PLUTO JACKS ISWS Presentation

Team Members:

Jonathan Alvarez Rojas
Theo Greenan
Kayleigh Rice
Trevion Booker
Amit Shah

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NORTHERN ARIZONA UNIVERSITY
2025-2026 ASCE CONCRETE CANOE
PLUTO JACKS

Team Introductions

Jonathan Alvarez Rojas

Project Manager

Theo Greenan

Construction Lead

Kayleigh Rice

Technical Report Lead

Trevion Booker

Mix Design Lead

Amit Shah

Structural Analysis Lead

Material Research

- Prior canoe team mix designs
- Inventory at NAU field lab
- Properties of suitable materials (either through testing or online research)

Aggregate Properties			
Aggregate	**Specific Gravity**	**Absorption (by weight)**	**Particle Size**
Horticulture Perlite	0.125	665%	0.1 - 1 mm
Poraver	0.296	224%	0.25 - 2 mm
K1 Bubbles	0.125	0%	Fines (Passing #200)
Volcanic Pumice	1.64	11%	0.2 -2 mm
Utelite Expanded Shale	1.40	60%	0.2 - 2 mm
Lightweight Aggregate	1.66	30%	1 – 2 mm
Aero Aggregate	1.65	88%	.05 - 2 mm
Recycled Aggregate	1.47	9%	.05 - 2 mm

Table 2-1: Aggregate Properties

Material Testing

Completed Concrete & Material Testing and ASTM Designation		
Material/Concrete Test	**ASTM #**	**Test Purpose**
Standard Test Method for Compressive Strength of Cylindrical Concrete Specimens	ASTM C39	Compressive Strength
Standard Test Method for Slump of Hydraulic-Cement Concrete	ASTM C143	Workability
Standard Test Method for Density (Unit Weight), Yield, and Air Content (Gravimetric) of Concrete	ASTM C138	Density
Standard Test Methods for Sieve Analysis of Fine and Coarse Aggregates	ASTM C136	Gradation
Standard Test Methods for Splitting Tensile Strength of Cylindrical Concrete Specimens	ASTM C496	Tensile Strength
Standard Specification for Concrete Made by Volumetric Batching and Continuous Mixing	ASTM C685	Concrete Batching

Table 2-2: Tests Completed with Purpose

Trial Mix Properties

Mix 1 Properties	
Property	**Value**
Compressive Strength (28-day)	2260 psi
Tensile Strength (28-day)	360 psi
Density (hardened concrete)	67 pcf
Density (fresh concrete)	68.2 pcf
Slump, Spread	2 in
Weight	4.2 lb
Air Content	4.5%
w/cm	0.33

Table 2-3: Mix Design 1 Properties

Mix 2 Properties	
Property	**Value**
Compressive Strength (28-day)	3180 psi
Tensile Strength (28-day)	440 psi
Density (hardened concrete)	84 pcf
Density (fresh concrete)	84.3 pcf
Slump, Spread	2 in
Weight	4.5 lb
Air Content	2.0%
w/cm	0.30

Table 2-4: Mix Design 2 Properties

Mix 3 Properties	
Property	**Value**
Compressive Strength (28-day)	520 psi
Tensile Strength (28-day)	70 psi
Density (hardened concrete)	59 pcf
Density (fresh concrete)	60.5 pcf
Slump, Spread	6 in
Weight	3.4 lb
Air Content	5.0%
w/cm	0.36

Table 2-5: Mix Design 3 Properties

Decision Matrix

Scale	
1	Poor
2	Suitable
3	Excellent

Mix Design Decision Matrix							
	Density 30%	**Compressive Strength 20%**	**Tensile Strength 10%**	**Workability 20%**	**Cost 10%**	**Durability 10%**	
Mix 1	67.2 pcf	2260 psi	360 psi	2 in	$1,000	3	
Mix 2	83.6 pcf	3,180 psi	440 psi	2 in	$800	3	
Mix 3	58.6 pcf	520 psi	72 psi	6 in	$1,200	2	
Weighted Scores							**Total Weighted Score**
Mix 1	25.6	11.4	4.8	20.0	8.0	10.0	79.8
Mix 2	0.0	19.0	8.8	20.0	10.0	10.0	67.8
Mix 3	30.0	0.0	0.0	10.0	6.7	6.7	53.4

Table 2-6: Mix Design Decision Matrix

*Red highlight is a failure to meet rules and results in a 0.0 score for the mix

*Green Highlight is the chosen or winning mix design

*Scale is only used for durability values

Final Mix Design

HYDRAULIC CEMENT			
Component	**Specific Gravity**	**Volume (cf)**	**Amount (lbs)**
Lehigh White Portland Cement (Type I/II)	*3.15*	*1.48*	*290.79*
HYDRATED LIME			
Hydraulic Lime (Type S)	*2.32*	*0.23*	*33.37*
SCM/POZZOLAN			
Fly Ash (Type F)	*2.32*	*1.84*	*267.02*
CalPortland Nippon Slag Cement	*3*	*1.29*	*241.99*
SECONDARY REINFORCING (FIBERS)			
Master Fiber 150	*0.91*	*0.09*	*5.05*

AGGREGATES				
Aggregate	**Absorption (%)**	**SG_{SSD}**	**Amount SSD (lbs)**	**Volume (cf)**
Horticulture Perlite (.1-1 mm)	*665*	*0.96*	*24.92*	*3.19*
Poraver (1-2 mm)	*243*	*1.02*	*148.90*	*8.05*
K1 Bubbles (Fines)	*0*	*0.13*	*50.00*	*6.41*

ADMIXTURES				
Admixtures	**lb/gal**	**dose (fl oz/cwt)**	**% solids**	**Amount Water (lbs)**
MasterGlenium 7500 (HRWR)	8.9	0	40	*0*
MasterAir AE 200 (AEA)	8.3	1.5	10	*0.7*

Innovation & Sustainability

Material Innovation

69% Portland cement replacement

→ Fly Ash (Type F) + Slag + Hydrated Lime

Lightweight aggregate system (pcf):

→ Poraver expanded glass (SG 0.296)

→ Perlite (SG 0.125, 665% absorption)

→ K1 Microspheres (SG 0.125, zero absorption)

Master Fiber 150 for crack resistance

MasterGlenium 7500 HRWR for workability

w/cm = 0.33 (well below 0.50 limit)

Sustainability

Reduced carbon footprint:

→ Only 30.8% Portland cement used

→ 47.2% Slag (industrial by-product)

→ 18.9% Fly Ash (coal combustion by-product)

→ 3.1% Hydrated Lime

Lightweight = less material per volume

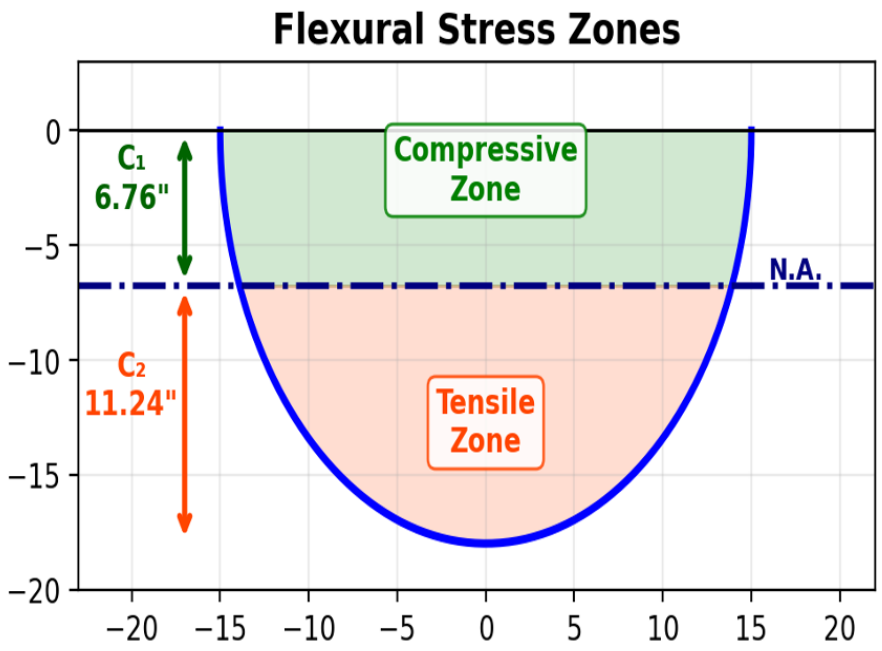
67 pcf vs 150 pcf normal concrete

→ 55 % material reduction by weight

Fiber reinforcement replaces steel rebar

69% Portland replacement = significant reduction in embodied carbon. Lightweight aggregates achieve 67 pcf — well under 80 pcf ASCE limit.

Structural Analysis



Neutral Axis at 11.24" from bottom

C_1 = 6.76" (top to N.A.)
→ Compressive zone

C_2 = 11.24" (N.A. to bottom)
→ Tensile zone

$C_1 + C_2$ = 18.00" ✓

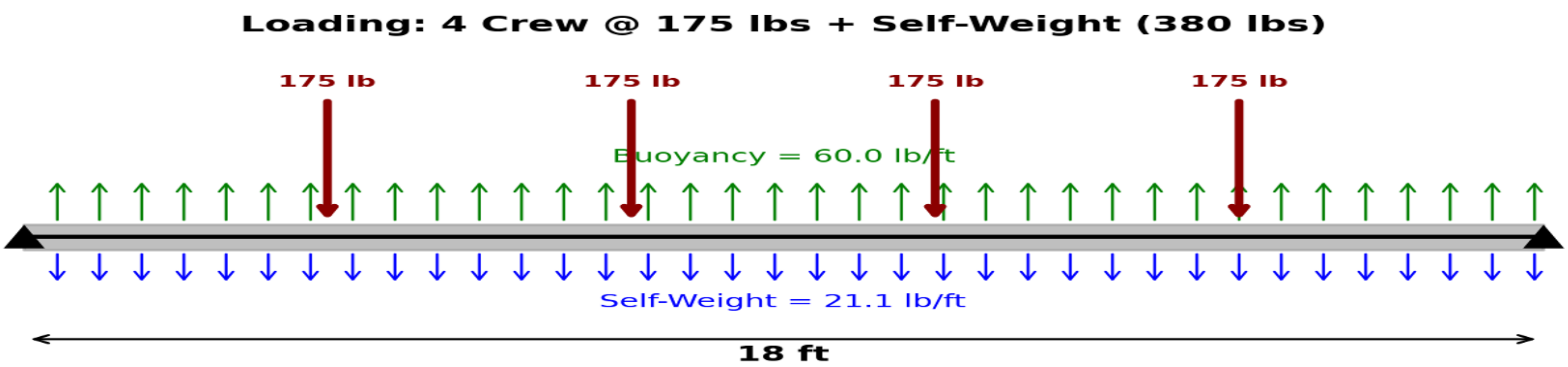
In plain terms: when the canoe bends, the top gets squeezed (compression) and the bottom gets stretched (tension). The neutral axis is where neither happens.

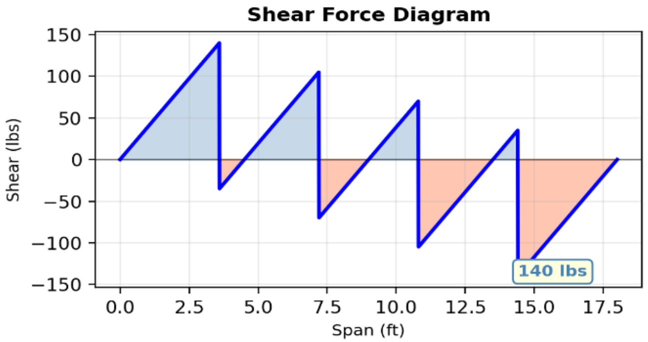
Formulas:
$A = \frac{1}{2}\pi ab = 26.31\ in^2$
$\bar{y} = 4b/(3\pi)$ from flat edge
$I = a^3b(\pi/8 - 8/9\pi) = 834.07\ in^4$

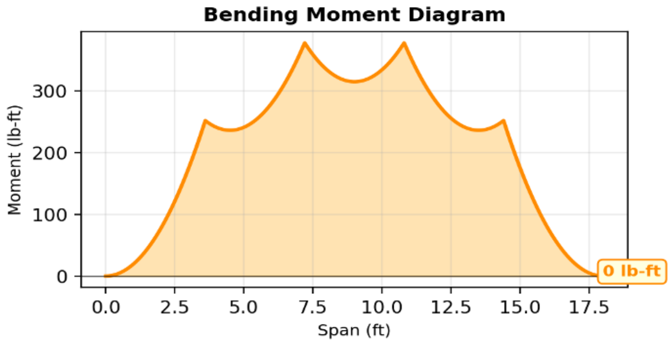
Structural Analysis

Loading

The canoe acts like a beam: paddlers push down, water pushes up. SFD shows where shear is highest; BMD shows where bending is worst.



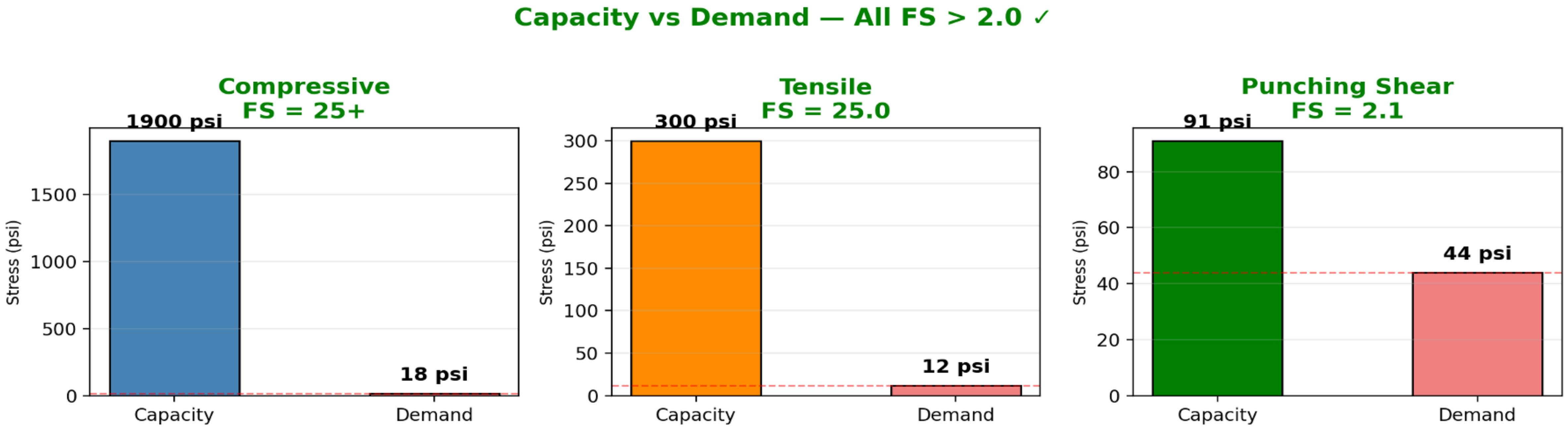




Property	Value
Width	30 in
Depth	18 in
Area	26.31 in^2
Centroid	11.24 in (from bottom)
MOI	834.07 in^4

Structural Analysis

Factor of Safety = how many times stronger than needed. FS > 2.0 = at least 2× stronger than required.



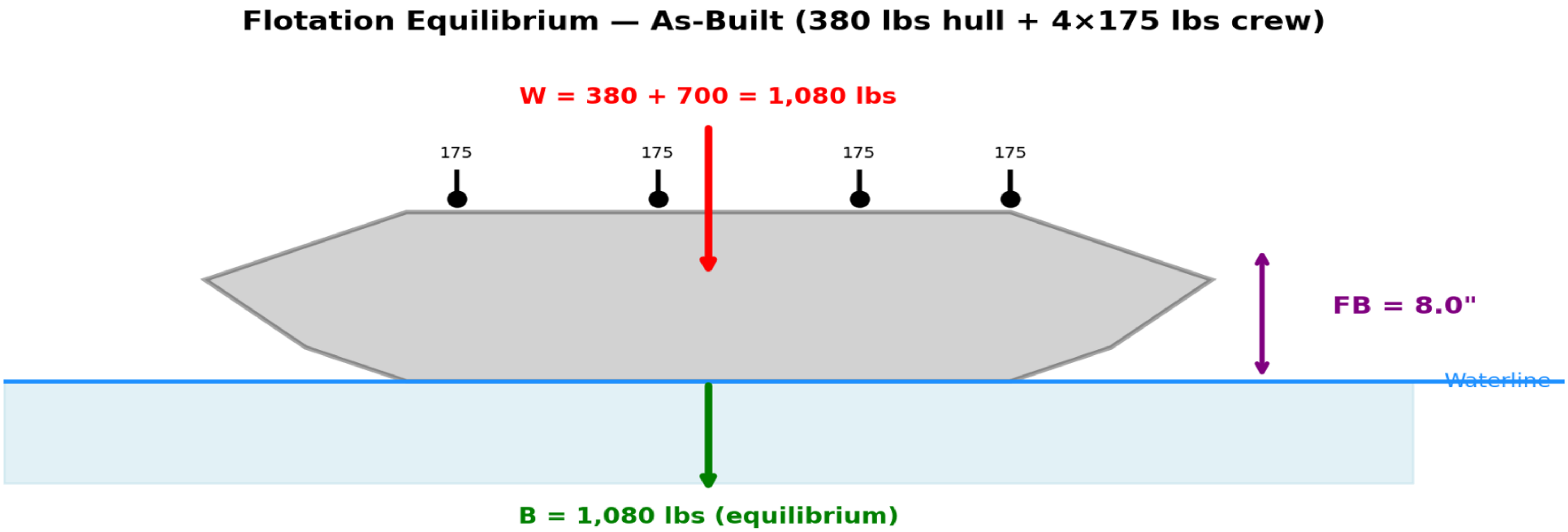
Stress Type	Capacity (psi)	Demand (psi)	Factor of Safety	ACI Reference
Compressive	1,900	18	FS = 25 ✓	σ = Mc/I
Tensile	300+	12	FS = 25 ✓	σ = Mc/I
Punching Shear	91	44	FS = 2.06 ✓	ACI 22.6.5.2

Punching shear governs (FS=2.06): where a paddler's knee contacts the hull (3"×3" contact patch).

Flotation & Stability

The canoe sinks until the water it displaces weighs the same as everything on board (Archimedes' principle).

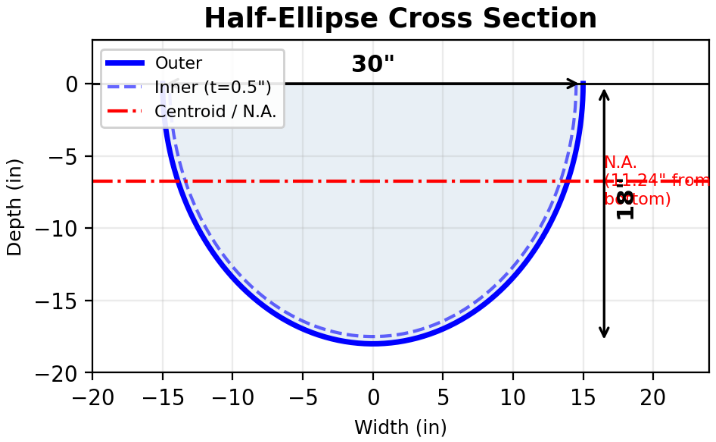
At equilibrium: Freeboard = 8.0" (≥ 6.0" req) | GM = 8.68" (≥ 6.0" req) | SF = 2.30 (≥ 2.0 req)



Hull Design Decision Matrix

Design	Stability 40%	Speed 25%	Maneuver 20%	Constructability 15%	Total Score
Design 1: 18ft, 30in, 18in Notched, Rocker	1.25 (.50)	.80 (.20)	1.11 (.22)	.50 (.08)	1.00
Design 2: 18ft, 30in, 18in Arch, No Rocker	1.25 (.50)	.68 (.17)	.89 (.17)	2.25 (.34)	1.18
Design 3: 16ft, 30in, 16in Arch, Rocker	1.66 (.67)	.68 (.17)	1.25 (.25)	.50 (.08)	1.17

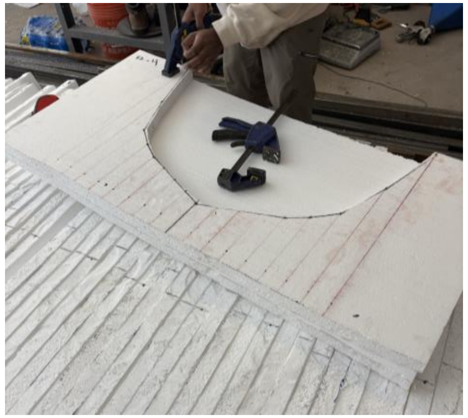
Design 2 selected (1.18): best constructability + competitive stability/speed.



Property	Value
Width	30 in
Depth	18 in
Area	26.31 in^2
Centroid	11.24 in (from bottom)
MOI	834.07 in^4

Construction

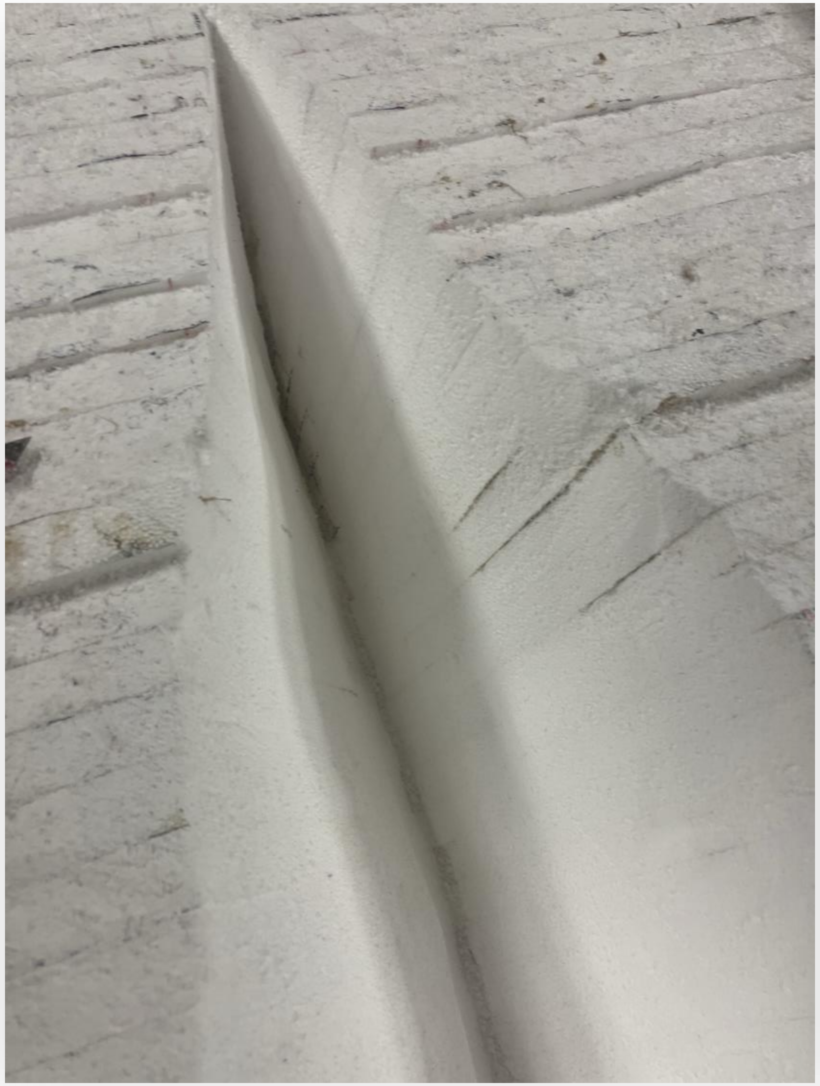
Phase	Days	Description
Mold Construction	1 – 8	Foam lamination, station cutting, all-thread alignment, sanding, sealing
Reinforcement	9	Basalt mesh + Master Fiber 150 dry-fit and layout
Concrete Placement	10	Lift 1 (inner layer) + mesh + Lift 2 (outer layer) = wall thickness
Curing	11 – 39	Moist curing with plastic wrap, strength monitoring
Demolding	40	6-person team, foam removal, inspection
Finishing	41-48	Sanding, patching, sealing, graphics application



Figures 4-1, 4-2, 4-3: Foam Mold Construction (Cutting)- Kayleigh


Figures 4-4, 4-5: Foam Mold Construction (Gluing and Frame Construction)- Kayleigh

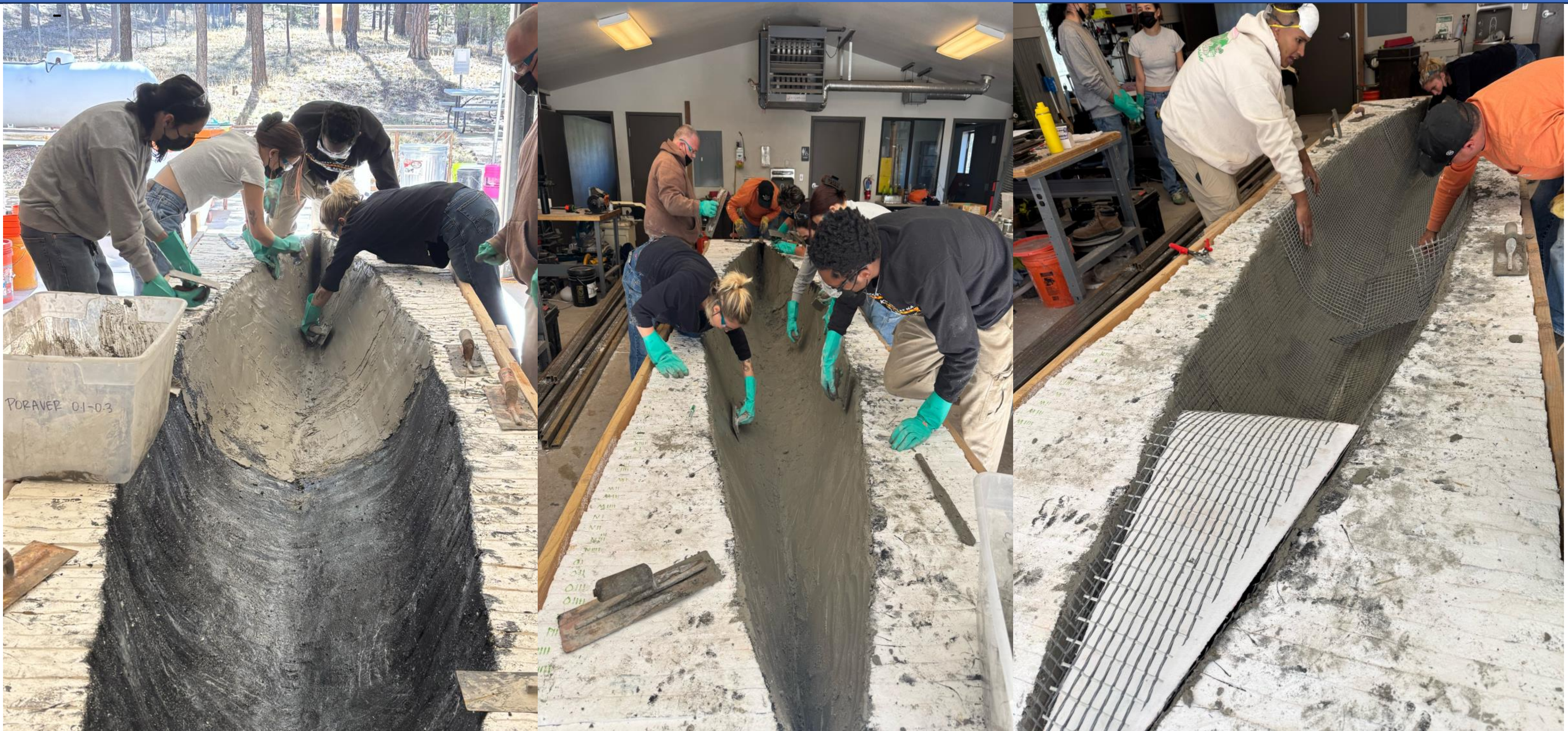


Figures 4-6, 4-7, 4-8: Mold Sanding and Sealing -Kayleigh

Concrete Batching

Figures 4-9. 4-10, 4-11: Canoe Batching Process –Alondra

Concrete Placement



Figures 4-12, 4-13, 4-14: Concrete and Reinforcement Placement- Kayleigh

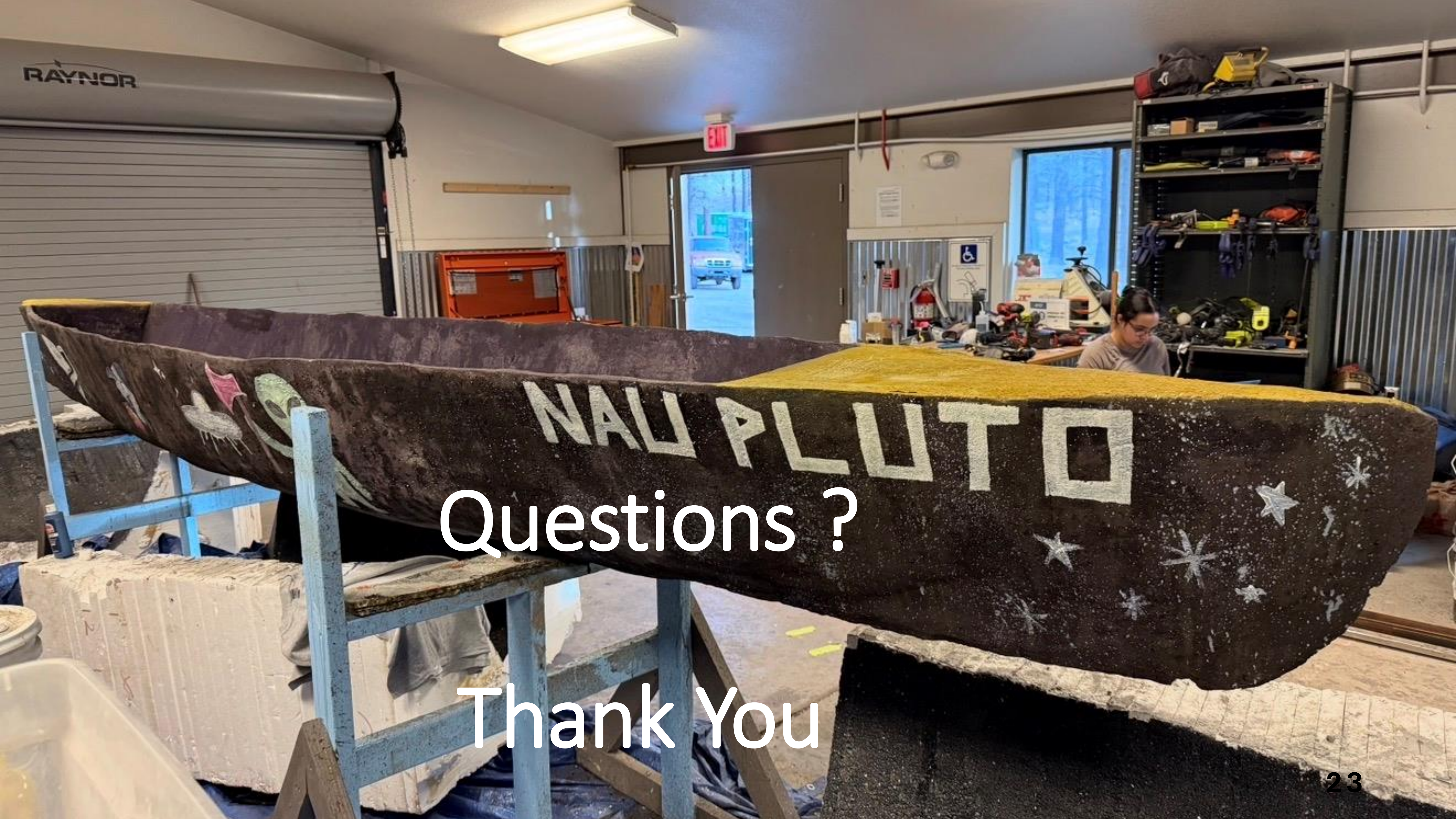
Figures 4-15. 4-16, 4-17: Final Canoe Placement–Alondra

Figures 4-18, 4-19, 4-20: Concrete Canoe Curing Process- Amit

Concrete Finishing

Project Cost

Project Cost Comparison				
Actual Project Cost			Proposed Project Budget	
Labor (DL) Subtotal	$45,701.40		Labor (DL) Subtotal	$47,790.00
Canoe Fabrication	$5,336.55		Proposed Direct Labor Total	$47,790.00
Mold Fabrication	$6,221.55			
Expenses (E) Subtotal	$4,111.36		Expenses (E) Subtotal	$7,700.00
Canoe Fabrication	$2,389.86		Proposed Project Expenses	$7,700.00
Mold Fabrication	$1,721.50			
Actual Project Cost	$49,812.76		Proposed Project Cost	$55,490.00



Questions ?

Thank You