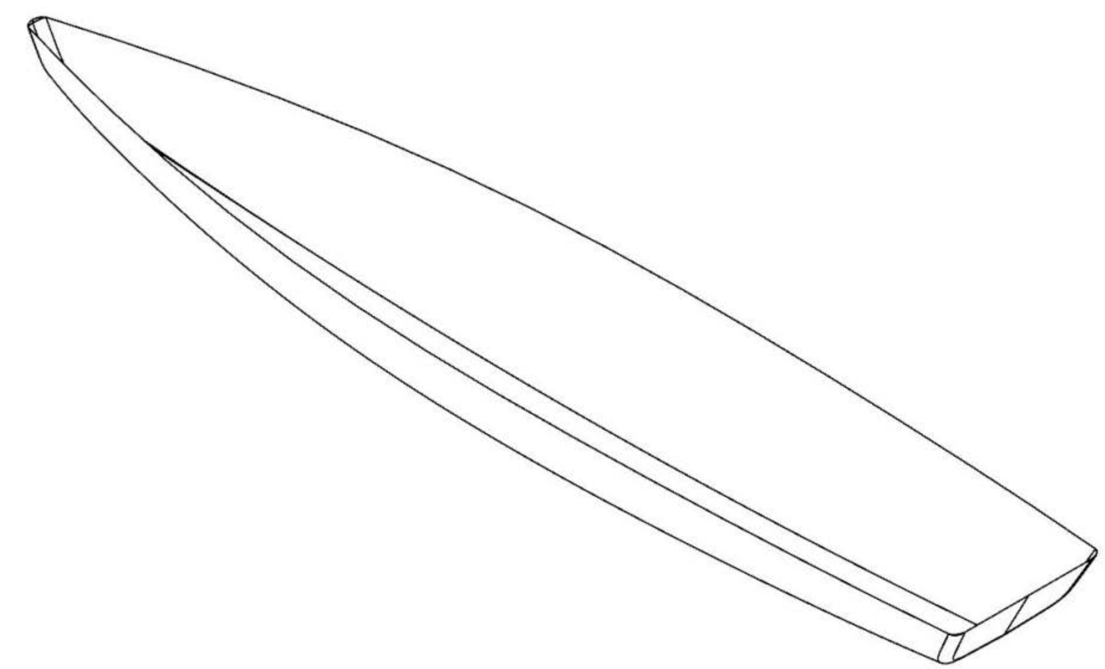
DL Total	$ 3,646.20
Expenses Total	$ 3,466.56
Mold Fabrication Original Cost	**$ 7,112.76**
Quantity of Canoes Cast Before Replacing Mold	10
Mold Fabrication Cost Per Canoe	**$ 711.28**

Mold Fabrication Expenses	Extended
Materials Cost	
3-lb Polystyrene Foam	$ 3,082.00
Tuck Tape Release Agent	$ 28.17
Ratchet Straps	$ 19.99
Curing Plastic	$ 21.26
Expenses Subtotal	$ 3,151.42
Markup (M) 10%	$ 315.14
Mold Fabrication Expenses (E)	**$ 3,466.56**







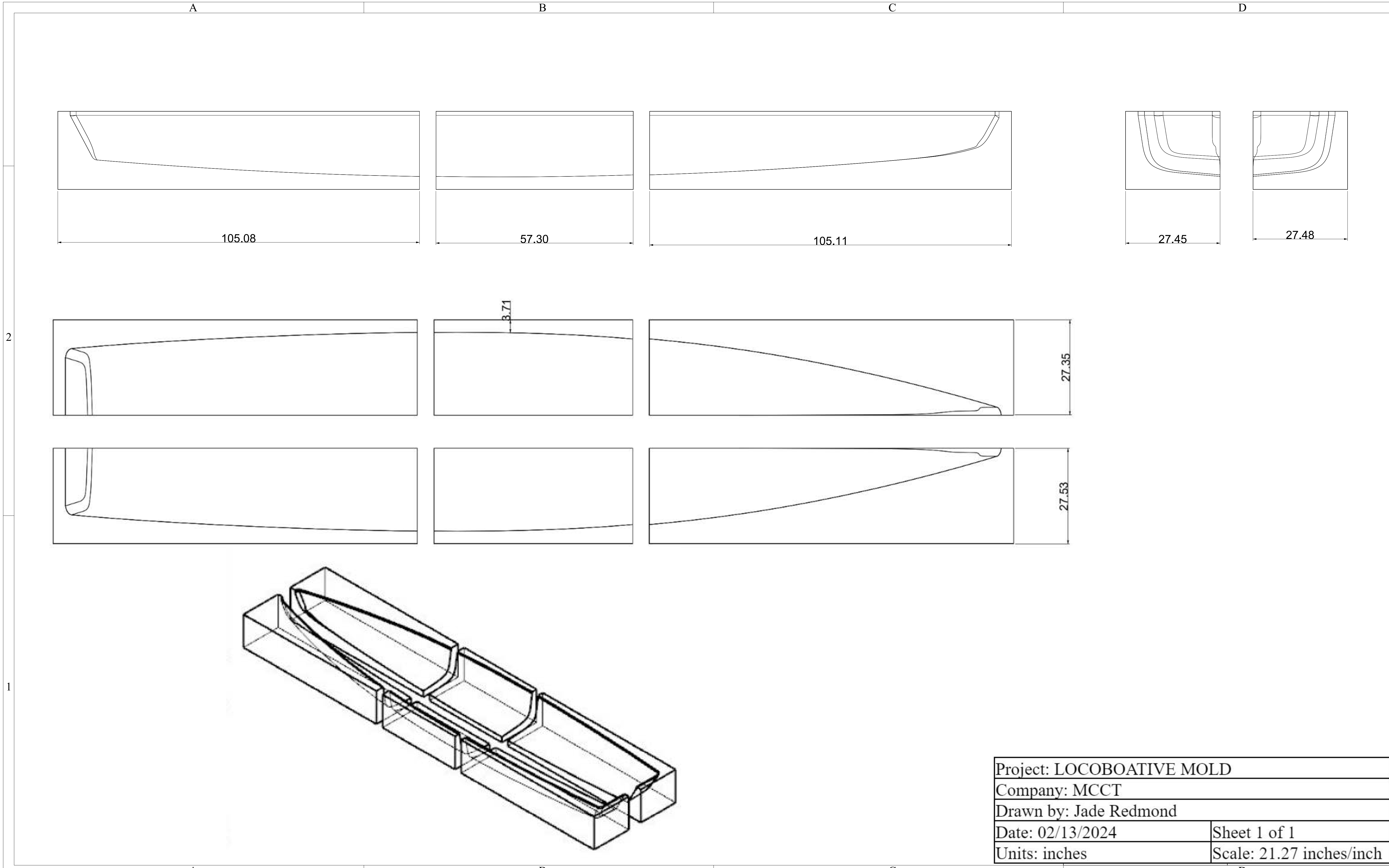


WATERLINE HALF-BREADTHS									
Station	Waterline #1 2.143	Waterline #2 4.286	Waterline #3 6.429	Waterline #4 8.571	Waterline #5 10.714	Waterline #6 12.857	Waterline #7 15.000	3D Curve	Station
21.091			5.705	6.450	6.808	7.137	7.466		**21.091**
			-5.705	-6.450	-6.808	-7.137	-7.466		
42.182		9.013	10.732	11.277	11.600	11.919	12.238		**42.182**
		-9.013	-10.732	-11.277	-11.600	-11.919	-12.238		
63.273	7.229	13.425	14.512	14.950	15.264	15.577	15.891		**63.273**
	-7.229	-13.425	-14.512	-14.950	-15.264	-15.577	-15.891		
84.364	13.141	16.141	17.020	17.407	17.721	18.034	18.348		**84.364**
	-13.141	-16.141	-17.020	-17.407	-17.721	-18.034	-18.348		
105.455	15.133	17.513	18.312	18.683	19.001	19.319	19.637		**105.455**
	-15.133	-17.513	-18.312	-18.683	-19.001	-19.319	-19.637		
126.545	15.458	17.834	18.640	19.019	19.345	19.670	19.996		**126.545**
	-15.458	-17.834	-18.640	-19.019	-19.345	-19.670	-19.996		
147.636	14.383	17.392	18.303	18.713	19.051	19.389	19.727		**147.636**
	-14.383	-17.392	-18.303	-18.713	-19.051	-19.389	-19.727		
168.727	10.249	16.280	17.476	17.961	18.318	18.674	19.029		**168.727**
	-10.249	-16.280	-17.476	-17.961	-18.318	-18.674	-19.029		
189.818		14.116	16.178	16.840	17.231	17.616	17.999		**189.818**
		-14.116	-16.178	-16.840	-17.231	-17.616	-17.999		
210.909		2.874	14.049	15.197	15.682	16.125	16.562		**210.909**
		-2.874	-14.049	-15.197	-15.682	-16.125	-16.562		

BUTTOCK HEIGHTS										
Station	Buttock #1 -20.000	Buttock #2 -14.286	Buttock #3 -8.571	Buttock #4 -2.857	Buttock #5 2.857	Buttock #6 8.571	Buttock #7 14.286	Buttock #8 20.000	3D Curve	Station
21.091				4.918	4.918					**21.091**
42.182			4.061	3.055	3.055	4.061				**42.182**
63.273		5.771	2.294	1.709	1.709	2.294	5.771			**63.273**
84.364		2.613	1.343	0.811	0.811	1.343	2.613			**84.364**
105.455		1.811	0.867	0.352	0.352	0.867	1.811			**105.455**
126.545	15.028	1.704	0.827	0.323	0.323	0.827	1.704	15.028		**126.545**
147.636		2.111	1.207	0.719	0.719	1.207	2.111			**147.636**
168.727		2.995	1.992	1.531	1.531	1.992	2.995			**168.727**
189.818		4.375	3.141	2.723	2.723	3.141	4.375			**189.818**
210.909		6.705	4.649	4.285	4.285	4.649	6.705			**210.909**

Principal Characteristics	
LOA = 218 in	BOA = 40 in
D = 15 in	T = 6.64 in
Lwl = 207 in	Bwl = 37.4 in
Cb = 0.514	Cp = 0.633
Displacement = 950 lbf	S = 48.5 ft^2

Project: LOCOBOATIVE	
Company: MCCT	
Drawn by: Jade Redmond	
Date: 02/15/2024	Sheet 1 of 1
Units: inches	Scale: 19.49 inches/inch



Project: LOCOBOATIVE MOLD	
Company: MCCT	
Drawn by: Jade Redmond	
Date: 02/13/2024	Sheet 1 of 1
Units: inches	Scale: 21.27 inches/inch

Appendices

Appendix A - Bibliography

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Appendix B - Hull Thickness/Reinforcement and Percent Open Area Calculations

Hull Thickness and Reinforcement

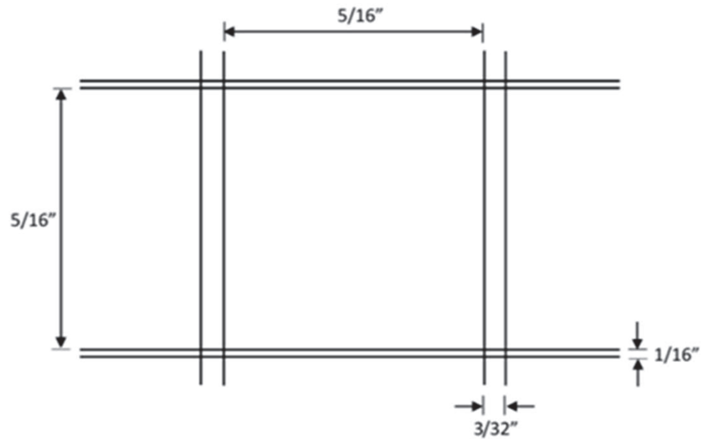
MCCT used a consistent 0.6 inch thickness for the keel, bilge and sidewalls of the canoe. 1/16th inch SpiderLath fiberglass reinforcement was applied in overlapping sections. The calculations below demonstrate that mesh does not exceed 50% of the thickness of the canoe.

First layer of concrete: 0.2375 inches
Mesh reinforcement: 0.0625 inches
Second layer of concrete: 0.2375 inches
Net Thickness: 2(0.2375) + 2(0.0625) = 0.6

Percent Mesh reinforcement by thickness:
20.8% < 50% → Compliant

Percent Open Area[2]

One layer of SpiderLath fiberglass was used in the construction plan chosen for *LOCOBOATIVE*.



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

$$\text{Open Area} = 20 \cdot 20 \cdot \frac{5}{16} \cdot \frac{5}{16} = 39.06\ in^2$$

$$\text{Aperture Area (considering half stand thickness) } W = \frac{5}{16}in + \frac{1}{2}\left(2 \cdot \frac{3}{32}in\right) = \frac{13}{32}in$$

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

$$\text{Length of sample} = 20 \cdot \frac{6}{16}in = 7.50\ in$$

$$\text{Width of sample} = 20 \cdot \frac{13}{32}in = 8.13\ in$$

$$\text{Total sample area} = 8.13\ in \cdot 7.50\ in = 60.98\ in^2$$

$$\text{Percent Open area} = \frac{39.06\ in^2}{60.98\ in^2} \cdot 100\% = 49.3\%$$

49.3% > 40% → Compliant

Pre-Qualification Form (Page 1 of 3)

University of Michigan

(school name)

We acknowledge that we have read the 2024 ASCE Society-wide Concrete Canoe Competition Request for Proposal and understand the following (*initialed by one (1) team captain and ASCE Faculty Advisor*):

Statement	Captain Initials	Advisor Initials
The requirements of all teams to qualify as a participant in the ASCE Student Symposium and Society-wide Competitions as outlined in Section 3.0 and Exhibit 3.	VK	FEG
The eligibility requirements of registered participants (Section 3.0 and Exhibit 3).	VK	FEG
The deadline for the submission of *Letter of Intent, Preliminary Project Delivery Schedule* and *Pre-Qualification Form* (uploaded to ASCE server) is November 3, 2023; 5:00 p.m. Eastern.	VK	FEG
The last day to submit *ASCE Student Chapter Annual Reports* to be eligible for qualifying (so that they may be graded) is February 1, 2024.	VK	FEG
The last day to submit a *Request for Information* (RFI) to the C4 is January 29, 2024.	VK	FEG
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.	VK	FEG
The submission date of the *Project Proposal*, *Mix Design Sheets*, and *Materials Notebook* for the Student Symposium Competition (uploading of electronic copies to ASCE server) is Friday, February 16, 2024.	VK	FEG
The submission date of the *Project Proposal*, *Mix Design Sheets*, and *Materials Notebook* for Society-wide Final Competition (hard copies received by ASCE and uploading of electronic copies to ASCE server) is May 15, 2024; 5:00 p.m. Eastern.	VK	FEG

Vivian Kim — 10/25/23 — Fernando (Estefan) Garcia

Team Captain *(date)* — *(date)* — *ASCE Student Chapter Faculty Advisor*

Vivian Kim — F. Estefan T. Garcia

(signature) — *(signature)*

Pre-Qualification Form (Page 2 of 3)
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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?

The Michigan Concrete Canoe Team (MCCT) operates under the public health plans of the state of Michigan, City of Ann Arbor, University of Michigan, College of Engineering (CoE), and the facilities in which it operates, including the Wilson Student Team Project Center (WSTPC). MCCT also adheres to personal health requirements in all facilities, requiring proper PPE, training, and safe work environments. [1] Required training includes but is not limited to training from the WSTPC on how to properly use equipment and tools. The team is continually working with the WSTPC and Office of Student Affairs to ensure safe events.[1]

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?

MCCT's QA/QC program has three branches: Quality Assurance, Risk Management, and Technical Submissions. The Quality Assurance Lead oversees the quality of the canoe during construction. This includes training members on construction methods, preparing the mold, preparing QA devices, and monitoring concrete mixing and testing. The Risk Manager ensures that the team follows all requirements and guidelines in the competition rules and ensures that final products align with the outlined rules and standards prior to production. The Technical Submissions Lead ensures that all technical and written submissions are complete, cohesive, and follow guidelines set by the competition rules. All positions are elected by vote at the end of the previous season.

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

MCCT has reviewed all safety policies regarding material research, material lab testing, and construction for the facilities that MCCT uses (Wilson Center, College of Engineering, Department of Civil and Environmental Engineering, etc.). MCCT is in continuous contact with the heads of the aforementioned facilities and any other relevant facilities in order to maintain a safe environment for students.[1]

In 150 words or less, provide your team's perspective on the use of ChatGPT and other AI/NLP algorithms in the competition. Do you intend to use it? If so, in what areas? (Note: C4 neither encourages or discourages the use of AI/NLP algorithms, but is interested in collecting data on student usage in the competition.)

[1] Michigan Concrete Canoe Team (2022). Prequalification Form, University of Michigan, Ann Arbor, Michigan.

Pre-Qualification Form (Page 3 of 3)

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MCCT believes that as long as ChatGPT and other AI/NLP tools are used ethically and are properly cited, they are useful tools that can enhance project efficiency and allow team members to experiment with technology that could aid them in industry. The team strongly believes that any task completed or aided by AI must be reviewed and edited for clarity and correctness in order to uphold academic integrity.

If feasible, MCCT plans to explore using ChatGPT as an aid for writing the project proposal. Currently MCCT plans to use outputs from these tools as inspiration, rather than directly taking text, but will likely experiment with both. In the future, the team may research the feasibility of using a trained ChatGPT model and other AI/NLP tools to help with information retrieval.

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