ASCE Concrete Canoe Competition

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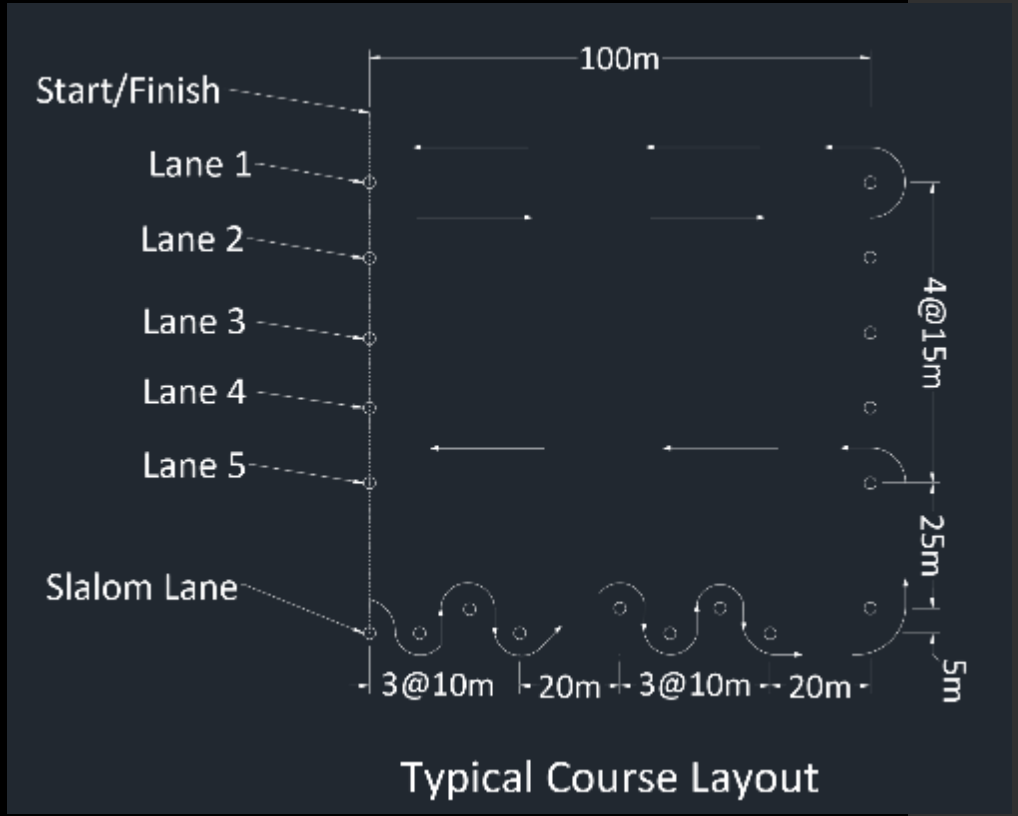
Problem Statement and Background

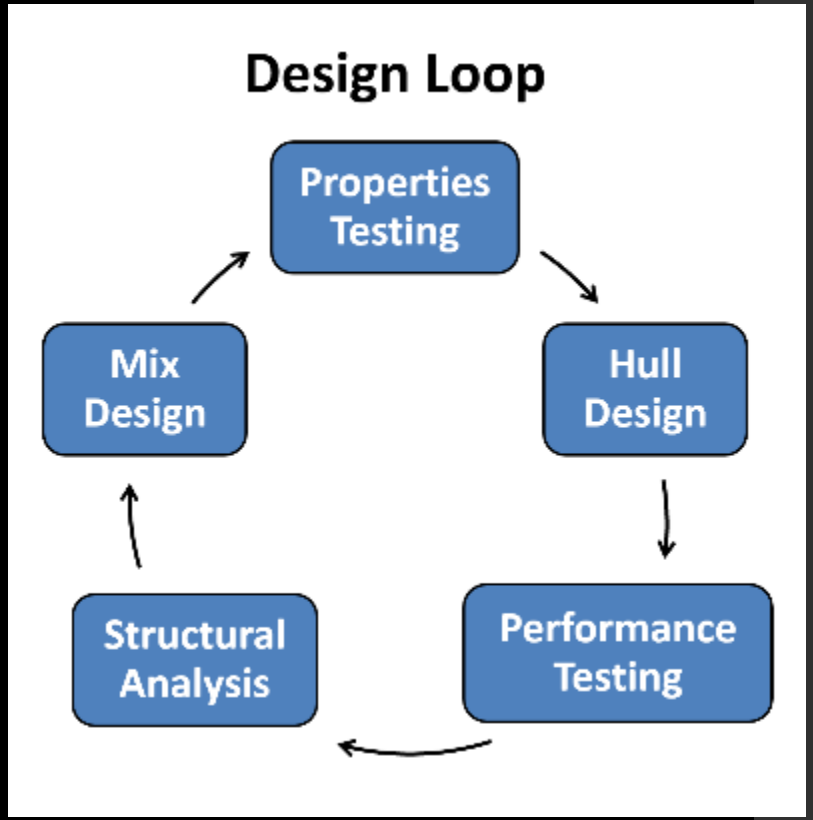
- Design and fabrication
- Constructability, mix design, and hull design
- 2024 ASCE Metropolitan Region Student Symposium
- 5 races: slalom and sprint
- Proposal and presentation



Typical Course Layout

Design Goals and Process

- Functional canoe
- Comply with design constraints
- Address realistic constraints
- Constructability
- Competitive at regionals
- Project schedule



Design Constraints

- Aggregates
  - Minimum 30% of total volume
- Cementitious material
  - Maximum 50% of total cement volume hydraulic
- Fibers (ASTM C1116)

Cementitious Materials	ASTM
Hydraulic Cement	C150, C595, C1157, or C845
Fly Ash	C618 (Class C or F)
Metakaolin or Calcined Clay	C618 (Class N)
Slag Cement	C989 (Grade 80 minimum)
Silica Fume	C1240
Hydrated Lime	C207 (Type S or N) or C821
Ground-Glass Pozzolan	C1866
Pumice, Pumicite, Natural Pozzolan	C618 (Class N)

Design Constraints (cont.)

- Admixtures
  - Bonding adhesives, waste latex paint and latex emulsions are prohibited
- Curing
  - Maximum 2 coats of liquid membrane
- Sealer
  - Clear, non-pigmented sealers are permitted

Admixtures	ASTM
Water-Reducing & Set-Control	C494
Air-Entraining	C260
Coloring Admixture/Agents & Concrete Pigments	C979
Specialty Admixtures	C494 (Type S)

Realistic Constraints

Constructability

- Workability of concrete mix
- Mold shape
  - Needed to be possible to construct
- Mold material
  - Easy canoe removal
  - Plan ahead

Realistic Constraints (cont.)

Economic

- Proposed budget
  - Materials: $2,450
  - Regionals: $3,200
  - Canoe Trips: $200
  - Total: $5,850

Environmental

- Water Pollution

Material Cost Breakdown	
Mold	$425
Concrete Mix/Finish	$1,690
Team Safety	$105

Regionals Cost Breakdown	
Registration	$800
Canoe Transportation	$795
Lodging	$1,260
Fuel and Tolls	$330

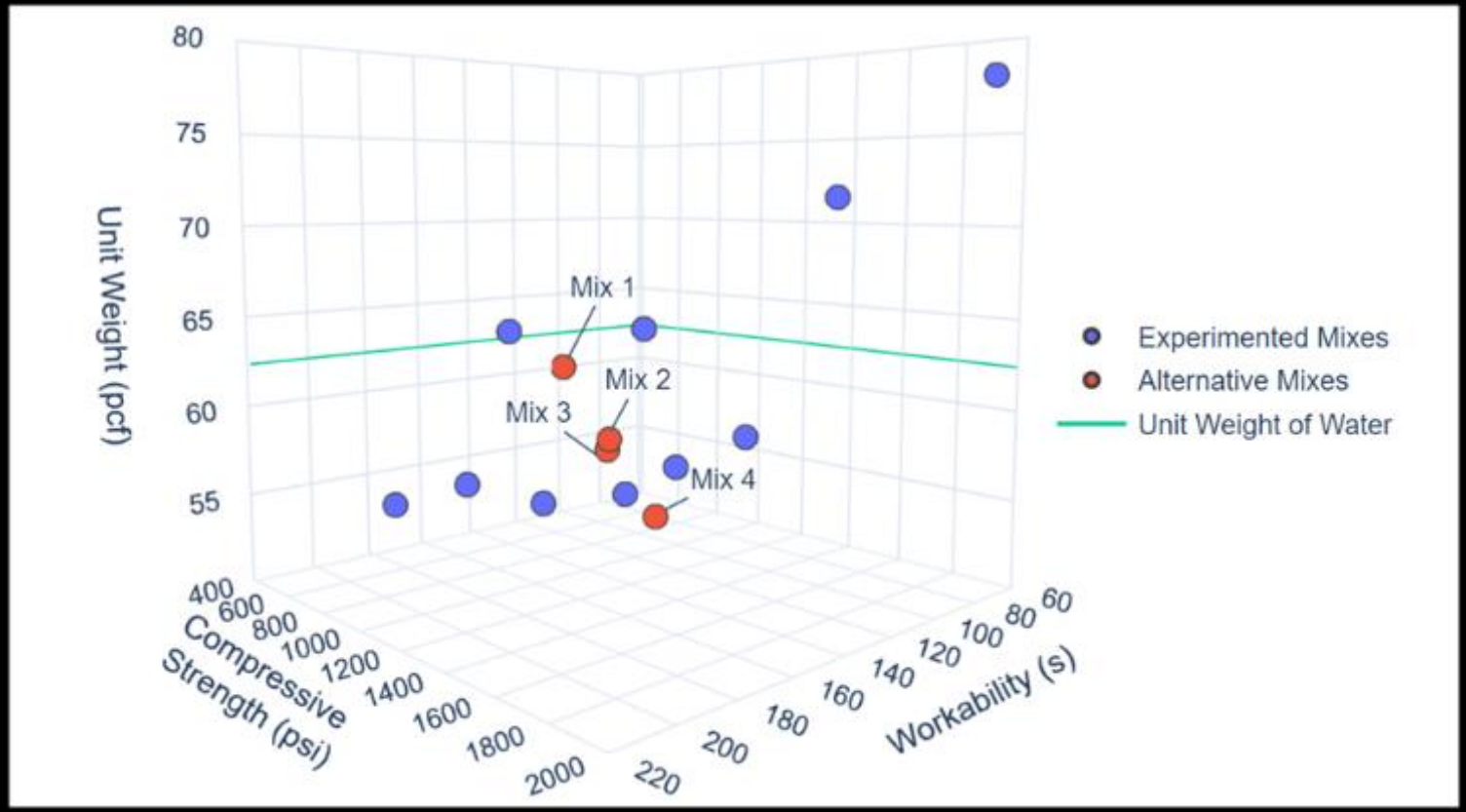
Alternative Mix Designs

	Mix 1	Mix 2
Aggregates	Elemix, Pumice, Poraver	Pumice, Poraver
Unit Weight (pcf)	60.84	56.16
Strength (psi)	405.7	712.0
Workability	High workability	Low Workability
Economic	Elemix no longer available	Pumice: $25/bag Poraver: $70/bag

Alternative Mix Designs (cont.)

	Mix 3	Mix 4
Aggregates	Stalite, Poraver	Poraver
Unit Weight (pcf)	54.72	51.48
Strength (psi)	589.3	859.3
Workability	Low Workability	Low Workability
Economic	Stalite: $28/bag Poraver: $70/bag	Poraver: $70/bag

Mix Design Alternatives Graph



Final Mix Design

Unit Weight
52.2 pcf

Strength
680 psi

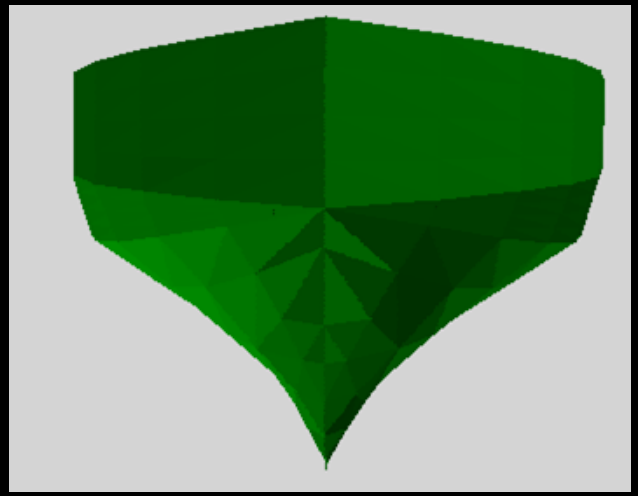
Air Entrainer
2 fluid ounces per 100 lb of aggregate

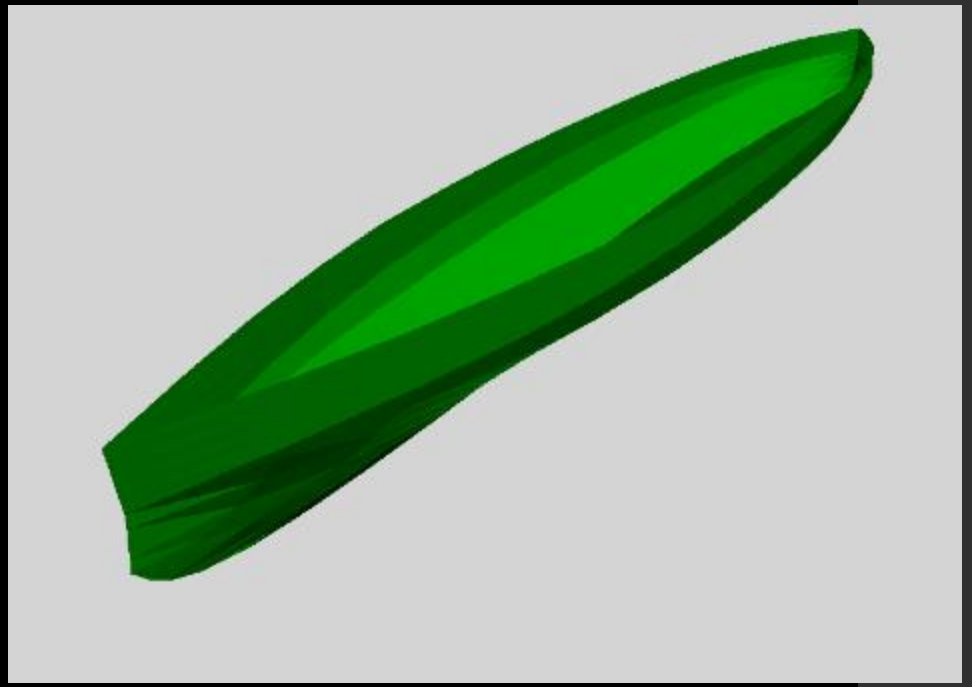
Property	Value
Slump	¼ in
Air Content	5.5%
W/CM Ratio	0.42

Category	Material	Percent of Mixture by Mass
Cementitious Material	Portland Cement	23%
	Slag Cement	12.5%
	Fly Ash	10.5%
Aggregate	Poraver (0.25-0.5mm)	9.7%
	Poraver (0.5-1mm)	11.6%
	Poraver (1-2mm)	13.5%
Water	Tap Water	19.2%

Alternative Hull Designs - Design 1

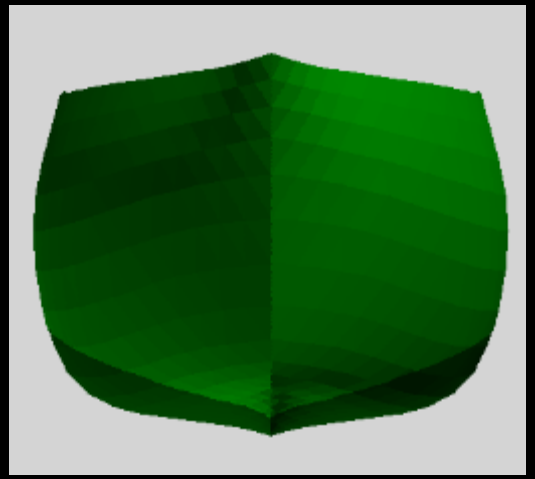
- Length: 20 feet
- Beam: 2 feet
- Side Profile: Straight
- Bottom Profile: Shallow V

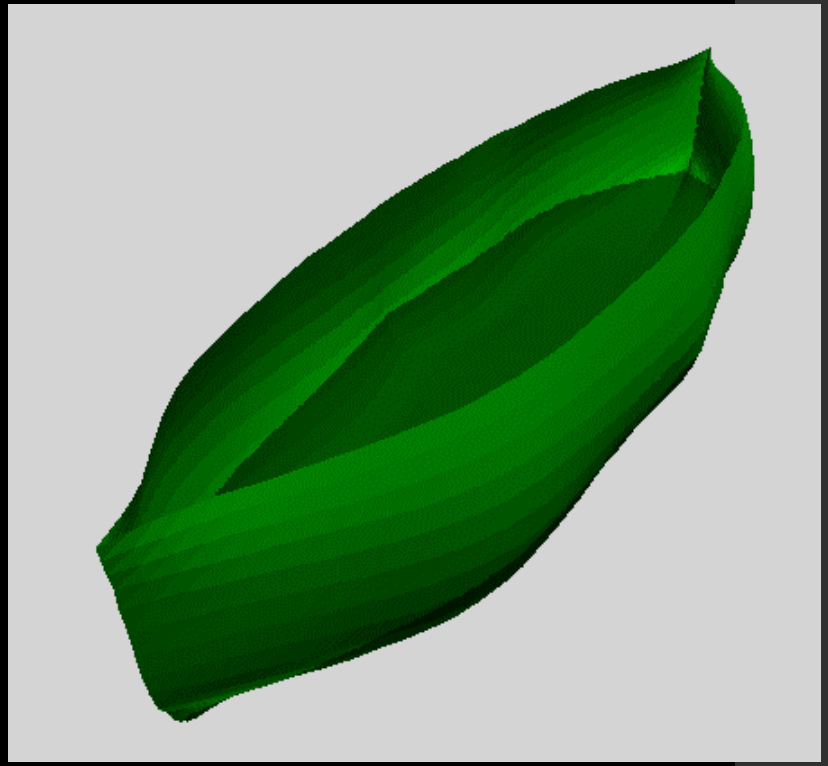




Alternative Hull Designs - Design 2

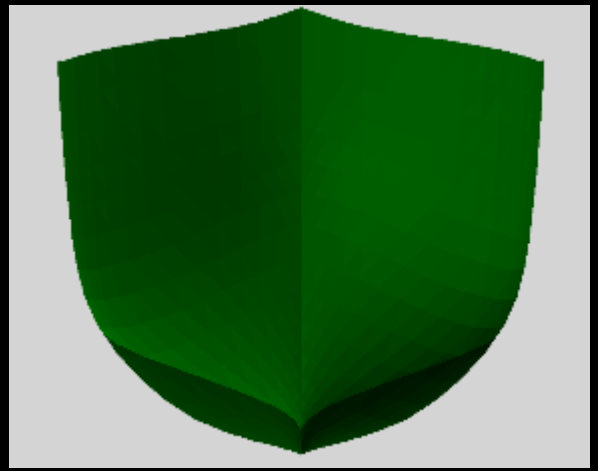
- Length: 16 feet
- Beam: 3 feet
- Side Profile: Tumblehome
- Bottom Profile: Flat

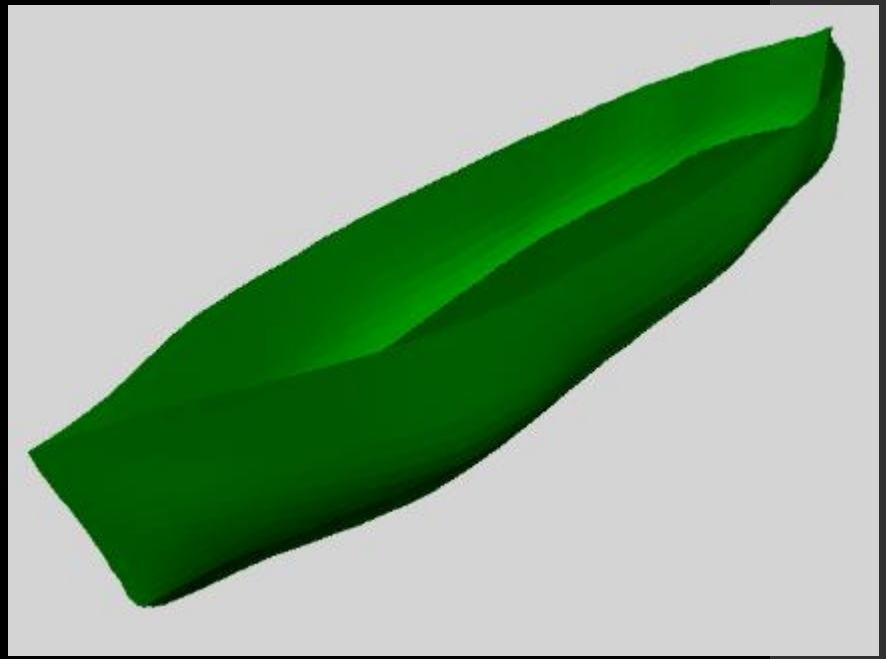




Alternative Hull Designs - Design 3

- Length: 18 feet
- Beam: 2.5 feet
- Side Profile: Flare
- Bottom Profile: Shallow Arch

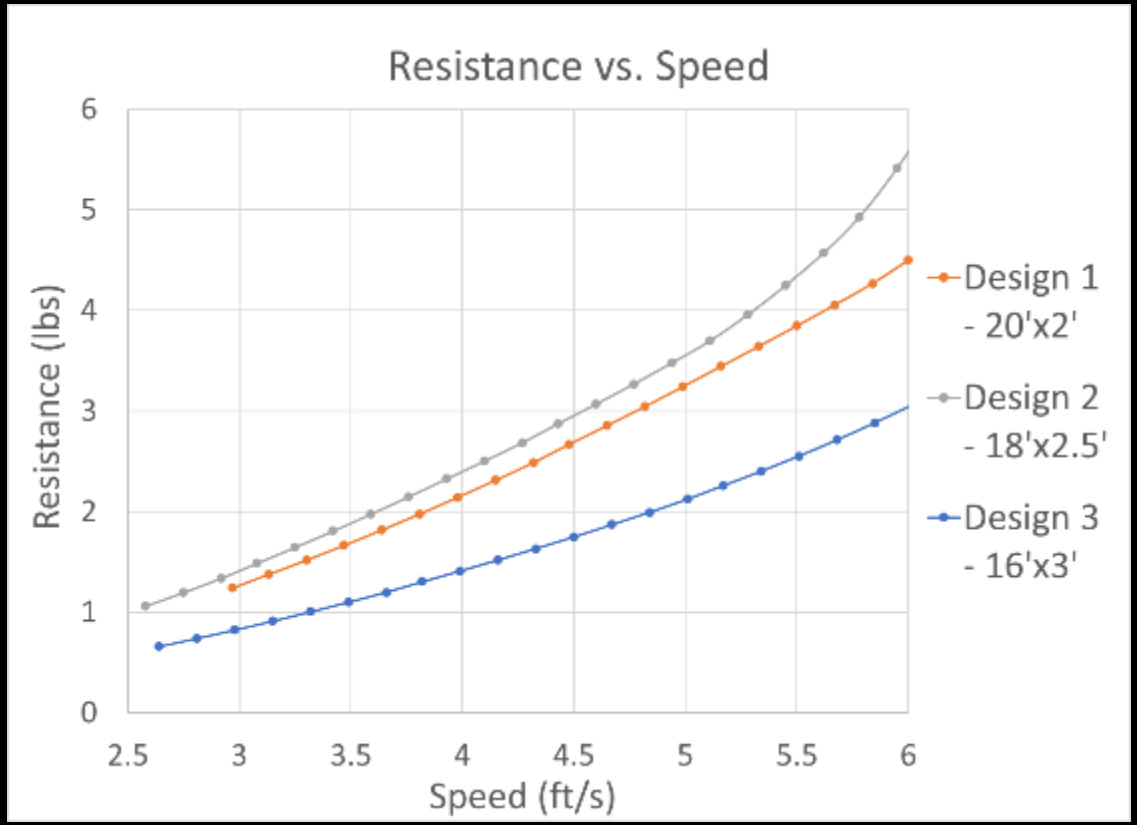




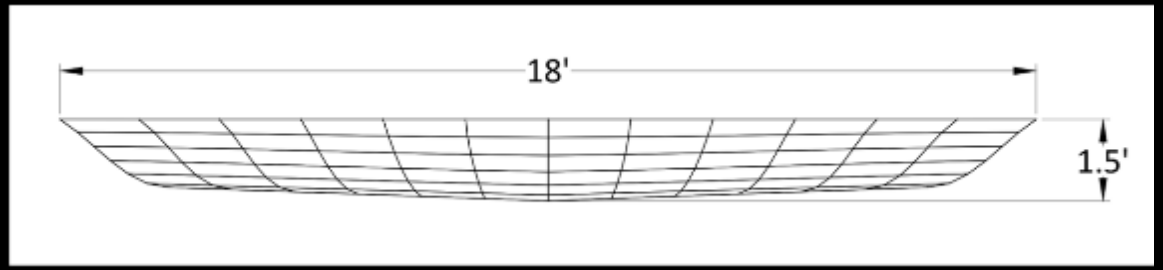
Hull Design Decision Matrix

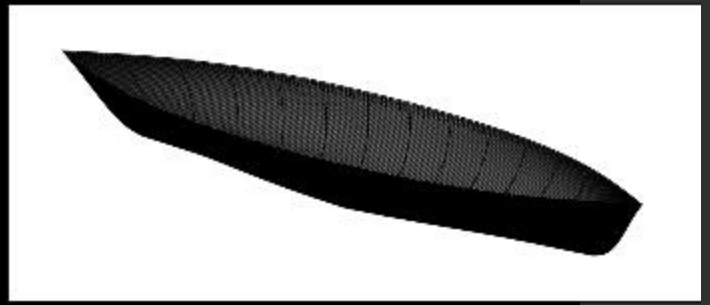
	Weight	Design 1	Design 2	Design 3
Constructability	5	1	2	3
Stability	5	1	3	2
Maneuverability	3	1	3	2
Speed	2	3	1	2
Tracking	1	3	1	2
Total		**22**	**37**	**37**

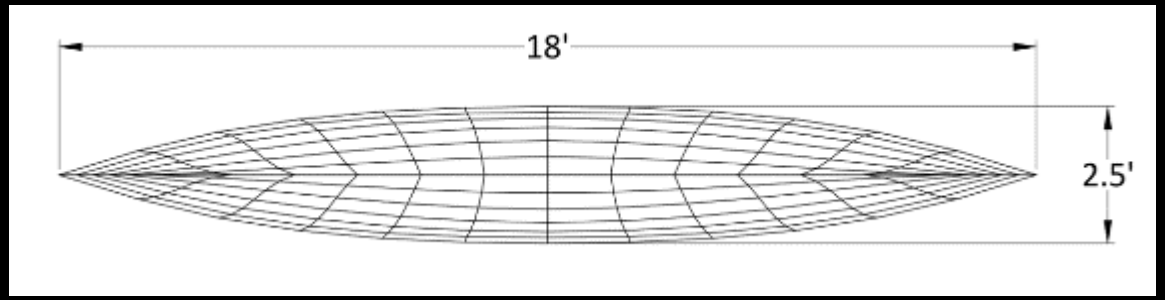
Hydrostatic Analysis



Final Hull Design

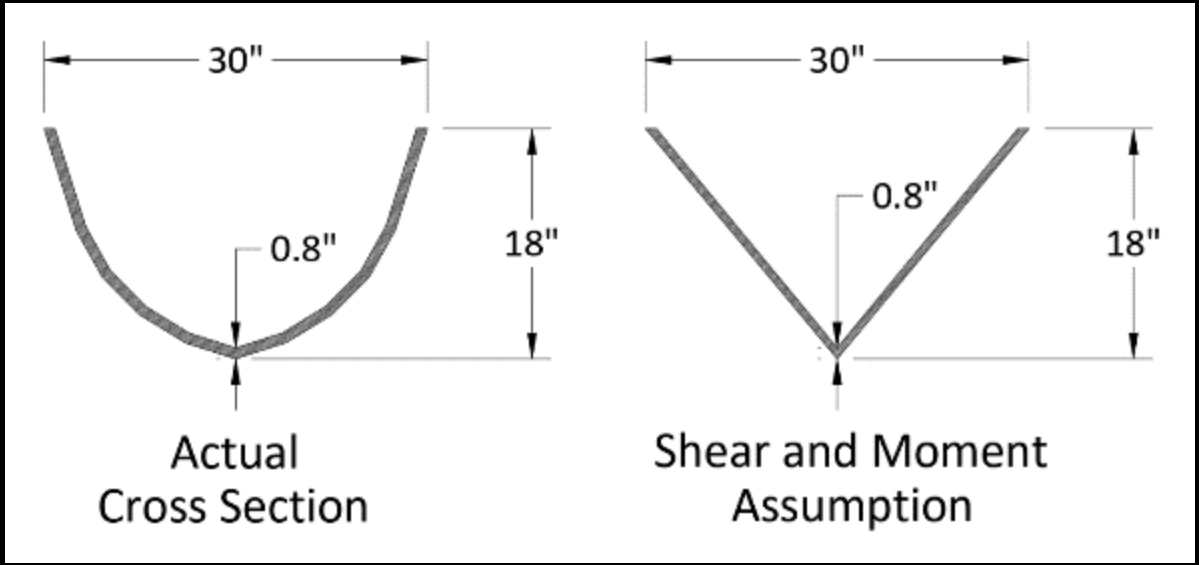




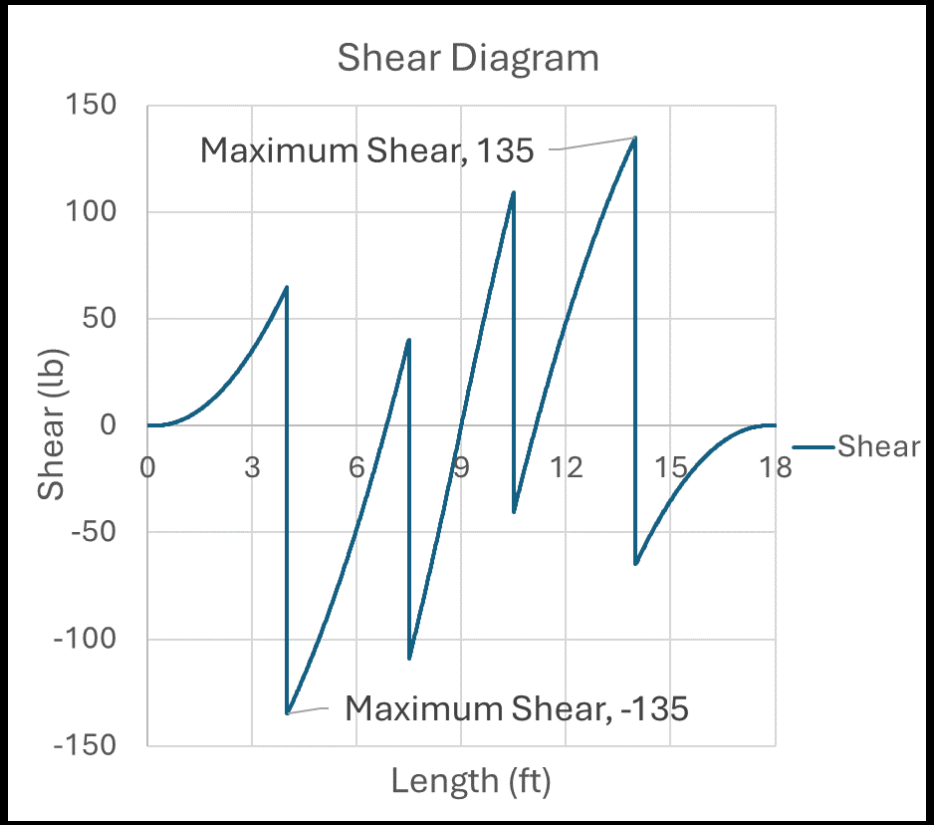


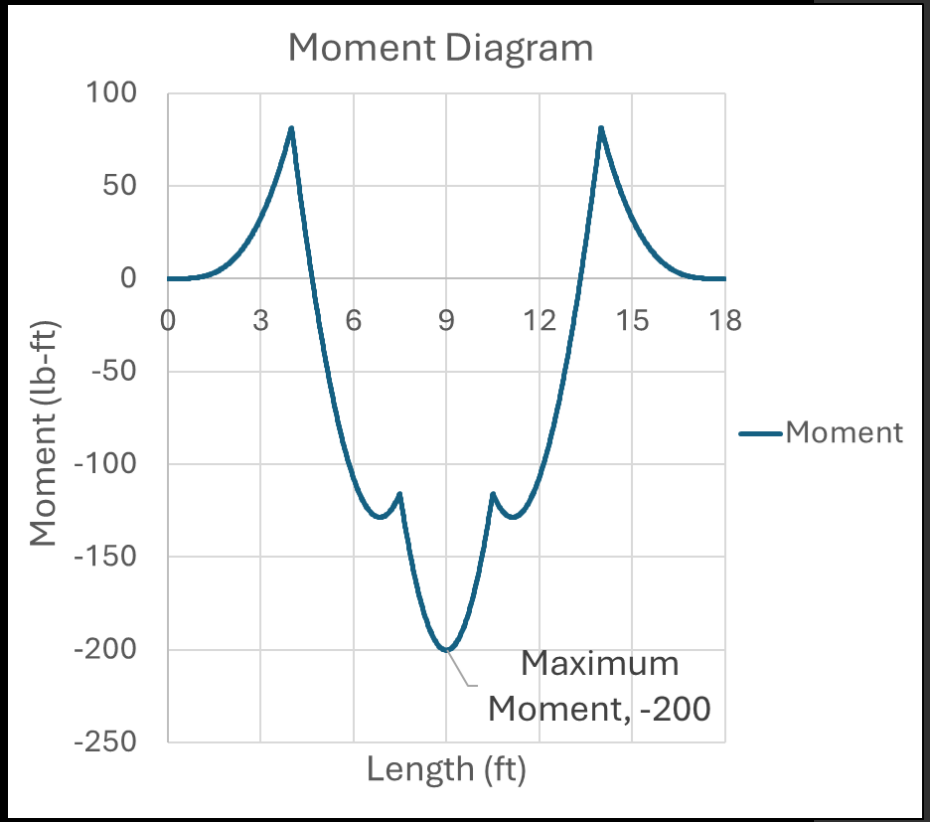
Structural Analysis

- Assumptions
  - Linear increase of height and width
  - 4 person sprint race loads



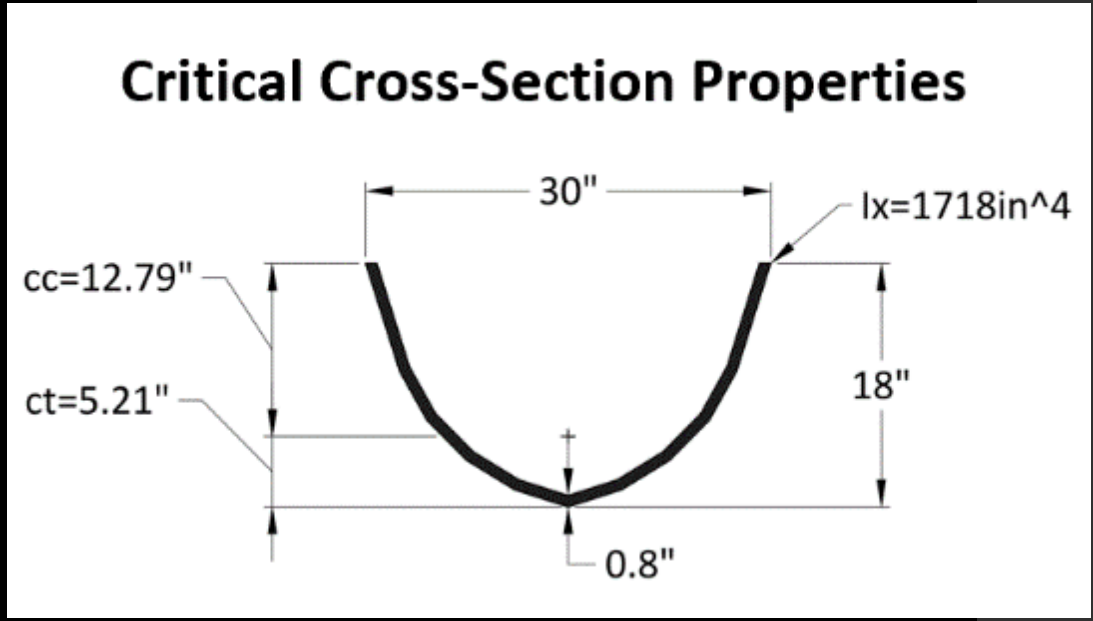
Structural Analysis (cont.)





Structural Analysis (cont.)

- Compressive stress: 20 psi
- Tensile Stress: 10 psi
- Punching Shear:
  - Two-way shear strength (ACI 318)
  - Stress of 25 psi
  - Shear strength of 65 psi



Mold Construction

- Accessible mold
- Frame constructed in two parts
- Easy removal
- Modular repair
- Used for transportation

Mold Construction (cont.)

- Female mold
- Constructed in-house
- Wood frame
- Plywood cross-sections
- Masonite strips
- Plaster and paint
- Oil and saran wrap

Mold Construction (cont.)

Half Mold

Full Mold

Completed Mold

Canoe Construction

Reinforcing Mesh

1 linear foot styrofoam

0.8 inch thickness

Curing

Week 1

Weeks 2 & 3

Week 4

Staining and Sealing

Transportation

- Moving Blankets
- In mold
- Dolly
- Forklift
- 3-hour drive
- Cracked during transportation

Competition Results

Repairs made

Table Setup

Competition Results (Cont.)

Swamp test passed

- Attempted Women’s Slalom
- Placed 5th out of 6
- 3rd for project proposal

Recommendations for Next Year

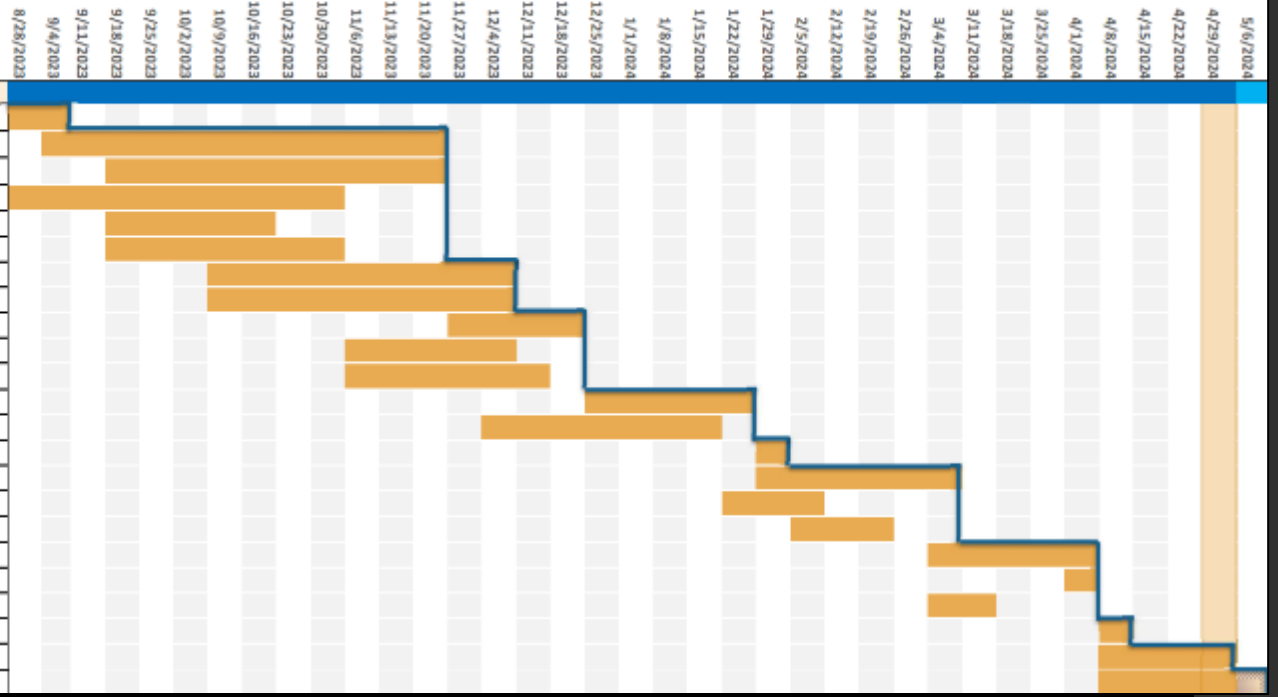
- Strength over unit weight
- Use more foam if needed
- Soak aggregates
- Double reinforcement
- Simplified hull geometry
- Support on both sides during transportation

Project Schedule

ASCE Concrete Canoe Competition Gantt Chart

Period Highlight: 36 | Duration | % Complete

ACTIVITY	% COMPLETE
Total Project Completion:	99%
Problem Statement and Background Presentation	100%
Mix Design	100%
Hull Design	100%
Research and Fundraising	100%
Alternative Design Presentations	100%
Fall Quarterly Report	100%
Hydrostatic Analysis	100%
Structural Analysis	100%
Order Materials	100%
Engineering Services Presentation	100%
Engineering Services Proposal	100%
Mold Construction	100%
Mold Placement Practice	100%
Final Concrete Pour	100%
Treat and Remove Concrete From Mold	100%
Material Testing	100%
Spring Quarterly Report	100%
Prepare Competition Materials	100%
Practice Canoeing	100%
Poster Presentation	100%
Competition	100%
Final Presentation	100%
Final Report	90%



Engineering Services Cost

Engineering Labor Costs								
Item		Fall			Spring			
		Engineering Supervisors	Engineer II	Engineer I	Engineering Supervisors	Engineer II	Engineer I	Technician
Salary	Employees	2	1	4	2	1	4	1
	Rate (per hour)	$50	$39	$37	$50	$39	$37	$30
	Hours	16	80	320	17	68	270	8
	Base Salary	800	3120	11840	850	2633	9990	240
Overhead Allocation Rate		**$19.94**	**$29.44**	**$24.44**	**$19.94**	**$31.53**	**$25.65**	**$129.26**
Total Billable Rate		**$69.94**	**$68.44**	**$61.44**	**$69.94**	**$70.53**	**$62.65**	**$159.26**
Total Costs	Employee Cost	$1,120	$5,480	$19,660	$1,190	$4,760	$16,920	$1,270
	Profit Multiplier (6%)	$1,190	$5,800	$20,840	$1,260	$5,050	$17,930	$1,350
	Total Labor Cost	**$27,830**			**$25,590**			

Construction Cost

Total Construction Cost	
Mold	$484
Canoe	$378
Miscellaneous	$519
Total	**$1379**

Thank You

Questions?