YANGTZE

TONGJI UNIVERSITY
2024 CONCRETE CANOE
PROJECT PROPOSAL

To: **Concrete Canoe Competition Committee (C4)**

From: **Tongji Concrete Canoe Team**

Date: **February 10, 2024**

Re: ***2024 ASCE Concrete Canoe Competition ™ Request for Proposals***

Attached please find the *Technical Proposal* of our canoe prototype, *Yangtze*.

The 2024 Concrete Canoe Team from the Tongji University certificates the followings:

a) 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.*
b) Material Technical Data Sheets (MTDS) and Safety Data Sheets (SDS) have been reviewed by the team for completeness and compliance.
c) The team acknowledges receipt of the *Request for Information* (RFI) Summary and that their submissions comply with the responses provided.
d) 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).
e) All text generation AI/NLP algorithm uses are properly cited within the respective document.

Registered Participant	ASCE National Member ID Number
Ziyue Huang	000012441603
Hongrui Wu	000012419561
Tianze Han	000012441606
Junzhe Zhang	000012444866
Shuyi Chen	000012378084
Dexin Liu	000012439029
Chumeng Jiang	000012441832
He Liu	000012438397
Xiaoyu Ren	000012438581
Yanghao Liu	000012441356

Ziyue Huang

Ziyue Huang
Team Captain
+86 18772290925
2153515@tongji.edu.cn

02/10/2024
Date

Haibei Xiong

Haibei Xiong
Faculty Advisor
+86 13701928957
xionghaibei@tongji.edu.cn

02/10/2024
Date

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YANGTZE 2024

Properties	Density(fresh concrete) (lb/ft^3)	Density(hardened concrete) (lb/ft^3)	Slump	Air Content	Compressive Strength(28 days)	Tensile Strength (28 days)	Composite Flexual Strength(28 days)
Inner Mix	86.1	81	2.50 ± 0.25 inch	9.0%	3370 psi	310 psi	790 psi
Outer Mix	91.6	87	3.00 ± 0.25 inch	5.4%	2850 psi	210 psi	550 psi
EGC	112.9	104	0.25 inch	7.9%	5530 psi	960 psi	2640 psi

Tongji Student Chapter

ASCE STUDENT CHAPTER Tongji University

ASCE-Tongji-ISG, founded in 2012, has won 6 regional championships in the Mid-Pacific Concrete Canoe Competition since 2013. It has gained Tongji University a strong reputation on the international stage.

To improve students' engineering literacy, ASCE-Tongji-ISG organizes various activities. These include the Structure Competition for Freshmen in November, the Structural Competition for high school students in September, and the Enterprise Open Day in spring.

ASCE-Tongji-ISG has been awarded the Certificate of Commendation in 2022 and the Letter of Honorable Mention in 2023. Moving forward, they will continue to build on these accomplishments.

Tongji 2024 Concrete Canoe Team

HULL

A keel was proposed

Stability
Flexibility
Speed

MIX

Slag Cement
Engineering Geopolymer Composite
Standard Impermeability Testing
Fly Ash Ceramic Granules

Sustainability
Impermeability
Balance between Strength and Other Properties

CONST

Six-Axis Robotic Manipulator
Brand New Mold Coating System

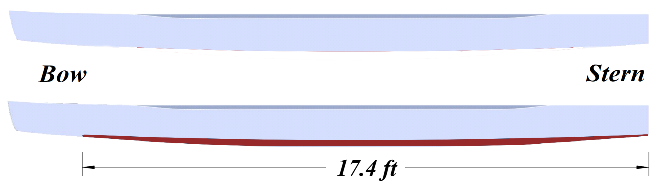
Reusable Mold
Easier Mold Removal
More Convenient Costruction
Canoe with Higher Quality

QA&QC

Quality Assurance and Quality Control

Consumers will obtain:
A **stable, fast, flexible, durable, sustainable, high-quality, aesthetic-pleasing** canoe.

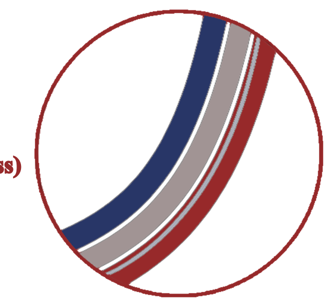
The client will obtain:
An excellent product-construction scheme with **low-cost, high accuracy,** and **high feasibility**.



The unprecendented keel deign enables the canoe to be more stable.

Keel

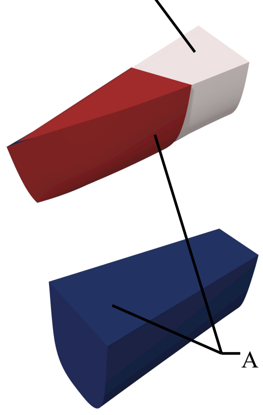
Mixes (Thickness)



- Outer Mix(0.12 in)
- Inner Mix (0.12in.)
- EGC (gunwale only)

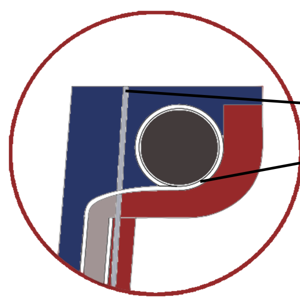
Flotations

High-density Expanded Polystyrene Foam (Density: 1.25±.12 lb/ft³)

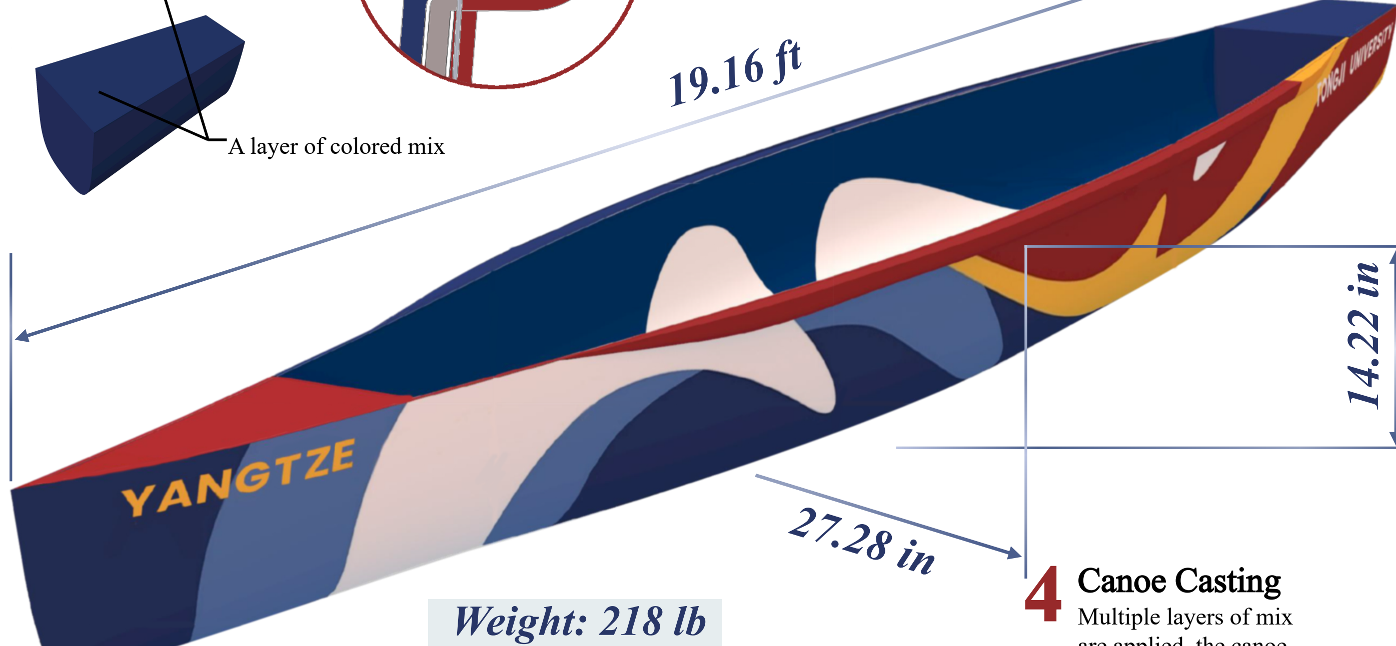


A layer of colored mix

Reinforcements



Steel Strand Tendons(Primary)
Carbon Fiber Meshes(Secondary)



Weight: 218 lb

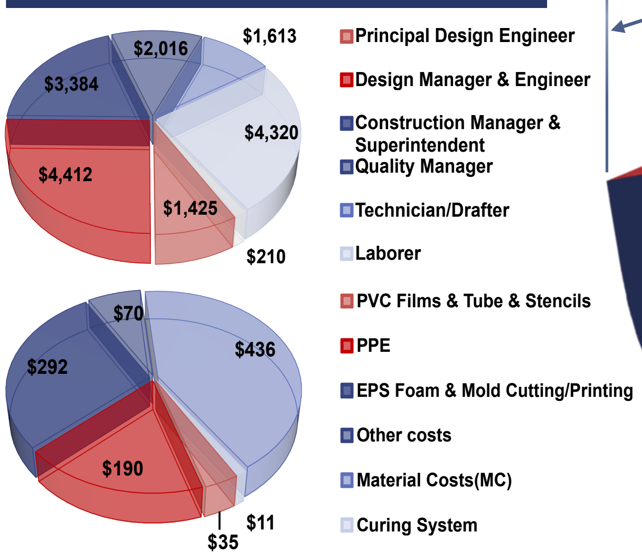
Aesthetic Theme

- flowing river
- sturgeon leaping out of water

The aesthetic scheme is derived from the Chinese Sturgeon, which first appeared 150 million years ago in the Mesozoic era. Chinese Sturgeon is the largest fish in the Yangtze River in China, called "the King of the Yangtze River Fish". In Chinese culture, it is a symbol of endless life.

Due to changes in the natural environment, it has been assessed as critically endangered in the IUCN Red List of Threatened Species in 2021. However, its re-emergence in 2023 showed that the ecological balance and bio-harmony has been regained in the Yangtze River.

The high-strength, eco-friendly and elegant canoe matches the profile of the mysterious and robust Chinese Sturgeon, demonstrating the team's pursuit of practicality, durability, and sustainable design concepts.



Manufacturing Cost Allocation Estimate

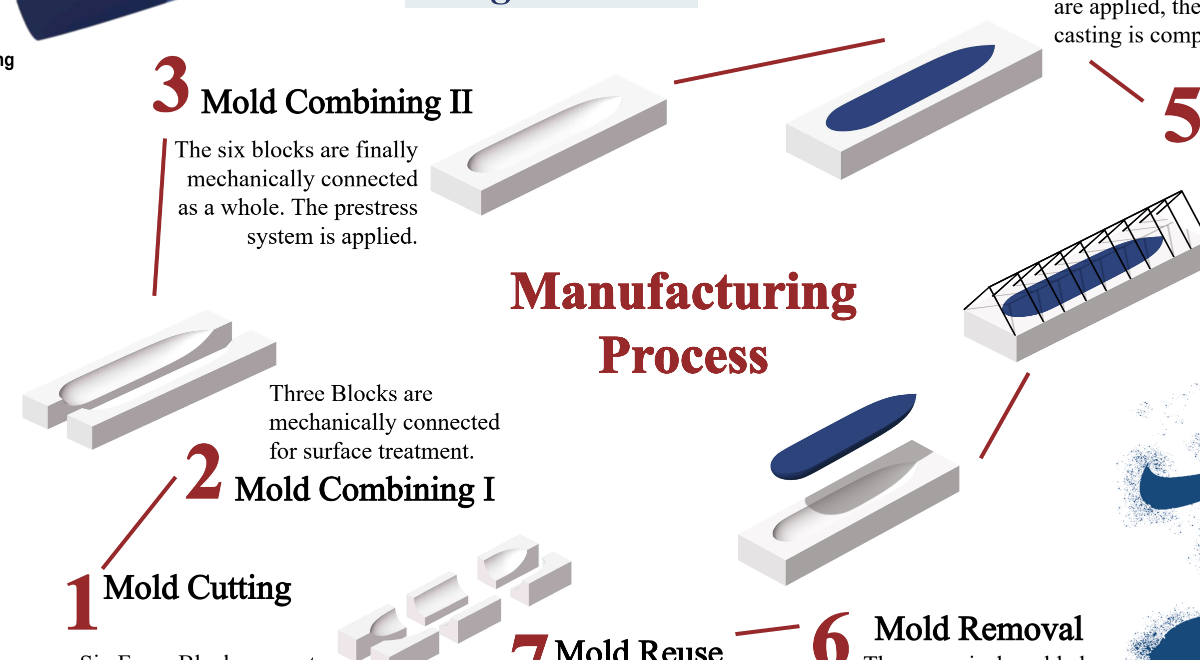
Manufacturing Cost

With acrylic cylinders protecting prestressing holes and plastic membrane protecting the foam surface, a mold can generally be reused **5** times before replacement, as the team estimate, and the cost only increases by 25% compared to disposable molds.

The unit price used for bulk purchase was calculated based on the assumption of purchasing materials for **10** canoes each time. To minimize material storage costs, the next batch of materials will be purchased after the previous batch was used up.

The total cost estimation is $32739/canoe.

Manufacturing Process



1 Mold Cutting
Six Foam Blocks are cut by the Six-Axis Robotic Manipulator.

2 Mold Combining I
Three Blocks are mechanically connected for surface treatment.

3 Mold Combining II
The six blocks are finally mechanically connected as a whole. The prestress system is applied.

4 Canoe Casting
Multiple layers of mix are applied, the canoe casting is completed.

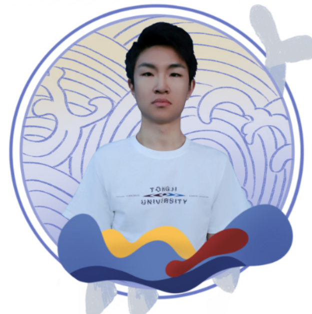
5 Curing
The two-phase curing is carried out. Two different curing chambers are applied.

6 Mold Removal
The canoe is demolded and sanded, leaving the empty mold to be reused.

7 Mold Reuse
The six blocks are ready to be used again.

Hongrui Wu
Hull Design Engineer

Responsible for the research and application of advanced hull design.



Tianze Han
Structural Analysis Engineer

Responsible for the 3D reconstruction and the comprehensive structural analysis.

Assistant:
- Dianzhe Tang
- Tongyu Zhang
- Binshu Fu
- Bo Peng
- Zheng Bian

HULL DESIGN &STRUCTURAL ANALYSIS

Ziyue Huang
Project Manager

Overview of the entire project, responsible for schedule formation and task delegation. Manage the quality of the product and the efficiency of the teamwork.

PROJECT MANAGER

Assistant:
- Yaqi Li
- Zixin Fang
- Luoyu Feng
- Fengyi Xu
- Shiju Han

Yizhang Zhu
Mold Fabrication Engineer

Responsible for the management of the mold construction, mold surgace treatment and mold protection.Train new members.

Xiaoyu Ren
Prestress Design Engineer

Responsible for the design and application of the prestress system.

Yanghao Liu
Construction Engineer

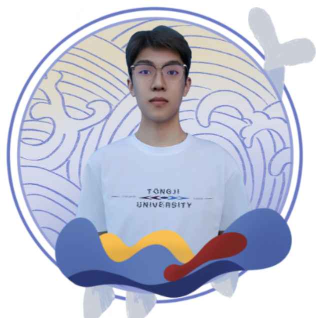
Responsible for the entire process of canoe construction, mold construction and display.

He Liu
Curing Design Engineer

Responsible for determining the concrete curing plan, constructing the curing chamber and supervising the curing condition.

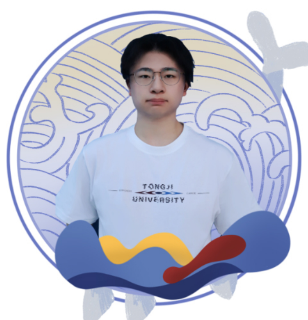
CONSTRUCTION

MIX DESIGN



Junzhe Zhang
EGC Design Engineer

Responsible for the design of EGC mix and corresponding experiments. Assist in the assembling of EGC gunwales.



Ningyuan Wu
Mix Design Engineer

Responsible for the material design.Formulate the overall development plan of the mixture. Assist in the design of experiments.

Yuchen Zhou
Material Testing Engineer

Responsible for the design of materials experiments. Conduct ASTM tests to ultimately determine concrete performance.

Yiwen Zhang
Experiment Design Engineer

Responsible for innovative experiments. Design and conduct the prototype experiment. Assist in mixture design and testing.

Assistant:
- Shanqing Gao
- Qinkang Long
- Jingmao Li
- Zixin Ye
- Zirui Zhou

JR. PROJECT MANAGER

Assist in the overall project, responsible for the budget appropriation and financial records. Managethe communication with advisors and sponsors.

Shuyi Chen
Jr. Project Manager

GRAPHICS&AESTHETICS

Assistant:
- Jialin Wang
- Yuxin Fan

Chumeng Jiang
Graphic&Aesthetics Designer

Responsible for aesthetic design of the canoe and project display, illustration and proposal layout.

PADDLING&SAFETY

Paddlers:
- DeXin Liu
- ChuMeng Jiang
- ZiYue Huang
- He Liu
- TianZe Han
- XiaoYu Ren

Dexin Liu
Paddling Coach

Responsible for the paddling training and paddling safety.

Project Scope

The Tongji Concrete Canoe Team updated design and production schemes in accordance with RFP. Seaworthiness was improved to ensure excellent sailing performance in irregular waters in America. Structural capacity was improved to make the canoe more durable. Light aggregates were used to reduce canoe weight and increase speed. PE fibers were used to improve the durability of the canoe in the water to resist the impact of gravel and sand in rivers. The team also use all iron and steel slag cementitious combined with engineering geopolymer composite (EGC) as part of the canoe cementitious materials, to reduce damage to the environment as well as contributing to the environmental sustainability. To produce 100 canoes, molds and other devices were reused to save costs, and quality programs and processes were improved to enhance production quality.

Health and Safety

Our team prioritized the health and safety program, taking multiple measures both in the lab and on the training field.

In the lab, measures were taken to protect members from hazardous substances.

Before entering the lab, members were asked to wear face masks and gloves, and an N95-rated face mask or 3M dust respirator was also needed during sanding. A lab manager was elected to manage the ventilation system and the waste disposal. A smokeless, dust-free environment was ensured, and waste generated during experiments and the construction process was categorized and discharged in strict accordance with the emission or disposal standards. The team chose the low-VOC concrete finishing and conducted harmful substance testing on samples. After submerging them in water and testing the water quality after seven days, team members carried out chemical analysis and ensured the content of toxic substances like cadmium was all within the prescribed limits.

On the training field, paddlers were kept from injuries and dangers. Paddlers were only allowed to carry out the training with a life-saving coat and under the supervision of the coaches. Apart from that, a paddling safety volunteer was always on the scene to monitor the safety conditions. The team applied chamfering to the edge of the gunwale and cut the loose ends of transverse tendons in case they scratched the paddlers. With the measures stated above, paddlers can train without safety concerns.

Project Management Plan (PMP)

The design and preparation for *Yangtze* began after the release of the RFP. 2024 is the first year for Tongji University to resume offline competition. Considering transportation and the advancement of the ASCE Mid-Pacific competition, the overall project progress of *Yangtze* needed to be advanced by two months earlier than last year. The team held a kick-off meeting in September to formulate the project stage plan as follows.

Stage 1: Preliminary design. Goals and aesthetic design were formulated according to the RFP. Researches of hull design, mix design, and structural analysis were carried out, while meetings were held to assess rationality and feasibility.
Milestone: Structural Analysis research completed

Stage 2: Experimental canoe fabrication. Captains confirmed the plan of the experimental canoe to verify the preliminary design of Stage 1. Construction captains completed the mold fabrication. Mix design captains developed the mix through a series of strength tests. Canoe fabrication was completed.
Milestone: Experimental canoe curing completed

Stage 3: Final canoe design. Hull design captains completed further optimization and adjustment on the design scheme according to the performance of the experimental canoe. Construction captains reviewed and optimized the construction process. Mix design captains determined the final mix according to a standard impermeability test.
Milestone: Ultimate design scheme formulated

Stage 4: Final canoe fabrication. The final canoe was cast. The curing was completed.
Milestone: Mold removal

Stage 5: Polishing, Training, and Presentation. *Yangtze* was sanded and sealed. The project proposal was submitted, and the presentation was prepared. Paddlers practiced throughout the quarter.

Once the above stages had been planned, the team met once a week to exchange ideas, resolve difficulties, monitor progress and assign tasks. If a delay occurred, the captain would seek reasons and make compensation to ensure the completion of the project.

The major risk came from the keel design. Captains needed to confirm whether the keel would bring some side effects based on the feedback from the experimental canoe. If the outcome is negative, little time will be left to update the design due to the tight schedule. To minimize the risk, the hull design captain found a way of conducting CFD analysis in the software to refine the design. The result revealed a successful attempt.

Quality Assurance and Quality Control

As defined by ISO, *quality assurance* (QA) refers to management activities "focused on providing confidence that the quality requirements will be fulfilled", while *quality control* (QC) focuses on "fulfilling quality requirements".

QA regulations were established to provide confidence and ensure baseline quality. Materials must be purchased through reliable suppliers and with comprehensive testing reports to ensure that their MTDS and SDS comply with the ASTM standards. One merchant should be designated to each material for continuous contact so that material consistency can be assured. Each portion of aggregate and cement must be weighed twice before mixing to prevent deterioration caused by moisture. The prestress scheme must be formed with friction and relaxation considered according to ASTM Standard Specification for Steel.

QC measurements were strictly carried out during construction. To align with above-stated QA requirements, prestress tendons were not tightened until the casting day to avoid relaxation. Over-stretching was applied to ensure adequate prestress under friction. **Independent QC measures were also conducted.** The graduated thickness measuring needle device was used to check the thickness during the casting training. The team shortened the construction time gap between layers and color blocks to ensure construction integrity, enhancing the bonding of the carbon fiber mesh and the concrete layer.

Research and Development Cost

The team co-considered time and financial allocations to save Research and Development (R&D) cost while guaranteeing a high-quality project.

For R&D time planning, the team tried to reduce the preparation hours of team members and lower the labor costs as much as possible through rational schedules, but for those phases that required refined work such as mix testing and construction, the team invested 44% of the total for better results. Finally, the total working hours were controlled at 2,395h.

In the process of allocating labor costs, the team objectively evaluated the workload of different positions in the past years. Based on this, the team set the salary. In the cost allocation of R&D expenses, the team members paid attention to the maintenance of tools to avoid secondary costs. At the same time, the team tried to reach local testing organizations and suppliers for experimental materials, which reduced the cost of material to $3,222, and the final total R&D costs are controlled at $193,807.8.

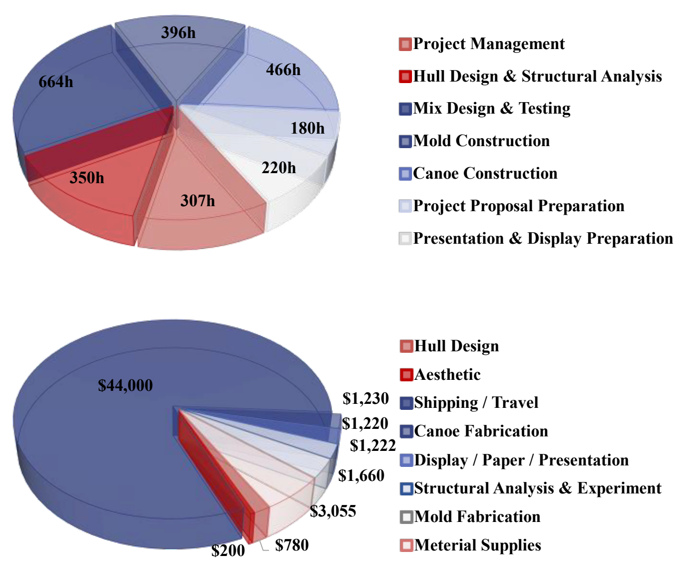


Figure 1. R&D Time and Expenses Allocation

Research and Development Cost - Fee Schedule

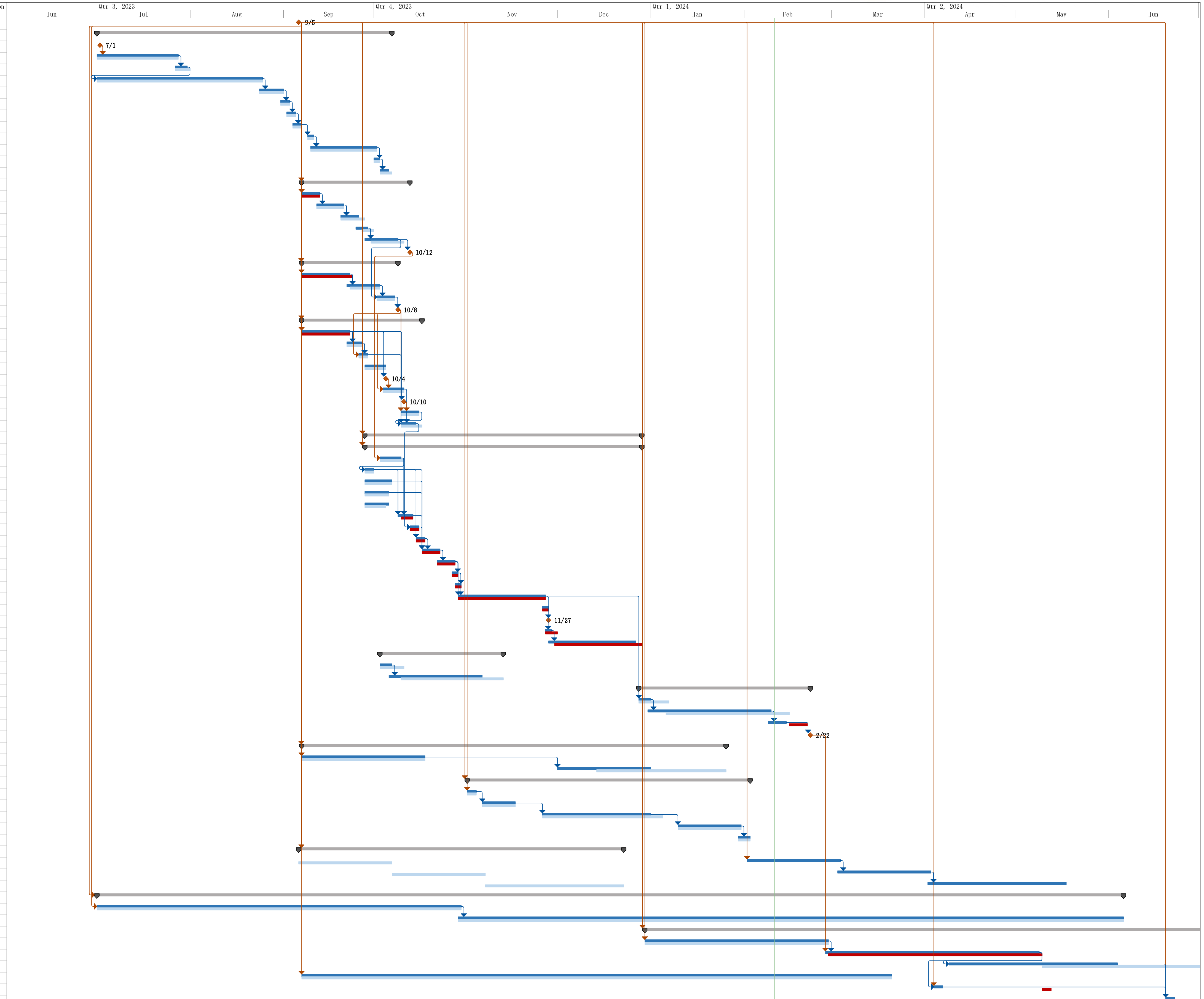
Project Total Hours			
Work Scope	Hours	Work Scope	Hours
Project Management	307	Canoe Construction	466
Hull Design	275	Project Proposal Preparation	180
Structural Analysis	75	Presentation Preparation	120
Mix Design & Testing	664	Display Preparation	100
Mold Construction	396		
		Total	866

R&D Labor Costs				
Role	RLR	DEC	HRS	Extended
Principal Design Engineer	$ 50.00	1.5	133	$ 9,975.00
Design Manager	$ 45.00	1.5	175	$ 11,812.50
Project Construction Manager	$ 40.00	1.5	145	$ 8,700.00
Construction Superintendent	$ 40.00	1.5	120	$ 7,200.00
Project Design Engineer (P.E.)	$ 35.00	1.5	377	$ 19,792.50
Quality Manager	$ 35.00	1.5	266	$ 13,965.00
Graduate Field Engineer (EIT)	$ 25.00	1.5	65	$ 2,437.50
Technician/Drafter	$ 25.00	1.5	689	$ 25,837.50
Laborer	$ 25.00	1.5	570	$ 21,375.00
Clerk/Office Admin	$ 20.00	1.5	43	$ 1,290.00
		Labor Subtotal	2583	$ 122,385.00
		Profit Multiplier (P)	18%	$ 22,029.30
			R&D Direct Labor Total (DL)	$144,414.30

DL Total	$ 144,414.30
Expenses Total	$ 58,703.70
R&D Total Cost	$203,118.00

R&D Expenses			Cost
Materials / Other Cost			
Meterial Supplies			$ 3,055.00
Tool Supplies			$ 958.00
Meterial Testing			$ 167.00
Structural Experiment			$ 552.00
Paddling Supplies			$ 98.00
Books			$ 57.00
Express Logistics			$ 190.00
Working Meals			$ 90.00
Mold (lump sum cost)			$ 980.00
Display / Paper / Presentation Costs			
Display Materials			$ 580.00
Printing			$ 318.00
Information Service			$ 212.00
Aesthetic			$ 110.00
Shipping / Travel Costs for Competition			
Ship to America			$ 11,000.00
Airplane to America			$ 30,000.00
Accommodations			$ 3,000.00
Outside Consultants	HRS	$/HR	Extended
	10	200	$ 2,000.00
		Expenses Subtotal	$ 53,367.00
	Markup (M)	10%	$ 5,336.70
		R&D Expenses (E)	$ 58,703.70

ID	Task Name	Baseline Start	Baseline Finish	Actual Start	Actual Finish	Duration
1	**Issuance of Request for Proposal**	**9/5/2023**	**9/5/2023**	**9/5/2023**	**9/5/2023**	1 d
2	**Experimental canoe**	**7/1/2023**	**10/5/2023**	**7/1/2023**	**10/6/2023**	**98 d**
3	Beginning of summer vacation	7/1/2023	7/1/2023	7/1/2023	7/1/2023	1 d
4	Material experiment	7/1/2023	7/27/2023	7/1/2023	7/27/2023	27 d
5	Material preparation	7/27/2023	7/30/2023	7/27/2023	7/31/2023	5 d
6	Hull Design Research	7/1/2023	8/24/2023	7/1/2023	8/24/2023	55 d
7	Prepare foam model	8/24/2023	8/31/2023	8/24/2023	8/31/2023	8 d
8	Prestressing System Installation	8/31/2023	9/2/2023	8/31/2023	9/2/2023	3 d
9	Gunwale Molds Preparation	9/2/2023	9/4/2023	9/2/2023	9/4/2023	3 d
10	Tendon Application	9/4/2023	9/6/2023	9/4/2023	9/6/2023	3 d
11	Casting	9/9/2023	9/10/2023	9/9/2023	9/10/2023	2 d
12	Canoe curing	9/10/2023	10/1/2023	9/10/2023	10/1/2023	22 d
13	Flotation chamber construction	10/1/2023	10/2/2023	10/1/2023	10/2/2023	2 d
14	Paddling	10/3/2023	10/5/2023	10/3/2023	10/6/2023	4 d
15	**Hull Design**	**9/7/2023**	**10/10/2023**	**9/7/2023**	**10/12/2023**	**36 d**
16	Hull Design Research	9/7/2023	9/12/2023	9/7/2023	9/12/2023	6 d
17	Preliminary Hull Design	9/12/2023	9/20/2023	9/12/2023	9/20/2023	9 d
18	Experimental Test Design	9/20/2023	9/25/2023	9/20/2023	9/27/2023	8 d
19	Experimental Test and Results Analysis	9/25/2023	9/28/2023	9/27/2023	9/30/2023	4 d
20	Hull Design Completion	9/28/2023	10/8/2023	9/30/2023	10/10/2023	11 d
21	Drawing	10/8/2023	10/10/2023	10/10/2023	10/12/2023	3 d
22	**Structural Analysis**	**9/7/2023**	**10/8/2023**	**9/7/2023**	**10/8/2023**	**32 d**
23	Research	9/7/2023	9/22/2023	9/7/2023	9/23/2023	17 d
24	Composite Analysis & Design	9/22/2023	10/2/2023	9/23/2023	10/2/2023	10 d
25	Hand Calculation	10/2/2023	10/7/2023	10/2/2023	10/7/2023	6 d
26	Analysis Completion	10/7/2023	10/8/2023	10/7/2023	10/8/2023	2 d
27	**Mix Design**	**9/7/2023**	**10/15/2023**	**9/7/2023**	**10/16/2023**	**40 d**
28	Material Research	9/7/2023	9/22/2023	9/7/2023	9/22/2023	16 d
29	ECC Mix Design & Testing	9/22/2023	9/26/2023	9/22/2023	9/26/2023	5 d
30	ECC Mix Selection	9/26/2023	9/28/2023	9/26/2023	9/28/2023	3 d
31	Structural Mix Ⅰ Design & Testing	9/28/2023	10/4/2023	9/28/2023	10/4/2023	7 d
32	Structural Mix Ⅰ Selection	10/4/2023	10/4/2023	10/4/2023	10/4/2023	1 d
33	Structural Mix Ⅱ Design & Testing	10/4/2023	10/10/2023	10/4/2023	10/10/2023	7 d
34	Structural Mix Ⅱ Selection	10/10/2023	10/10/2023	10/10/2023	10/10/2023	1 d
35	Impermeability experiment	10/10/2023	10/15/2023	10/10/2023	10/15/2023	6 d
36	Mix Color Modulation	10/10/2023	10/14/2023	10/10/2023	10/16/2023	7 d
37	**Construction**	**9/28/2023**	**12/26/2023**	**9/28/2023**	**12/28/2023**	**92 d**
38	**Construction Method Research**	**9/28/2023**	**10/9/2023**	**9/28/2023**	**12/28/2023**	**92 d**
39	Prepare foam model	10/3/2023	10/9/2023	10/3/2023	10/10/2023	8 d
40	Design of thickness control device	9/28/2023	9/30/2023	9/28/2023	9/30/2023	3 d
41	Water Treatment Experiment	9/28/2023	10/6/2023	9/28/2023	10/6/2023	9 d
42	Surface treatment experiment	9/28/2023	10/5/2023	9/28/2023	10/5/2023	8 d
43	Mold coating system experiment	9/28/2023	10/5/2023	9/28/2023	10/4/2023	7 d
44	Prestressing System Installation	10/9/2023	10/13/2023	10/10/2023	10/13/2023	4 d
45	Gunwale Molds Preparation	10/13/2023	10/15/2023	10/13/2023	10/15/2023	3 d
46	Tendon Application	10/15/2023	10/17/2023	10/15/2023	10/17/2023	3 d
47	Materials Preparation	10/17/2023	10/22/2023	10/17/2023	10/22/2023	6 d
48	Release Agent Application	10/22/2023	10/27/2023	10/22/2023	10/27/2023	6 d
49	Casting	10/27/2023	10/28/2023	10/27/2023	10/28/2023	2 d
50	Curing Room Building	10/28/2023	10/29/2023	10/28/2023	10/29/2023	2 d
51	Canoe Curing	10/29/2023	11/26/2023	10/29/2023	11/26/2023	29 d
52	Prestressed Tendon Release	11/26/2023	11/27/2023	11/26/2023	11/27/2023	2 d
53	Mold Removal	11/27/2023	11/27/2023	11/27/2023	11/27/2023	1 d
54	Flotation chamber construction	11/27/2023	11/28/2023	11/27/2023	11/30/2023	4 d
55	Flotation chamber curing	11/28/2023	12/26/2023	11/30/2023	12/28/2023	29 d
56	**Cross-section**	**10/3/2023**	**11/5/2023**	**10/3/2023**	**11/12/2023**	**41 d**
57	Cross-section Design	10/3/2023	10/6/2023	10/3/2023	10/10/2023	8 d
58	Cross-section Construction	10/6/2023	11/5/2023	10/10/2023	11/12/2023	34 d
59	**Finishing**	**12/28/2023**	**2/24/2024**	**12/28/2023**	**NA**	**57 d**
60	Preliminary Patching & Sanding	12/28/2023	12/31/2023	12/28/2023	1/6/2024	10 d
61	Superior Patching & Sanding	12/31/2023	2/9/2024	1/6/2024	NA	41 d
62	Sealing & Polishing	2/9/2024	2/14/2024	NA	NA	6 d
63	Canoe Finishing	2/14/2024	2/14/2024	NA	NA	1 d
64	**Aesthetic Design**	**9/7/2023**	**12/31/2023**	**9/7/2023**	**1/25/2024**	**141 d**
65	Canoe Aesthetic Design	9/7/2023	10/17/2023	9/7/2023	10/17/2023	41 d
66	Stands Design	12/1/2023	12/31/2023	12/14/2023	1/25/2024	43 d
67	**Technical Proposal**	**11/1/2023**	**2/2/2024**	**11/1/2023**	**NA**	**94 d**
68	Data Ordering	11/1/2023	11/3/2023	11/1/2023	11/3/2023	3 d
69	Rough Draft	11/6/2023	11/16/2023	11/6/2023	11/16/2023	11 d
70	Peer/Professional Editing	11/26/2023	12/31/2023	11/26/2023	1/4/2024	40 d
71	Final Revisions & Review	1/10/2024	1/30/2024	1/10/2024	1/30/2024	21 d
72	Printing &Submission	1/30/2024	2/2/2024	1/30/2024	NA	4 d
73	**Technical Presentation**	**2/2/2024**	**5/17/2024**	**NA**	**NA**	**108 d**
74	Verbal Part Preparation	2/2/2024	3/3/2024	NA	NA	31 d
75	Visual Part Preparation	3/3/2024	4/2/2024	NA	NA	31 d
76	Rehearsal	4/2/2024	5/17/2024	NA	NA	46 d
77	**Paddling**	**7/1/2023**	**6/5/2024**	**7/1/2023**	**NA**	**341 d**
78	Paddling Training	7/1/2023	10/29/2023	7/1/2023	10/29/2023	121 d
79	Group Selection & Training	10/29/2023	6/5/2024	10/29/2023	NA	221 d
80	**Shipping & Transportation**	**12/30/2023**	**6/3/2024**	**12/30/2023**	**NA**	**188 d**
81	Out-port Procedure	12/30/2023	2/28/2024	12/30/2023	NA	61 d
82	Shipping & Transportation	2/28/2024	5/8/2024	NA	NA	71 d
83	Transportation to Brigham Young University	4/9/2024	6/3/2024	NA	NA	56 d
84	**Fundraising**	**9/7/2023**	**3/20/2024**	**9/7/2023**	**NA**	196 d
85	**Mid-pacific Conference**	**4/4/2024**	**4/6/2024**	**NA**	**NA**	3 d
86	**National Competition**	**6/20/2024**	**6/22/2024**	**NA**	**NA**	3 d



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日期：2/11/2024

Baseline Duration | Baseline Milestone | Summary | Actual Duration | Critical Path

Hull Design

The team strived to improve the anti-capsizing properties and create a faster and more flexible canoe.

To enhance the anti-capsizing performance, the team added an unprecedented keel design. Relevant literature mentioned that a full-length keel as a backbone extending from the bow to the stern at the bottom of the hull can help the canoe resist drifting sideways and maintain a straight course. With the assistance of Star CCM+®, the team proposed a beta version. However, the feedback from the experimental canoe showed that while the stability was improved, it added extra weight and impaired flexibility. To address this issue, the team conducted a scale experiment (detailed in Improvements) and a CFD analysis to jointly update a final version.

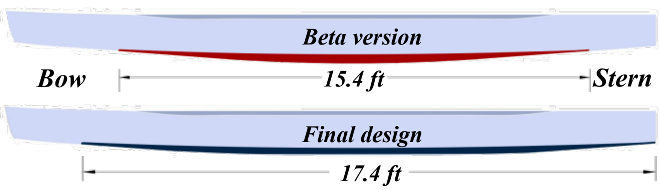


Figure 2. Keel Length

To achieve the goal of velocity and flexibility, the team increased the prismatic coefficient by 2% and conducted a CFD analysis in Star CCM+®. Considering that a quick widen-out near the bow would make the canoe more stable, the team enlarged the canoe's fullness. During the paddling, the longitudinal hull demonstrated a "seesaw" state, which repeatedly impeded the acceleration. So the team shortened the width of the transom stern by 27% to bring the center of gravity of the canoe closer to the middle and the length by 3.2% to reduce the wet area to create less resistance and more flexibility while cornering. To determine the best parameters for racing conditions, the team conducted another CFD analysis in Star CCM+®, simulating the conditions of the slalom and the sprint course. The parameters such as real-time resistance, velocity, angular velocity and displacement were measured, and the best ones were chosen. Compared with *Relic* (2023), the resistance of *Yangtze* was reduced by 46.98% and 1.76% in two courses. With the excellent performances stated above, *Yangtze* will surely be the most competitive canoe in the race and transportation and lead the standardized concrete canoe design in the future.

Table 1. Canoe Dimensions and Resistance

Canoe	Length	Effective Length	Width	Depth	Resistance (Fn=0.45)
Yangtze	19.16 ft	22.02 ft	27.28 in	14.22 in	36.73 lbf
Relic	19.8 ft	25.62 ft	25.98 in	13.00 in	37.39 lbf

Structural Analysis

The primary goal of structural analysis was to provide solid strength standards for mix design and reinforcement schemes. The team conducted accurate structural calculations using 2D analysis to determine the **bending moment and shear force.** In addition, the team conducted the **punching shear and failure envelope analysis** to determine the carrying capacity.

Longitudinally, four different loading cases were considered: female tandem, male tandem, four-person co-ed, and simply supported with extreme ends. To analyze the structure, the team divided the canoe into 30 segments and treated it as a Bernoulli-Euler beam with variable cross-sections. Microsoft Excel® Self-weight was used to compute the geometrical properties of each cross-section, while buoyancy was considered as distributed loads. Paddlers were treated as concentrated loads of 200 lb for males and 150 lb for females. Concentrated load positions were at 5.1 and 14.7 ft. from the bow for two-paddler races, changing to 3.8, 7.7, 11.5 and 15.4 ft. from the bow in the co-ed races. Based on the above assumptions, the shear force and bending moment distributions were calculated.

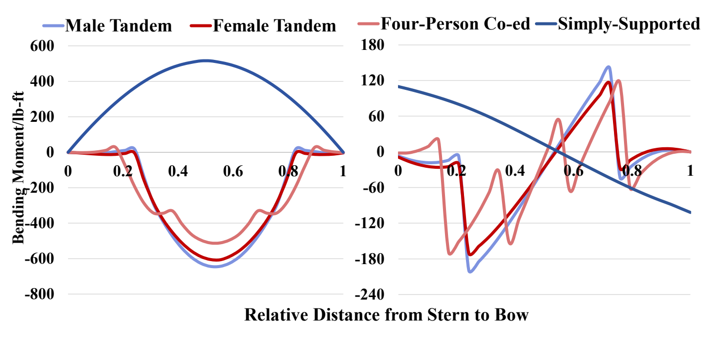


Figure 3. Bending Moment and Shear Force Diagram

The maximum negative and positive bending moments emerged from the male tandem race and simply-supported cases and are located at 10.21ft and

10.85 ft, which are 514.98lb-ft and -644.34lb-ft. The maximum shear force occurs at male tandem, which is located at 4.59 ft and has a magnitude of 199.16 lb.

For some critical section properties, the team used AutoCAD® to calculate the moment of inertia for each section. Based on it, the maximum bending moment cross-section extreme fiber distances are obtained as *cc* = 6.14 in and *ct* = 9.29 in.

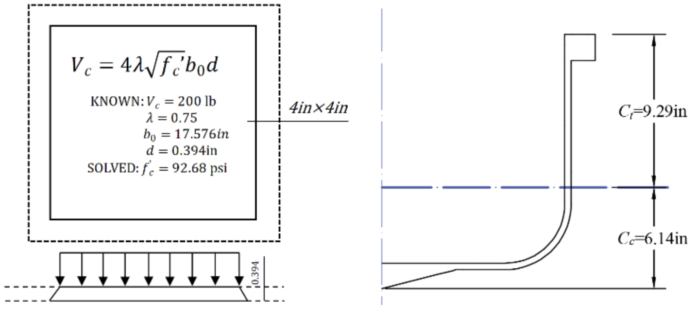


Figure 4. Extreme Fiber Distances and Punching Shear Analysis (ACI-318)

Based on previous experience（*Kwan*, 2017）and the above results, 2.5 was applied as the safety factor. The compressive and tensile strength design values turned out to be s_c = -122.18 psi, s_t = 184.86 psi.

Additionally, a local punching shear analysis was conducted. The local concentrated load is 200 lb under the most unfavorable condition. Since paddlers knelt on the canoe and their knees contact with it, a 4 in. by 4 in. size analysis area was selected, where the thickness of the concrete was uniformly distributed. Considering the concrete contribution only, the required compressive strength was 92.68 psi.

Combining Longitudinal and Punching Shear Analysis, the punching shear load can be considered as the maximum shear force obtained by longitudinal analysis. The former addresses overall bending and stretching, while the latter focuses on localized stress. Design implications: Longitudinal analysis prevents excessive hull bending / stretching for structural integrity while punching shear analysis ensures overall stability against localized damage, particularly under concentrated loads.

The load-carrying capacity was improved based on the internal force analysis and prestressing experiment results. Prestressing tendons were set in the longitudinal and transverse directions, respectively. Taking a 25% loss into account, the total longitudinal prestressing force is 340 lb. The assumed prestressing force gives a uniform pressure on the hull, and the pre-compressive stress can be calculated to be 13.4 psi in the lengthwise direction. Transversely, there are five inter-prestressing tendons located 1.15ft, 4.10ft, 7.05ft, 9.02 ft, and 11.97 ft away from the stern of the canoe, and the total prestressing force applied is 251 lb.

After the comprehensive consideration of the reinforcement schemes, three dangerous states were analyzed only considering the contribution of the concrete. The designed tensile and compressive strength turned out to be 184.86 psi and 206.45 psi. The overall structural analysis ensured *Yangtze*'s safety.

Table 2. Calculation Results

	M/lb·ft	Vc/lb	fc/psi	ft/psi
Bending Moment	-644.34	/	122.18	184.86
Static Shear	/	199.02	206.45	/
Punching Shear	/	200.13	92.68	/

Formula

$$f_t = \frac{M \cdot y_t}{I_x},\ f_c = \frac{M \cdot y_c}{I_x},\ V_c = 2\sqrt{f_c'}b_0 d,\ V_c = 4\lambda\sqrt{f_c'}b_0 d$$

The team performed Failure Envelope Analysis by conducting axial compression, axial tension, and pure shear experiments on the mix. It helped obtain the compressive strength (f_c = 2931.21 psi), tensile strength (f_t = 495.45 psi), and maximal shear stress (τ_{max} = 969.94psi) of the mix. They also created the ultimate stress circle envelope using the simplified Mohr's criterion. Meanwhile, based on the above analysis, the maximum compressive and tensile stresses are 184.86 psi and 206.45 psi.

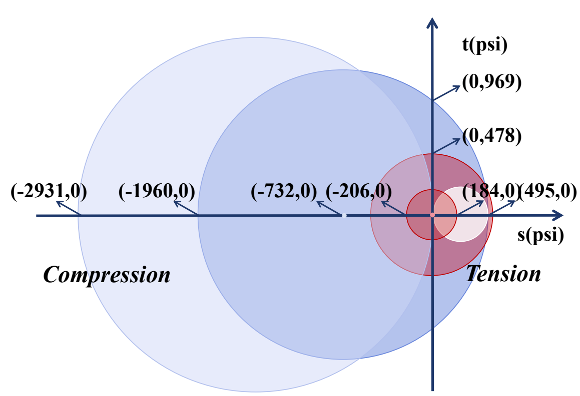


Figure 5. Failure Envelope Analysis

Mix Design

The mix design team endeavored to develop mixes to achieve **sustainability**, **impermeability**, and **the balance between strength and workability, strength and density**. Based on the calcined clay-limestone cement cementitious system (LC3), the team introduced slag cement and the engineering geopolymer composite (EGC). The team also started a parametric testing regimen and managed to maintain the 28-day tensile strength at 307.5 psi and compressive strength at 3373 psi. PE fibers of different lengths were selected to increase the flexural strength to 789 psi. Fly ash ceramic granules were adopted to improve the durability. Defoamer and more waterproofing additives improved the impermeability of the concrete, as proved by the standard impermeability testing (GB/T 50082).

Table 3. Properties of Three Mixtures (28 days)

Properties	Compressive Strength	Tensile Strength	Composite Flexural Strength
Inner Mix	3373 psi	308 psi	789 psi
Outer Mix	2849 psi	206 psi	546 psi
EGC	5527 psi	960 psi	2639 psi

Sustainability

Slag cement material was introduced as a sustainable alternative. We continued to use the LC3 system while incorporating the slag cement. This design helped to replace a portion of the white cement and lower emissions. Slag cement is a byproduct of steel-making, which enhances the traditional concrete benefits of strength and durability while offering reductions in waste, energy use and greenhouse gas emissions. According to the Slag Cement Association, substituting 50% slag cement for Portland cement reduces greenhouse gas emissions by more than 40% and lowers the concrete's embodied energy by more than 30%. The canoe has three concrete layers separated by carbon fiber meshes. The outer layer is made of LC3 system, while the inner layer is the slag cement LC3 system, which strengthens the structure and reduces carbon emissions.

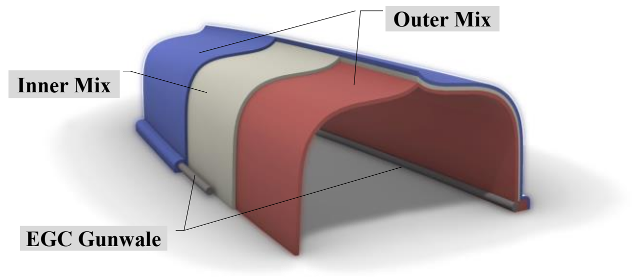


Figure 6. Three-layers Structure of the Hull

EGC was introduced as another sustainable alternative. The system is an aluminosilicate binder material formed from aluminosilicate raw materials (metakaolin, fly ash, blast furnace slag) activated by alkali silicate exciters. It can completely replace conventional cementitious materials including Portland cement. The canoe has EGC gunwales on both sides, wrapped with the inner and outer mix for construction requirements and higher strength. By replacing the previous ECC system, the EGC system successfully reduced carbon emissions by about 50%.

Impermeability

Improved admixture use, mixing process, and performance assessment enhanced impermeability. The team continued to use the waterproof additive and introduced the defoamer. For the mixing process, inspired by the research of Li (2016), the team compounded air-entraining agents and defoamers. Defoamers break harmful bubbles while air-entraining agents maintain a balanced concrete bubble structure. The team conducted a standard impermeability testing using a step-by-step water pressure method to assess the mix's impermeability and make adjustments to the additives. Through experiments, the mix reached a rating with water pressure impermeability of 130.5 psi.

Balance between Strength and Other Properties

Before one material was introduced, the team considered its impacts on strength and other properties. Primary testing of the construction performance narrowed the testing scope for strength and density. The cement-aggregate ratio testing determined the cementitious aggregate ratio of 0.88. Slag cement accounted for 0.66 of the mixture and increased compressive strength by 37%.

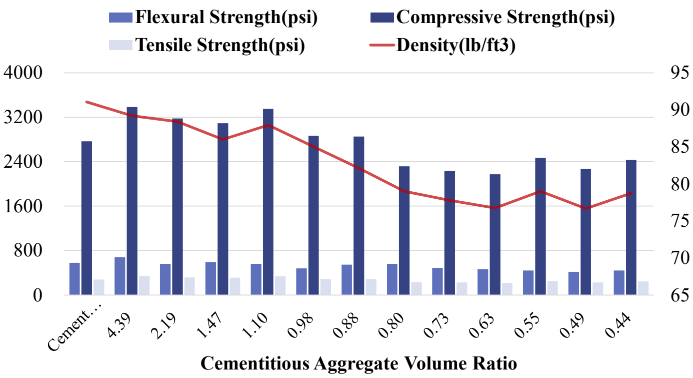


Figure 7. Influence of Cement-Aggregate Ratio on Strength and Density

A specific ratio for EGC was designed to balance strength and workability. The initial setting of EGC takes about three minutes, causing construction difficulties. Yang (2016) found that when the water-cement ratio is 0.36, alkali doping is 7%, and fiber volumetric doping is 2%, EGC could have a high compressive and flexural strength. Based on this, the team adjusted the ratio of GGBS to 0.8 to obtain a higher flexural strength at 2639 psi and prolong the initial setting time of EGC, thus meeting the construction requirements of the gunwale.

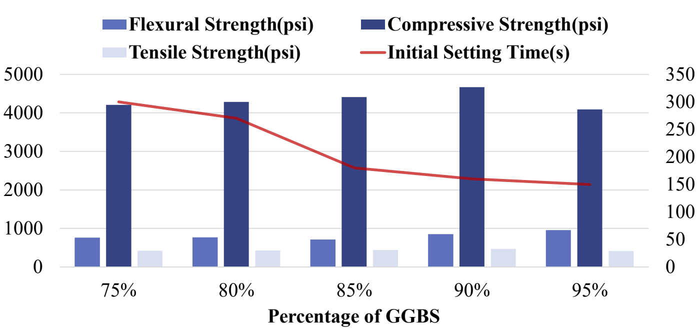


Figure 8. Influence of GGBS on Strength and Initial Setting Time

Fly ash ceramic granules were introduced as aggregate to balance strength and density. The team decided to introduce fly ash ceramic granules to reduce the density. The granules may reduce compressive strength due to their lightweight. However, later experiments have shown that when fly ash ceramic particles are substituted for 60% of the concrete's volume, its compressive strength remains acceptable for design. According to Cui (2010), the team utilized Dinger-Funk equation to determine the discontinuous gradation of fly ash ceramic.

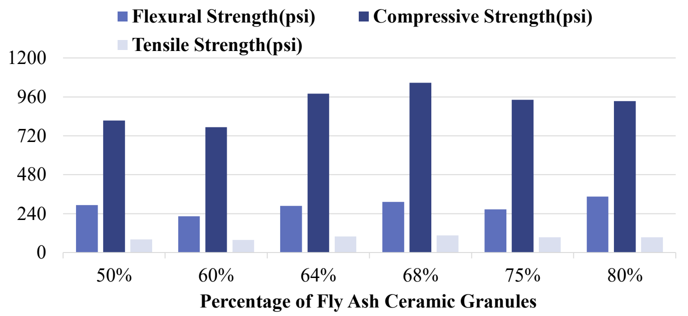


Figure 9. Influence of Fly Ash Ceramic Granules on Strength and Density

Construction Process

The construction team set goals for feasible construction methods and high-quality product, which align with the request of manufacturing 100 canoes.

Mold Fabrication

To create an accurate and detail-rich hull mold, the construction team introduced a Six-axis Robotic Manipulator machine to work on the high-density Expanded Polystyrene (EPS). The hull model was designed to be split along the central axis and divided into six parts to create the narrow keel shape accurately and ease the demolding. Several positioning grooves were cut so the six could be mechanically connected by "C" shaped wooden frames instead of being glued to ensure that the foam was unharmed after the demolding, which made the mold reusable. The mold can be separated easily to avoid friction, thus improving the demolding efficiency and saving effort. Prestressing steel strands controlling points were marked. Grasshopper plug-in of Rhino® was used to program all the cutting work. Compared to outsourcing for CNC processing, the newly adapted machine was accessible for members to operate by themselves, saving 23% of the cost.

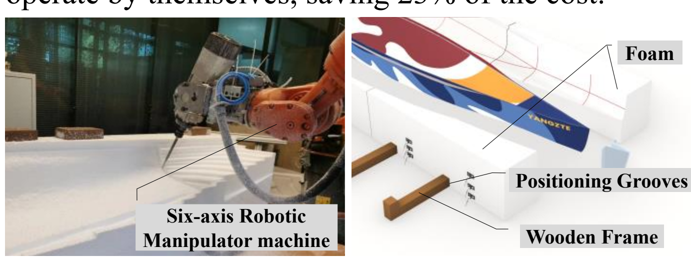


Figure 10. Mold Cutting and Combining

A brand-new mold surface coating system made the surface treatment in mass production

duplicable and the mold removal easier. For easy demolding, smooth Polyvinyl Chloride (PVC) film was used as a new surface treatment material. In the comparative experiment, the team discovered that applying a layer of epoxy resin with high surface fluidity and flatness under the film coating can effectively enhance the adhesion between the film and the mold. Moreover, it can improve the durability of the foam and avoid the stripping of foam particles, so the mold can be reused after the film changing. To determine the optimal film combination, the team conducted a pre-lamination test. Then each film boundary was marked red on the surface and then saved as a coating template for long-term production. After the test, testing films were removed, and epoxy resin and final films were applied to the template.

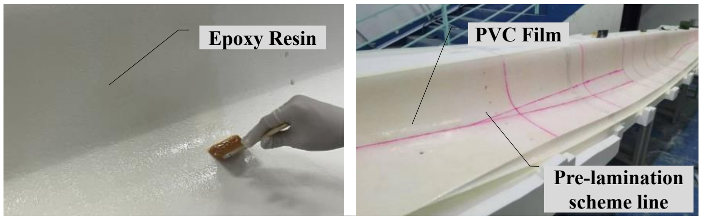


Figure 11. Mold Coating System

A two-way prestress system was applied to enhance cracks and impact resistance. To prevent the system from self-reacting against the canoe, the pre-tensioning method was chosen instead of post-tensioning. Pre-marked controlling points brought precise tendon paths. To control the drilling angle, a new drilling device that matched the mold perfectly was applied, which prevented cross-connection of the drill ways. Small acrylic cylinders were placed to protect the mold from string cutting.

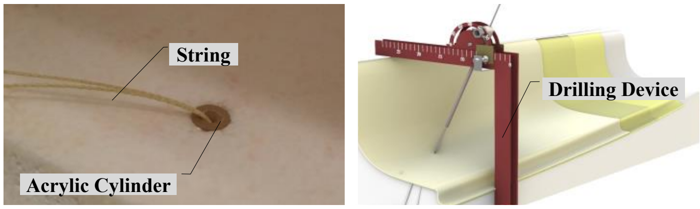


Figure 12. Holes Limiting and Drilling Device

Canoe Fabrication

To achieve the aesthetic goals, the inner and outer layers were segmented into blocks of colors, while the mid-layer adopted slag structural mix of high strength. Color borders and letters were controlled by pre-cut PVC stencils which also served as the thickness guide.

The team innovated to cast an integrated gunwale to improve its overall flexural strength. The team printed the top drawing of the gunwale 1:1 and adhered a PVC hose to it as mold, so the team could cast the gunwale in one piece while precisely demonstrating its curvature. The gaps between *Relic*'s separate gunwale segments were eliminated and the internal bond was enhanced. The gunwale's integrity enabled the canoe to be more durable.

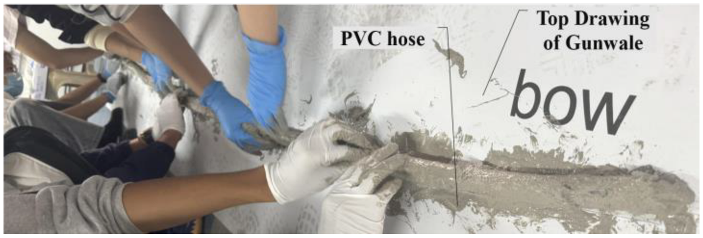


Figure 13. EGC Casting

Curing, Sanding and Finishing

To ensure adequate outer and inner concrete strength, the team conducted a two-phase, 28-day water-curing process. The team initially laid the canoe right side up for 14 days. After the mold removal, the device was redesigned to cure both surfaces simultaneously, which reduced hull cracking caused by uneven concrete shrinkage. The curing chamber was built with a heat-insulating membrane to trap heat and moisture. Temperature and humidity sensors were placed inside to regulate the water sprinkling and temperature. The water discharged by a drain device was recycled to reduce water wastage.

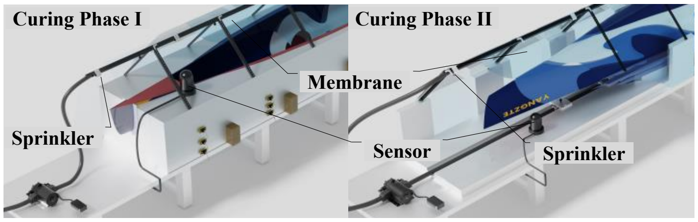


Figure 14. Curing System

To create a flawless and durable surface, the team sanded and applied a finish to the canoe after the curing. Surface patching was applied to fill in the small discontinuity. Two layers of waterproof sealant were used to prevent permeation. Almost all sanding was mechanized, which greatly saved person-hours.

Value

Tongji Concrete Canoe Team worked diligently this year to maximize value to their client C4, and the consumer. *Value* of the project was defined as practical value, production feasibility value, sustainable value and aesthetic value.

The team developed innovations to increase values and, ultimately, to provide C4 with an excellent product-construction solution and consumers with a high-performance, durable, sustainable and aesthetically pleasing canoe for transportation.

Practical value was defined in terms of the canoe's seaworthiness and the material durability. Canoe speed and agility are key to winning in slalom and sprint courses. For water transportation, the **anti-capsizing property** is essential to improve the canoe's stability, security, and user experience. Through software simulation, physical scaling experiments, and actual paddling feedback, the team iterated and revised the hull design scheme and created a fast, stable, and flexible prototype. For material durability, the higher strength of the mix, a more reasonable fiber ratio and the use of waterproof mortar additives brought a longer service life.

The team was dedicated to enhancing the feasibility value of production. In mass production, ensuring the easily accessible construction method and duplicable techniques can improve the smoothness and efficiency of production. The team used the grasshopper plug-in of Rhino® to program the Six-axis Robotic Manipulator, thus creating many details on the EPS mode at one time. By pre-lamination, a reusable surface lamination solution was provided and could be used directly in the production. These made mass production feasible and accurate.

The team recognized sustainability as a crucial potential value, which permeated the whole project. Environmental and economic sustainability were improved by utilizing cement-free materials and updating the water treatment system. The team tried to promote concrete application and environmental protection through campus and social influence.

***Yangtze* has achieved both visual and connotative aesthetic value.** Although involving only a few technical details, the body graphics, as light and elegant as a sturgeon leaping out of the blue water, brought a pleasing visual experience to both the client and consumers. The team brought unique Chinese elements and aesthetics to the public, while promoting environmental protection and sustainability concepts.

Sustainability

The team strived to implement the three pillars, environmental, economic, and social sustainability, throughout the construction process.

Environmental Sustainability

In line with the global carbon neutrality goal, the team reduced the use of cement with high carbon emissions and strived for recyclability. To reduce the use of white cement, slag cement was newly added to the LC3 system introduced last year, which achieved lower carbon emissions compared to the traditional LC3. EGC system was applied to gunwales to replace ECC system, which realized the application of cement-free mix. The recyclability of aggregates (RCA) made by crushing and grinding rounds of waste concrete was introduced, which reduced production costs.

To reduce the harm to water supplies, the sewage generated during the canoe construction was treated by an innovative three-layer water treatment system. The sieve of the first tank filtered out fibers, that of the second tank filtered out aggregates, and the pH of the clarified liquid was adjusted in the third tank after the fine impurities had settled in the bottom. Treated water was discharged into pipes. By a simpler-structured system, the sediment is easier to clean, and filters are easier to replace, leading to a longer service life.

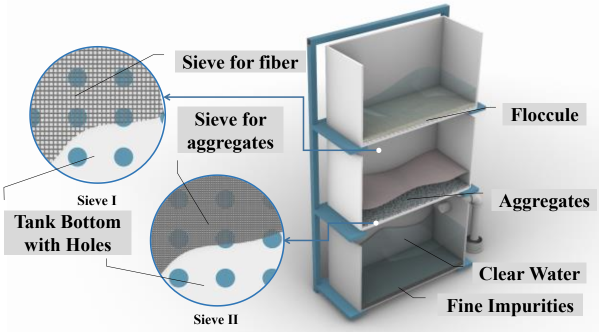


Figure 15. Water Treatment System

The excess concrete materials were collected and made into crafts to reduce the waste during canoe construction and material testing. The finished products were used as publicity gifts or sales.

Figure 16. Concrete Crafts and Paddling Day

Economic Sustainability

To save expenses on materials, the team cooperated with local enterprises to recycle waste slag as one of the raw materials of concrete. It significantly reduced material expenses and was also conducive to the sustainable development of the environment.

Social Sustainability

To raise the team's profile, the canoes built were annually displayed at school open days. Some of them were sent to the nearby primary and secondary schools for exhibition, which continuously improved the team's recognition in society, brought more people closer to concrete as an excellent material. a paddling experience open day activity was also held which created a positive campus impact.

The team is also committed to promoting environmental awareness across the society. The canoe was named after the *Yangtze*, and the aesthetic theme of this year was based on the *Yangtze* and the Chinese sturgeon element. They represented the team's hope to call on society to pay more attention to protecting the environment and cherished animals. With this canoe, this spirit will certainly be brought to the whole society.

Improvements

As Value section mentions, stability is **essential** for product performance. In the hull design process, to get the best keel dimensions to provide C4 and consumers with the best prototype design, the team conducted two scale experiments to determine the parameters of the keel more scientifically. **These practices were deemed as representative and worth detailing.**

The basic idea was to test replaceable keels of different dimensions at the bottom of the printed 1:5 flat-bottomed model canoe and then measure the corresponding data to compare the optimal keel design.

For the stability test, the team measured the exact data of the Z-axis of roll rotations with the same lateral tilt angle at the initial situation and chose the final keel design.

An inclinometer and an Inertial measurement unit (IMU) were fixed in the middle of the canoe set in the calm water. Different keels were mounted at the bottom of the canoe (10 keels in total; only the final keel and flat-bottomed canoe are shown in the figure). The angle data was measured at the initial roll inclination angles of 15°, 30° and 45° respectively. After processing and comparing the obtained data, the best design of keel was screened out, which corresponded to a shorter time and less angle fluctuation to revert to calm. The figure below illustrates that an average of 9% shortened recovery time compared with that of a flat-bottomed canoe under the same simulation situation, and an average of 38% reduced angle fluctuation after the addition of keel, **so that the stability of the canoe was comprehensively improved.**

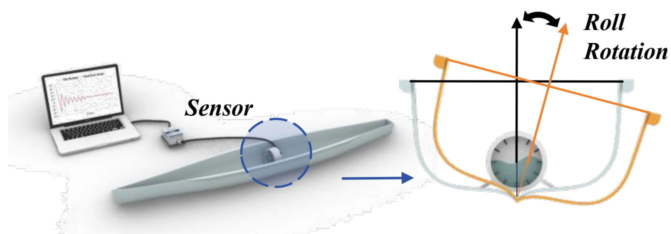


Figure 17. Scale Experiment

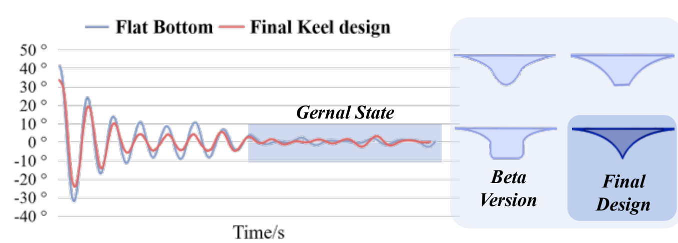


Figure 18. Processed Sensor Data of Scale Experiments

For the turning performance test, the team added a power unit to the model to simulate the movements of the paddler. Using Froude's criterion, the model was set to travel at a speed of 2.5 ft/sec, which was combined with the hull's resistance to select the appropriate power unit. Based on this, keels of different heights were installed. The model travelled in the river to remotely control the canoe to make turns. Afterwards, the captured image video was imported into the computer to measure the turning radius during the travelling process to select the optimal keel height (after scaling down).

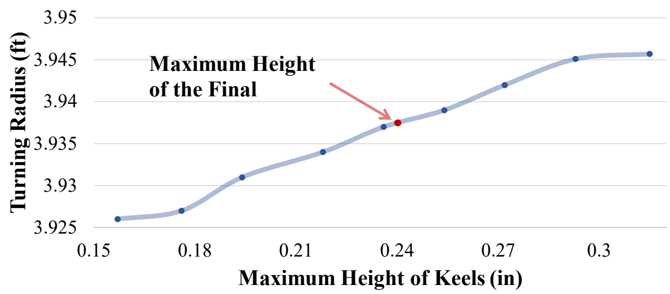


Figure 19. Turning Radius-Maximum Height of Keels Curve

Compared with previous canoe designs, the improvements of this experiment are more scientific, accurate, and environmentally friendly. For a more scientific method, the team selected the ratio 1:5 with the least impact of the scale effect through the results of theoretical calculations instead of small models of 1:12(*Relic* 2023) and 1:13 (*Origin* 2022). For accuracy, the data measurement and measuring instruments were upgraded to reduce the effect of error propagation. For environmental sustainability, the main body of the canoe did not need to be printed repeatedly and only needed to be substituted for different dimensions, so multiple iterations of the experiment could be achieved and the printing cost could be controlled.

Manufacturing Cost Estimate

According to the fee schedule, the manufacturing cost contains 3 parts: Permanent Material, Canoe Fabrication and Mold Fabrication. As for the two fabrication parts, the team members took both labor costs and expenses into consideration. The team conducted a statistical analysis of the manufacturing unit price for each canoe considering mass production.

For the permanent material costs (MC) of each canoe, to obtain a more favorable unit price, the unit price used for bulk purchase was calculated based on the assumption of purchasing materials for 10 canoes each time. To minimize material storage costs, the next batch of materials will be purchased after the previous batch was used up.

The canoe fabrication expenses include MC, personal protective equipment (PPE) for construction personnel, tape, tubes, sandpaper and film used for sanding. The team prioritized the health of our team members and PPE costs count for 31% of canoe fabrication expenses.

For mold fabrication expenses, EPS foam and mold cutting are the largest overhead, accounting for 76%. Due to the wear of EPS foam and the looseness of screw holes during the construction process, the service life of a mold is not unlimited. However, with acrylic cylinders protecting prestressing holes and plastic membrane protecting the foam surface, a mold can generally be reused 5 times before replacement, as the team estimate, and the cost only increases by 25% compared to disposable molds. This is a major selling point when it comes to sustainable mass production. The mold fabrication expenses mainly include EPS foam cutting, 3D printing, screws, wood frames and angle steel used in the fabrication. In addition, since the curing system and the mold are used together, the curing system is also considered part of the mold manufacturing cost.

After the above statistical calculation, adding the labor costs, the total cost of each canoe during mass production is approximately $32,739.

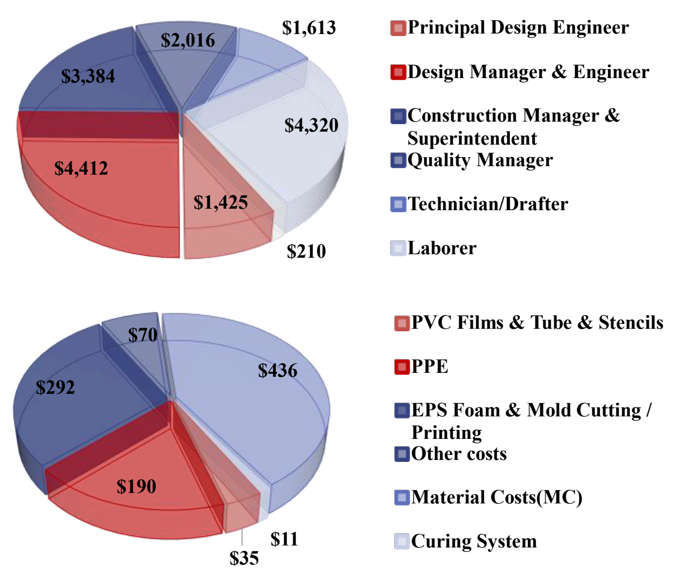


Figure 20. Manufacturing Cost Allocation Estimate

Manufacturing Cost Estimate - Fee Schedule

Permanent Material Costs - Per Canoe					
Material	QTY	Unit	Cost/Unit	Cost	Source
White Portland Cement	73.28	lb	$ 0.18	$ 13.19	AALBORG
Silica Fume	49.78	lb	$ 0.33	$ 16.43	MasterLife
Iron and steel slag cementitious materials	29.87	lb	$ 0.73	$ 21.81	CarbiCrete
Calcined Clay	43.97	lb	$ 0.47	$ 20.80	Unavailable
Ground Calcium Carbonate	21.98	lb	$ 0.42	$ 9.23	HuberCrete
Gypsum Cement	7.33	lb	$ 0.63	$ 4.63	CERAMICAL
Waterproofing	7.29	lb	$ 2.08	$ 15.19	SIKA
Expanded Glass	19.83	lb	$ 1.26	$ 25.05	PORAVER
Fly ash ceramic granules	41.38	lb	$ 1.77	$ 73.16	Unavailable
Ground Granulated Blastfurnace Slag	13.20	lb	$ 0.76	$ 10.01	LKAB
Fly Ash Class C Pozzolan	1.99	lb	$ 0.34	$ 0.68	Group PHONENIX
Sodium Metasilicate Anhydrous & Sodium Silicate Solution	3.34	lb	$ 0.58	$ 1.94	American Elements
Admixture (Air-Entraining & Water-Reducing & Defoamer)	1.01	lb	$ 0.81	$ 0.82	BASF & SIKA
Borax 10 MOL	0.88	lb	$ 3.66	$ 3.22	SDS
PE fiber	2.74	lb	$ 14.52	$ 39.78	donated
Integral Color	17.60	lb	$ 0.88	$ 15.49	Unavailable
Non-Carbonated Water	11.02	gal	$ 0.03	$ 0.33	-
Reinforcing Steel	200.08	ft	$ 0.02	$ 4.00	Jiangsu Hongtai Stainless Steel Wire Rope
Carbon Fiber Mesh	127.66	ft²	$ 0.24	$ 30.64	Zhangjiagang Lingzhi Composite Material
Concrete Sealer	1.44	gal	$ 89.95	$ 129.53	Liquid Rubber USA
Permanent Material Costs per Canoe (MC)				$ 435.90	

Canoe Fabrication Labor Costs - Per Canoe				
Role	RLR	DEC	HRS	Extended
Principal Design Engineer	$ 50.00	1.5	15	$ 1,125.00
Design Manager	$ 45.00	1.5	23	$ 1,552.50
Project Construction Manager	$ 40.00	1.5	24	$ 1,440.00
Construction Superintendent	$ 40.00	1.5	20	$ 1,200.00
Project Design Engineer (P.E.)	$ 35.00	1.5	29	$ 1,522.50
Quality Manager	$ 35.00	1.5	30	$ 1,575.00
Graduate Field Engineer (EIT)	$ 25.00	1.5	8	$ 300.00
Technician/Drafter	$ 25.00	1.5	33	$ 1,237.50
Laborer	$ 25.00	1.5	90	$ 3,375.00
Clerk/Office Admin	$ 20.00	1.5	6	$ 180.00
Labor Subtotal			278	$ 13,507.50
Profit Multiplier (P)			18%	$ 2,431.35
Canoe Fabrication Direct Labor Total (DL)				$ 15,938.85

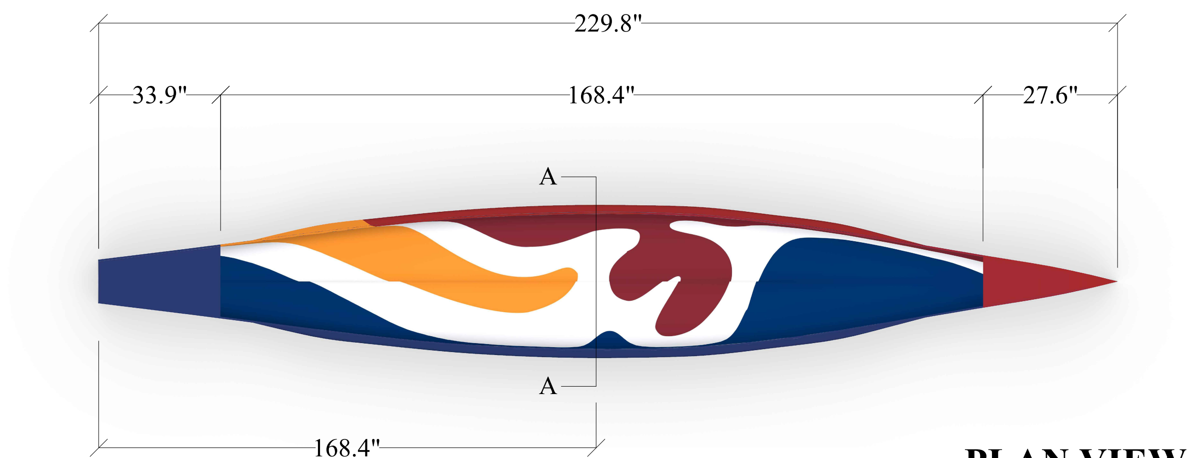
Canoe Fabrication Expenses - Per Canoe		
Description		Cost
Material Costs Per Canoe (MC) - Above		$ 435.90
PPE		$ 189.72
Sanding Expenses		$ 45.83
PVC Films		$ 13.89
PVC Tube		$ 7.64
Tape		$ 4.86
Epoxy Resin		$ 4.17
Expenses Subtotal		$ 702.01
Markup (M)	10%	$ 70.20
Canoe Fabrication Expenses		$ 772.21
Mold Fabrication Costs per Canoe		$ 4,933.51
Total Canoe Fabrication Expenses (E)		$ 5,705.72

Mold Fabrication Labor Costs				
Role	RLR	DEC	HRS	Extended
Principal Design Engineer	$ 50.00	1.5	20	$ 1,500.00
Design Manager	$ 45.00	1.5	35	$ 2,362.50
Project Construction Manager	$ 40.00	1.5	32	$ 1,920.00
Construction Superintendent	$ 40.00	1.5	30	$ 1,800.00
Project Design Engineer (P.E.)	$ 35.00	1.5	48	$ 2,520.00
Quality Manager	$ 35.00	1.5	42	$ 2,205.00
Graduate Field Engineer (EIT)	$ 25.00	1.5	8	$ 300.00
Technician/Drafter	$ 25.00	1.5	50	$ 1,875.00
Laborer	$ 25.00	1.5	126	$ 4,725.00
Clerk/Office Admin	$ 20.00	1.5	5	$ 150.00
Labor Subtotal			396	$ 19,357.50
Profit Multiplier (P)			18%	$ 3,484.35
Mold Fabrication Direct Labor Total (DL)				$ 22,841.85

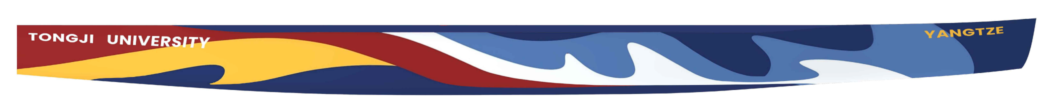
Mold Fabrication Expenses		Extended
Materials Cost		
EPS Foam and Mold Cutting		$ 1,388.89
3D-printing Female Bow Mold		$ 69.44
Polyvinyl Chloride (PVC) Stencils		$ 68.06
Curing System		$ 55.56
Screws, Planks, Angle steel		$ 20.83
Acrylic Cylinders		$ 20.83
Self-Gripping Fastener		$ 19.44
Wooden Frames		$ 16.67
Expenses Subtotal		$ 1,659.72
Markup (M)	10%	$ 165.97
Mold Fabrication Expenses (E)		$ 1,825.69

DL Total	$ 22,841.85
Expenses Total	$ 1,825.69
Mold Fabrication Original Cost	$ 24,667.54
Quantity of Canoes Cast Before Replacing Mold	5
Mold Fabrication Cost Per Canoe	$ 4,933.51

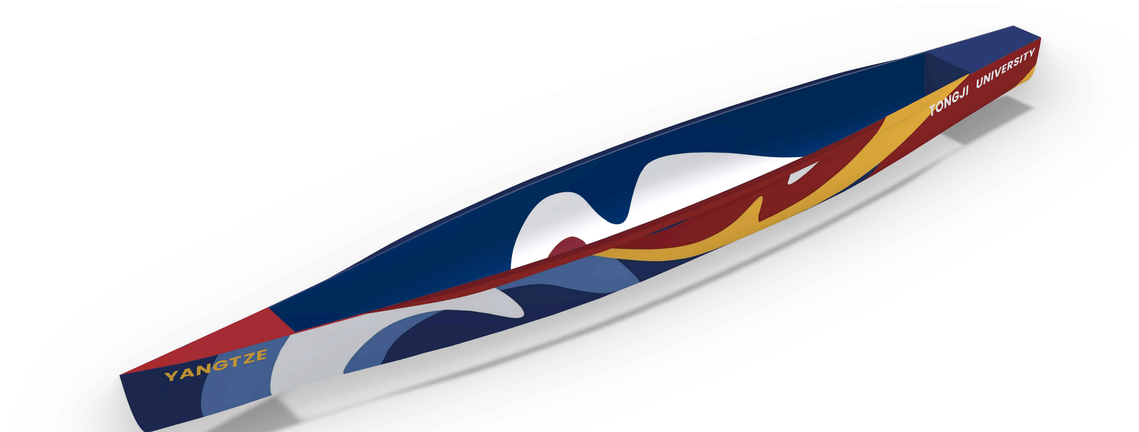
Total Cost Per Canoe	
Labor (DL)	$ 15,938.85
Expenses (E)	$ 5,705.72
Total	$ 21,644.57



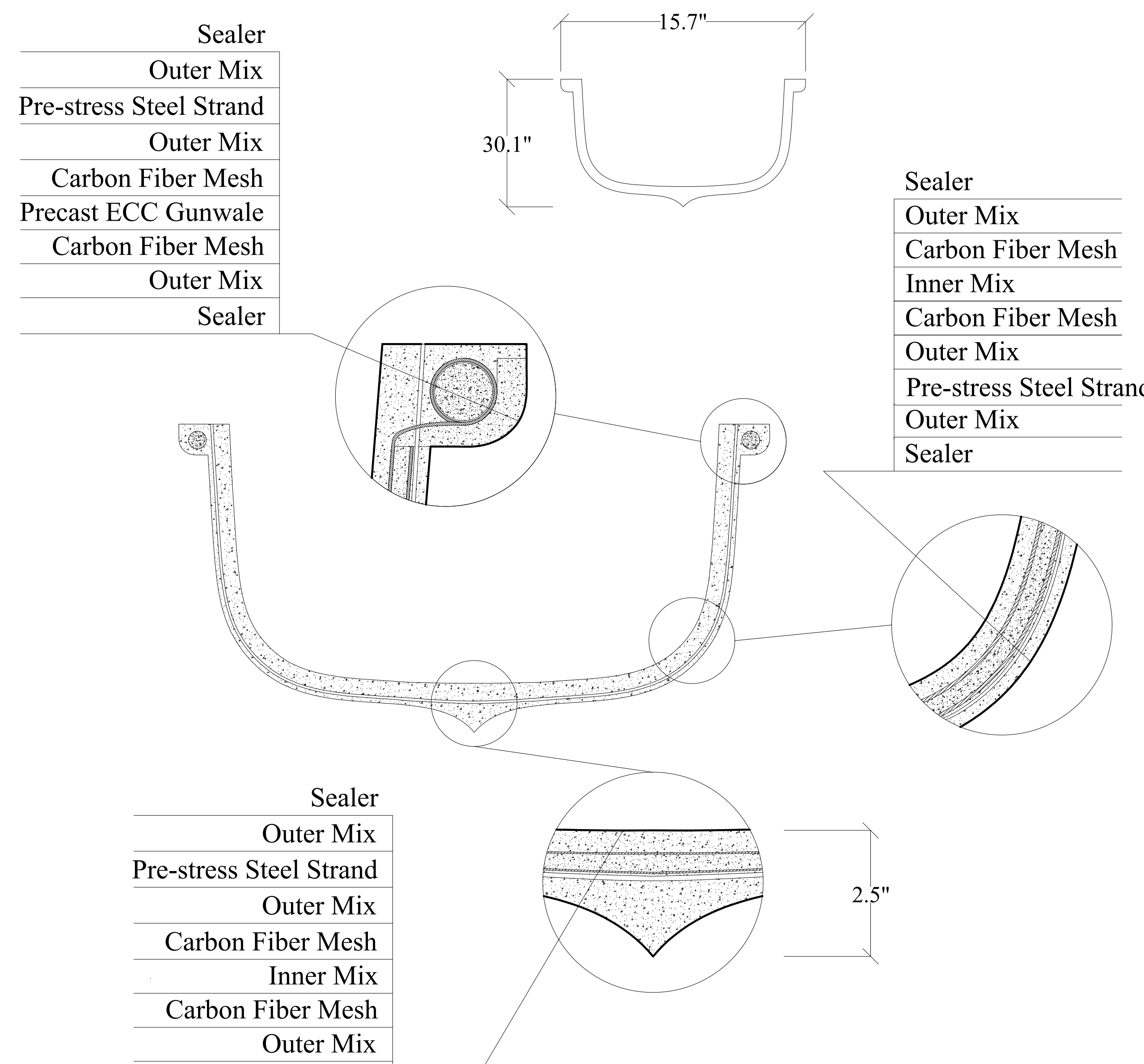
PLAN VIEW



ELEVATION VIEW



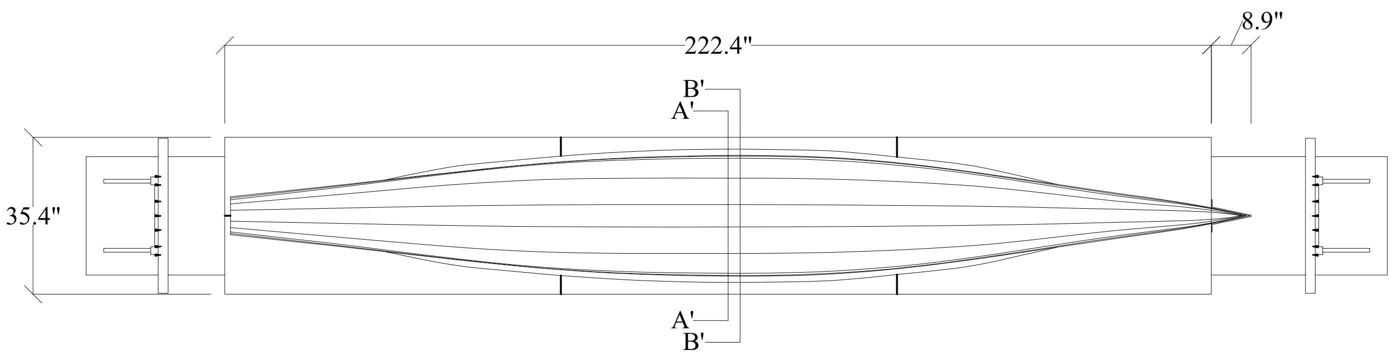
ISOMETRIC VIEW



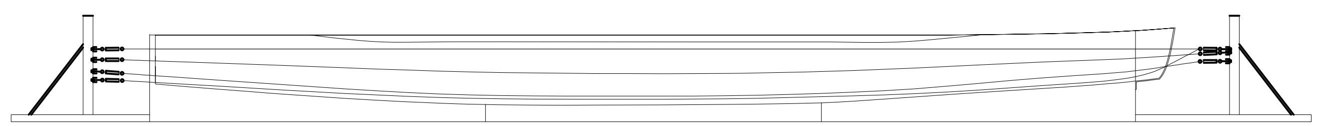
SECTION A-A

General Rules:
Drawings are not to scale

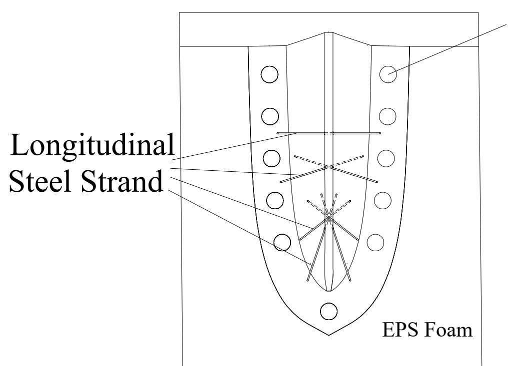
Canoe Construction Drawing		
Drawn by:	Xiaoyu Ren	Date: 02/13/2024
Checked by:	Ziyue Huang	Page Number: 1 of 2



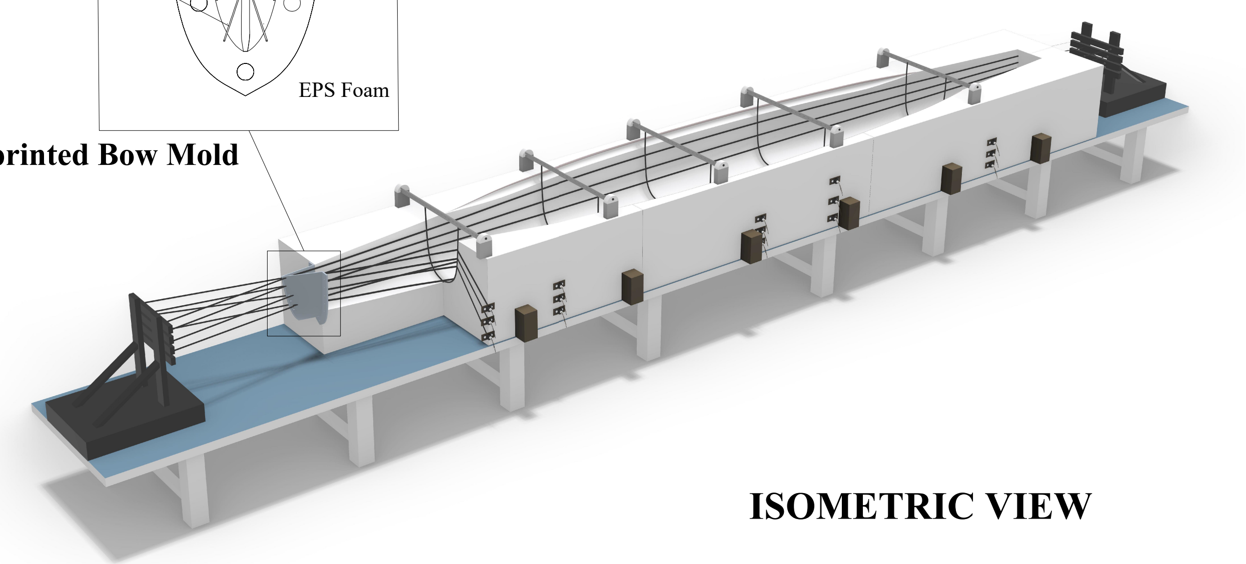
PLAN VIEW



ELEVATION VIEW



3D-printed Bow Mold



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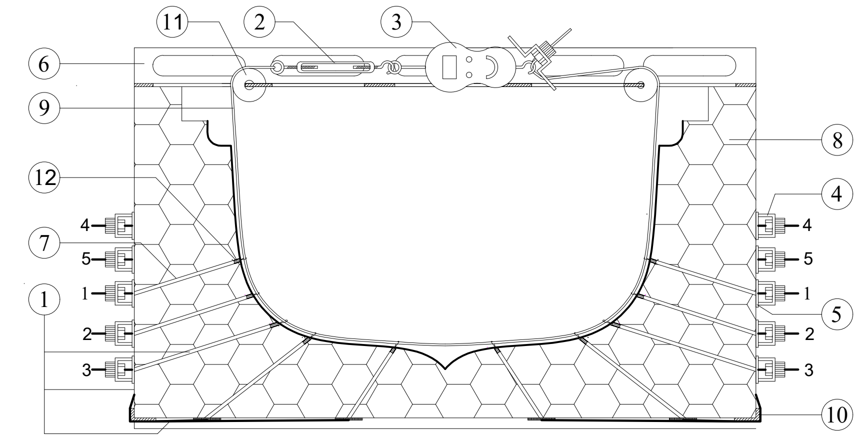
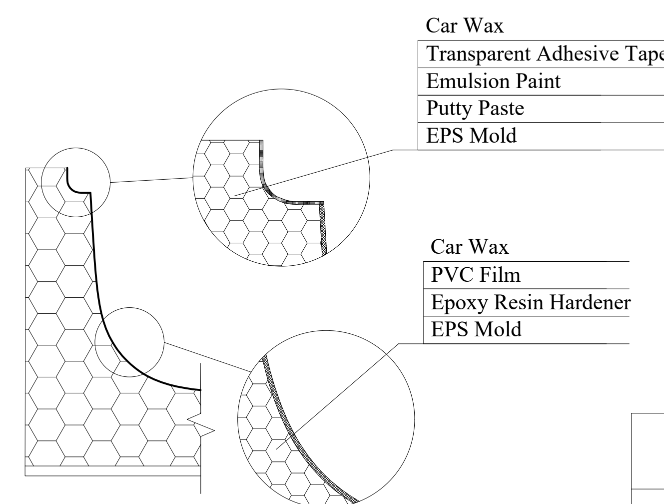


SECTION A'-A'

Bill of Materials			
No.	Description	No.	Description
1	Kevlar Strings	7	Rubber tubes
2	Turn Buckles	8	EPS Foam
3	Spring Gauge	9	Pre-stress Steel Strand
4	Self-gripping Fastener	10	Steel Corner Gasket
5	Board	11	Rubber Pad
6	Angle Steel	12	Acrylic Cylinder



SECTION B'-B'

General Rules:
Drawings are not to scale
Use polyurethane adhesive to adhere foam blocks together

Mold Construction Drawing		
Drawn by:	Xiaoyu Ren	Date: 02/13/2024
Checked by:	Ziyue Huang	Page Number: 2 of 2

Appendix A: Bibliography

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

Section A - Hull Thickness/Reinforcement Calculations

Hull Thickness (Walls)		
Total Hull Thickness		0.472 in.
1	Outer Mix	0.119 in.
2	Steel Strand	0.059 in.
3	Carbon Fiber Mesh	0.028 in.
4	Inner Mix	0.119 in.
5	Carbon Fiber Mesh	0.028 in.
6	Outer Mix	0.119 in.
Total Reinforcement Thickness		0.115 in.
Reinforcement/Hull		24.36%

No Ribs

Hull Thickness (Gunwales)		
Total Hull Thickness		1.081 in.
1	Outer Mix	0.119 in.
2	Carbon Fiber Mesh	0.028 in.
3	ECC Mix	0.787 in.
4	Carbon Fiber Mesh	0.028 in.
5	Inner Mix	0.119 in.
Total Reinforcement Thickness		0.056 in.
Reinforcement/Hull		5.18%

No Thwarts

Section B - Percent Open Area Calculations

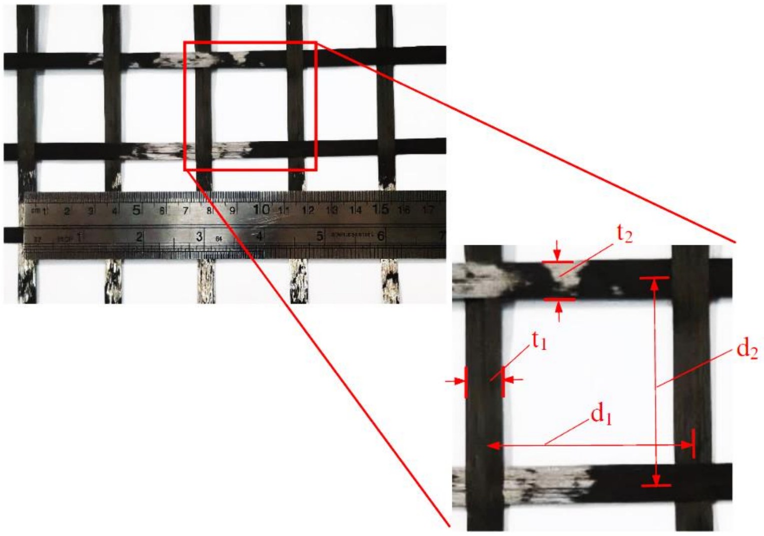

Figure. Percent Open Area Calculations

Apertures Dimension：

n_1: number of apertures along sample length = 20
n_2: number of apertures along sample width = 20
d_1: spacing of reinforcing (center – to center) along sample length
d_2: spacing of reinforcing (center – to center) along sample width
t_1: thickness of reinforcing along sample length = 0.28 in.
t_2: thickness of reinforcing along sample width = 0.28 in.
$Area_{open}$: aperture size = 1.18 in. × 1.18 in. = 1.39 in.^{2}

Solution:

$$d_1 = aperture\ dimension + 2 \times \frac{t_1}{2} = 1.18in. + 2 \times \frac{0.28in.}{2} = 1.46in.$$

$$d_2 = aperture\ dimension + 2 \times \frac{t_2}{2} = 1.18in. + 2 \times \frac{0.28in.}{2} = 1.46in.$$

$$Length = n_1 \times d_1 = 20 \times 1.46in. = 29.2in.$$

$$Width = n_2 \times d_2 = 20 \times 1.46in. = 29.2in.$$

$$\sum Area_{open} = n_1 \times n_2 \times Area_{open} = 20 \times 20 \times 1.39in.^2 = 556in.^2$$

$$Area_{total} = Length \times Width = 29.2in. \times 29.2in. = 852.64in.^2$$

$$POA = \frac{\sum Area_{open}}{Area_{total}} \times 100\% = \frac{556in.^2}{852.64in.^2} \times 100\% = 65\% (> 40\% \text{ min.})\ OK!$$

Pre-Qualification Form (Page 1 of 3)

Tongji University
(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.	Z.H.	H.X
The eligibility requirements of registered participants (Section 3.0 and Exhibit 3).	Z.H.	H.X
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.	Z.H.	H.X
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.	Z.H.	H.X
The last day to submit a *Request for Information* (RFI) to the C4 is January 29, 2024.	Z.H.	H.X
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.	Z.H.	H.X
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.	Z.H.	H.X
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.	Z.H.	H.X

Ziyue Huang 黄紫悦 10/23/2023 Haibei Xiong 熊海贝
Team Captain *(date)* *ASCE Student Chapter Faculty Advisor*
(date)

Ziyue Huang 黄紫悦 Haibei Xiong
(signature) *(signature)*

Pre-Qualification Form (Page 2 of 3)

Tongji University
(school name)

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 team has always been attaching great importance to health and safety issues and has given top priority to performing the team's Health & Safety Program. Since China lifted the pandemic lockdown in December 2022, all concrete canoe team activities have resumed offline.

Regarding operations, the experienced team members trained the newcomers patiently about every detail of the construction process, explaining the potential risks and corresponding protective measures. Instructional videos of material experiment and construction have been shot to provide the new team members with clear guidance of the operating standards. Additionally, the team has well-articulated safety regulations with safety supervisors on site.

High-quality protective devices such as rubber gloves and ventilation facilities are prepared in order to reduce the risks associated with physical contact and breathing.

Apart from physical protection, the team optimized the task arrangement and took shift to reduce the burden of the team members and alleviate their mental pressure. Meanwhile, we contacted the coaches of the school dragon boat team to guide us and equipped each paddler with a life jacket, gloves, and knee pads.

In 150 words or less, provide a high-level overview of the team's current QA/QC Program. If there is currently not one in place, what does the team envision their QA/QC program will entail?

The team has taken effective and comprehensive QA/QC measures to guarantee the high quality of the canoe.

In terms of daily training on construction skills of the newcomers, we have built a well-structured system. A shared document has been established to record daily performance and targeted advice will be given to realize the precision control. And during the construction process, several thickness monitor devices will be applied.

Before constructing the canoe for competition, we will first build a canoe for trial to verify and adjust our construction plans. This year we decided to allocate the admixture at the manufacturing day instead of the day before, besides we paid more attention to the storage of the material after the weather became cooler. These two measures could prevent the material from being damaged.

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

Yes. Each member of the team has passed the Laboratory Safety Specification Assessment of Tongji University and has reviewed the safety policies at the very beginning of the project.

Pre-Qualification Form (Page 3 of 3)

Tongji University

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.)

Our team believes that ChatGPT and other AI/NLP algorithms can be used to assist complex tasks, such as scheduling and translation. But the purpose of this competition is to build a improved canoe, while ChatGPT and other AI/NLP algorithms only excel at analyzing existing data and selecting optimal solutions instead of creating one.

The most important innovative part of the competition cannot be completed with the help of ChatGPT and other AI/NLP algorithms. This includes the design and iteration of the hull, the design of the actual construction and curing system, and the select of new material to be used. What's more, many optimal methods can only be tested in real experiment and can't be given by any algorithms. This is particularly important when it comes to construction process design.

Our team will use ChatGPT and other AI/NLP algorithms in this competition for scheduling and translation.

The core project team is made up of 15 number of people.

YANGTZE
TONGJI UNIVERSITY
2024 CONCRETE CANOE