Figure 1: NAU ASCE Student Chapter on Race Day
Credit: Kylie Hanson

2023 ASCE Concrete Canoe Competiton

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April 28, 2023

Project Background

- Design, construct, and race a concrete canoe
- Present and compete at Intermountain Southwest Student Symposium
- Team Goals
  - Environmentally conscious concrete mix
  - Place well at competition

Figure 2: 2023 Concrete Canoe Team
Credit: John Hritz

Figure 3: Final Product Prototype
Credit: Owen Allen

Project Organization

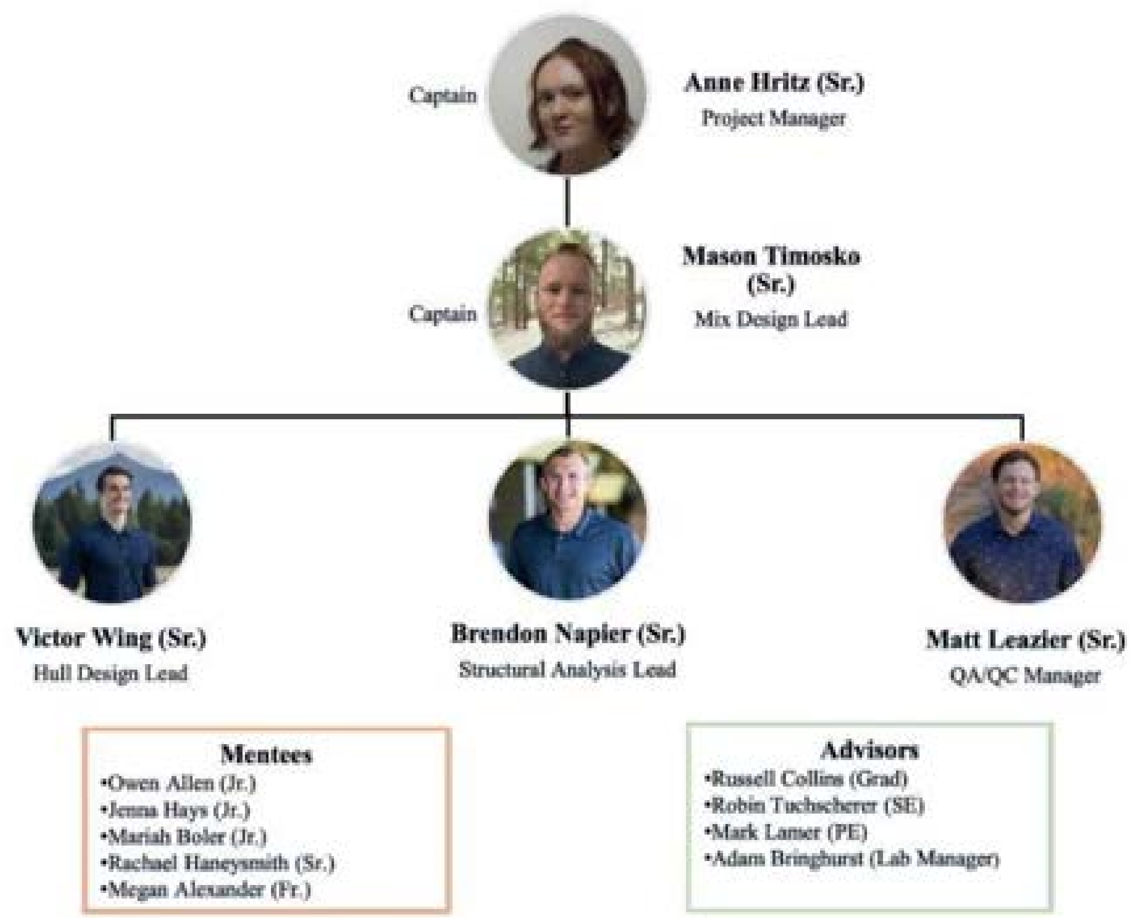

Figure 4: Team Chart

Concrete Mix Design

- Cementitious Materials
  - CalPortland Type IL AdvanCement LT Cement
  - Class F/C 80/20 Blend Fly Ash
  - 120 Grade Slag Cement
- Aggregates
  - Utelite Crushed Fines
  - Post-Consumer Carpet
  - Calcium Carbonate
  - Perlite
- Admixture
  - MasterGlenium 3400
- Fibers
  - MasterFiber M35

Figure 5: Mix Components
Credit: Victor Wing

Concrete Mix Design

Table 1: Concrete Properties

Property	Value	Units	Relevant ATSM
Plastic Unit Weight	85	pcf	C138
Oven Dry Unit Weight	69	pcf	C642
Compressive Strength (28-Day)	1,250	psi	C39
Tensile Strength (28-Day)	130	psi	C496
Composite Flexural Strength (28-Day)	270	psi	C78
Slump	4.0	in	C143
Spread	9.25	in	C1611
Air Content	7.8	%	C138

Figure 6: Slump Test
Credit: Mason Timosko

Figure 7: Compressive Testing Machine
Credit: Victor Wing

Concrete Mix Design

- Categories are rated on a 1-5 scale
  - 1 : Poor performance in the category standard
  - 3 : The design meets the category standard
  - 5 : Design exceeds the category standard

- Explanations:
  - Strength (35%)- Capacity must exceed demand
  - Density (35%)- Light concrete means easier floatation
  - Cracking (20%)- Cracking creates leaks & strength reduction
  - Aesthetics (10%)- Small points for the competition

Table 2: Concrete Decision Matrix

Mixture Design	Compression Strength (35%)	Density (35%)	Cracking (20%)	Aesthetics (10%)	Weighted Total (Max 5)
Mix 1: PC4 | AeroAgg | Utilite | High Water | 0.3 W/CM Ratio	4	3	4	4	3.65
Mix 2: PC4 | Perilite | Utilite | Low Water | 0.25 W/CM Ratio	3	5	5	5	4.3
Mix 3: PC4 | Poraver | Utilite | Low Water | 0.4 W/CM Ratio	3	4	3	3	3.35

Reinforcement Design

- Simpson Strong-Tie CSS-BCG Bidirectional Carbon Grid
- Percent Open Area Calculations
  - Ensure proper mechanical bonding
- Reinforcement lap length was done as 4 inches instead of 12 inches.
  - Tensile strength was reduced by a third to account for this.

$$POA = \frac{\sum Area_{Open}}{Area_{Total}}$$

Figure 4: Open Area Equation
Credit: C4 RFP [1]

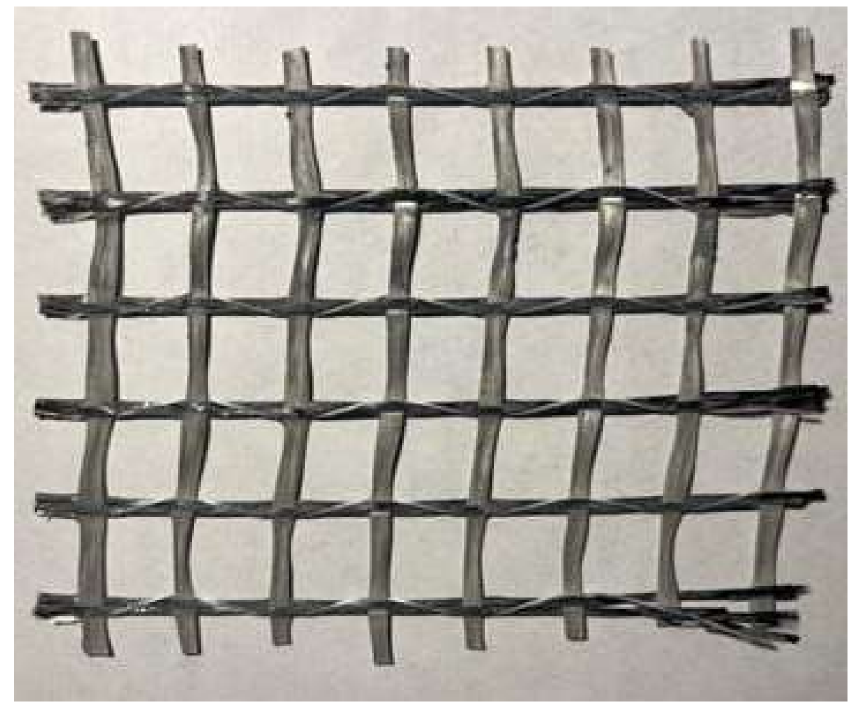

Figure 8: Reinforcement Sample
Credit: Anne Hritz

Hull Design

- Categories are rated on a 1-5 scale
  - 1 : Poor performance in the category standard
  - 3 : The design meets the category standard
  - 5 : Design exceeds the category standard

- Explanations:
  - Speed, Manueverability, Secondary Stability (20%)- Demands for a racing canoe
  - Initial Stability & Ease of Construction(15%)- Less user strain
  - Comfortability (10%)- Increases paddler productivity

Table 3: Hull Decision Matrix

Hull Design	Speed (20%)	Maneuverability (20%)	Initial Stability (15%)	Secondary Stability (20%)	Ease of Construction (15%)	Comfortability (10%)	Weighted Total
D1: Shallow-Arched Bottom | Flared Sides | Rockered Body	4	5	4	4	5	4	4.35
D2: Shallow-Arched Bottom | Tumblehome Sides | Rockered Body	4	5	4	4	2	5	4
D3: Flat Bottom | Flared Sides | Rockered Body	2	2	5	4	5	5	3.6
D4: Shallow Vee | Straight Sides | Rockered Body	5	5	2	5	3	2	3.95

Hull Design

- Final Canoe Dimensions
  - Total length must fall under 22ft and fit in the trailer

Table 4: Canoe Dimensions

Property	Value	Units
Length	19	ft
Width	2.75	ft
Depth	15	in
Thickness	1	in
Weight	370	lbs

Hull Design

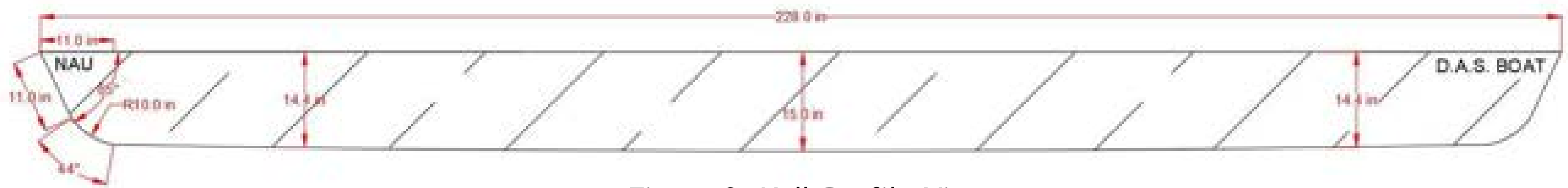

Figure 9: Hull Profile View

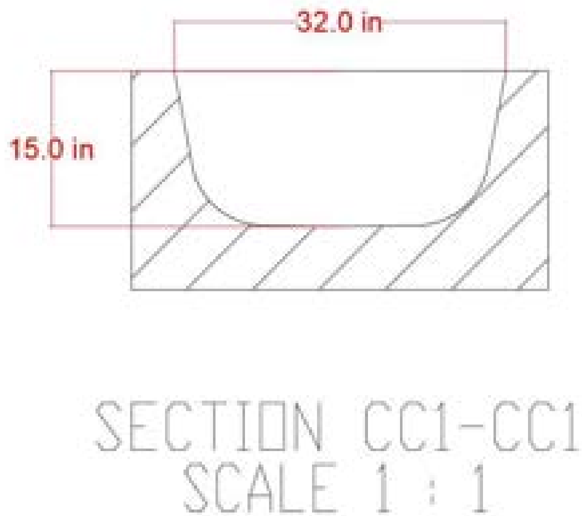

Figure 10: Cross Section View

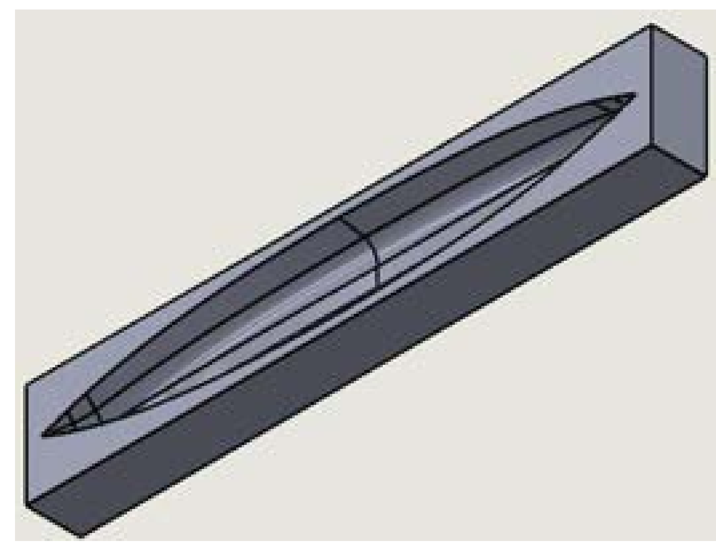

Figure 11: Hull Isometric View

Structural Analysis

Table 5: Shear & Moment Demands

Nex	Max Shear Magnitude (lb)	Max Shear Location (ft)	Max Moment Magnitude (lb*ft)	Max Moment Location (ft)
Male Tandem	150	8	600	8

Table 6: Demands Vs. Capacity

Load Condition	Demand	Capacity
Shear Force (lbs)	210	1590
Moment (lb-ft)	600	1290
Punching Shear (psi)	16	80

Table 7: Freeboard

Load Case	Freeboard (in.)
Male Tandem	9

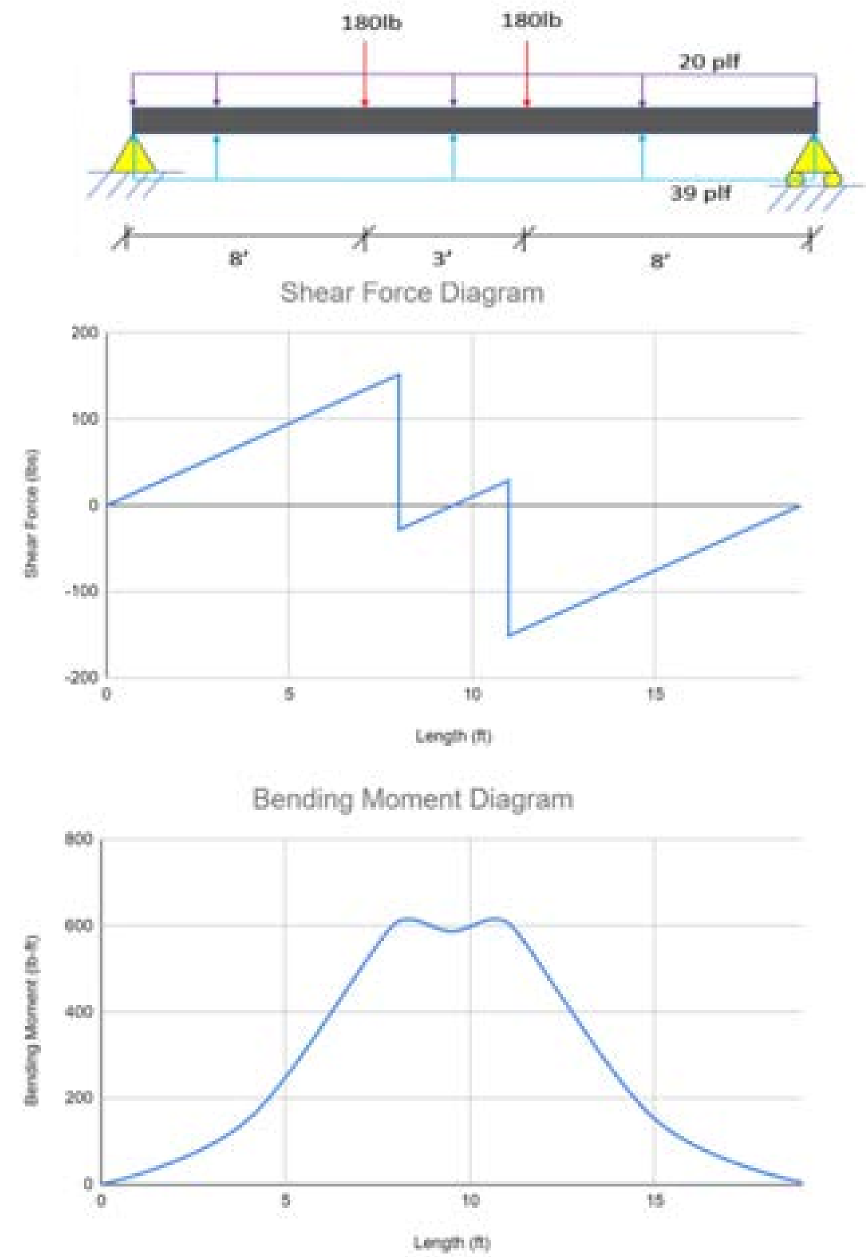

Figure 12: Shear & Moment Diagrams

Construction

- Styrofoam Female Mold
  - Suggested focus for next year to use more sustainable formwork
- Manufactured in 4" thick sections using 2D styrofoam cutter
- Mold Assembly
  1. Glue mold pieces together
  2. Sand mold to create smooth plane
  3. Fill voids with joint compound
  4. Apply petroleum jelly as releasing agent

Figure 13: Mold Pickup
Credit: Matthew Leazier

Construction

Figure 14: Mold Assembly

Figure 15: Mold Sanding

Figure 16: Drywall Application

Figure 17: Release Agent Application

Construction

Figure 18: Reinforcement Placement

Figure 19: Surface Finishing

Figure 20: Curing Process

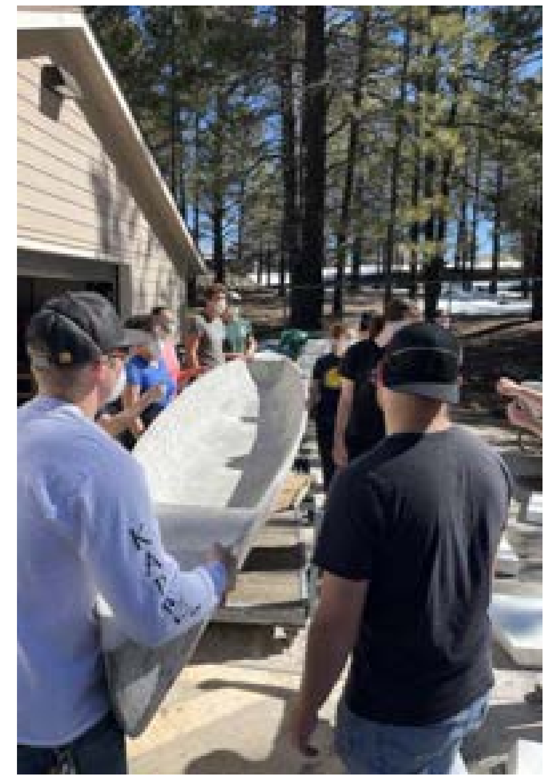

Figure 21: Foam Removal and Sanding

Competition - Display

Figure 22: Canoe Side View
Credit: Natalie Wahl

Figure 23: Poster, Material Samples, and Cross Section
Credit: Kylie Hanson

Figure 24: Canoe Front View
Credit: Kylie Hanson

Competition - Presentation

Figure 25: Team during Technical Presentation
Credit: Kylie Hanson

Competition - Racing

Figure 26: Loading Canoe into Water
Credit: Jenna Hays

Figure 27: Swamp Test
Credit: Jenna Hays

Competition - Racing

Figure 28: Men's Sprint Team
Credit: Kylie Hanson

Figure 29: Women's Slalom Team
Credit: Kylie Hanson

Competition Results

- Placed 4th overall
  - 1st in Project Proposal
  - 5th in Technical Presentation
  - 7th in Final Product Prototype
  - 6th in Race Demonstrations

Figure 30: Team with Proposal Award at Banquet
Credit: Mariah Boler

Figure 31: Project Proposal Award
Credit: Anne Hritz

Quality Control

- Safety Binder
  - Tool Safety Videos
- Team meeting prior to work
- Respirators and safety glasses
- Ventilation of lab facility

Figure 32: CECMEE Lab Field Station
Credit: Matthew Leazier

Figure 33: Team Safety Meeting
Credit: Anne Hritz

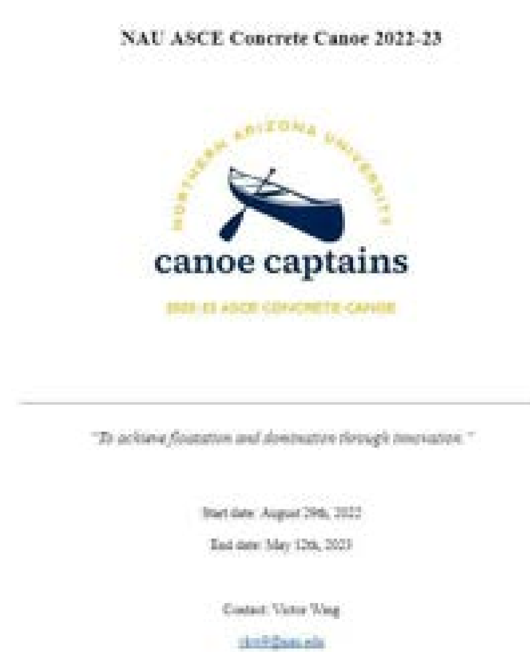

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Figure 34: Safety Binder Cover
Credit: Brendon Napier

Quality Assurance

- Grading Instructor guidance
- Technical advisor help
- Supervision of mentees
- Check calculations through industry Norms
  - Double check calculations
- ASTM test methods


Figure 35: Slump Test (ASTM)
Credit: Brendon Napier


Figure 36: Concrete Placement
Credit: Victor Wing

Evaluation of Project Impacts

- **Environmental Impacts**
  - Our concrete utilizes recycled material
    - PC4 – Recycled carpet
    - Fly ash – Coal burning by-product
    - Slag - Steel industry waste
  - Low Impact Cement
    - Type 1L Portland-Limestone cement - 9% less CO_2 emissions during production [2]

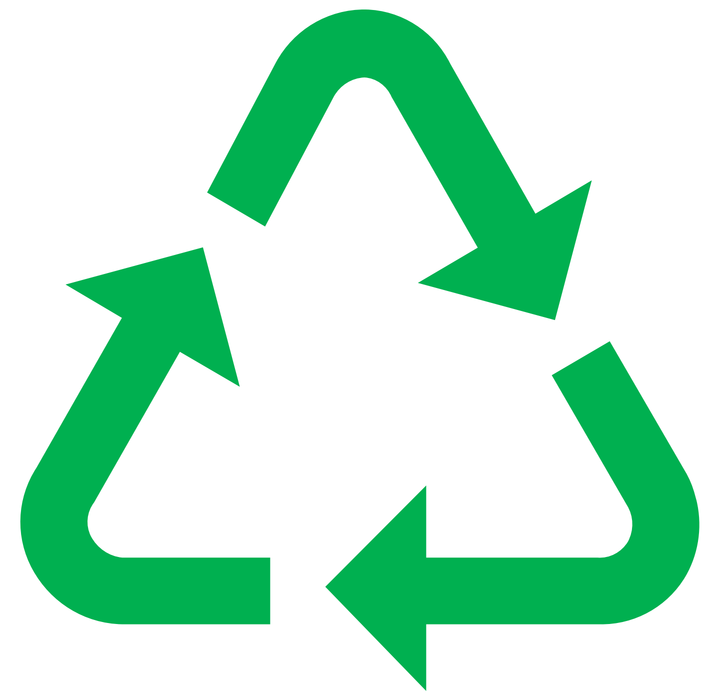

Figure 37: Recycling Opportunities

Evaluation of Project Impacts

- **Social Impacts**
  - Competition brings younger engineers together
    - Creates relationships for the professional world
  - Competition helped get the team out of their comfort zone
    - The team was exposed to new challenges, such as large-scale presentations, that can be used in the professional world

Figure 38: NAU ASCE Student Chapter
Credit: Cynthia Lamer

Evaluation of Project Impacts

- **Economic Impacts**
  - By sponsors funding this project, the canoe can be built without spending personal wealth
  - By using recycled and leftover materials, the canoe was able to be built without large purchases
  - Aggregates sourced from Southwestern United States to cut shipping costs and support regional suppliers

Figure 39: Project Sponsors

Questions?

Figure 40: Northern Arizona University Engineering Building Credit: Anne Hritz

THANK YOU!

Sources

[1] ASCE Committee on Concrete Canoe Competitions, "2023 American Society of Civil Engineers Concrete Canoe Competition Request for Proposals," American Society of Civil Engineers, Reston, 2022.

[2] CalPortland, "Product Data Sheet Type IL(13) Cement," [Online]. [Accessed 25 January 2023].