2016 NAU ASCE CONCRETE CANOE

POLARIS

NORTHERN ARIZONA UNIVERSITY

CHELSIE KEKAULA
COLTON MCCONNELL
BRENT LIPAR
EVAN KAICHI
EMILY MELKESIAN

Project Description

- Design and construct a concrete canoe
  - Maximum length/width: 22 feet/3 feet
  - Minimum reinforcement percent open area: 40%
  - No stain or paint
- Participate in ASCE Pacific Southwest Conference (PSWC)
  - Judged on technical paper, oral presentation, final product, paddling races
- Galaxy theme

Figure 1: 2016 Concrete Canoe

Hull Design

- Hull Design
  - Maximum Length: 21 ft
  - Maximum Width: 27 in (2 ft-3 in)
  - Maximum Depth: 14 in (1 ft-2 in)
  - Uniform Thickness: 0.5 in

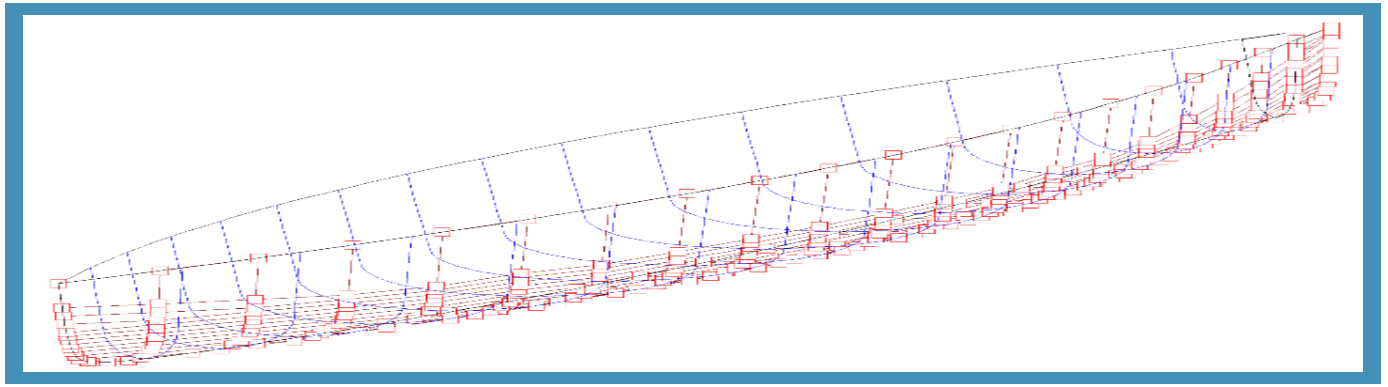


Figure 2: Prolines Software Model

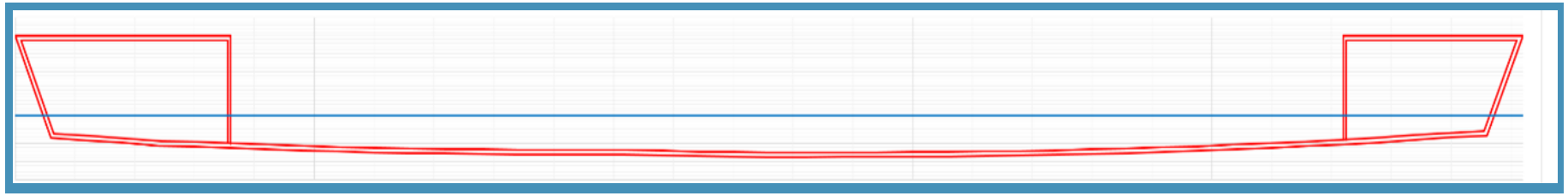


Figure 3: Longitudinal Cross Section

Hull Analysis

Improvements:

- Linear relationship to cubic function

Calculated Waterlines:

- Fully Submersed: 0.2 in
- 4-Person: 6.9 in
- 2-Men: 8.5 in
- 2-Women: 9 in

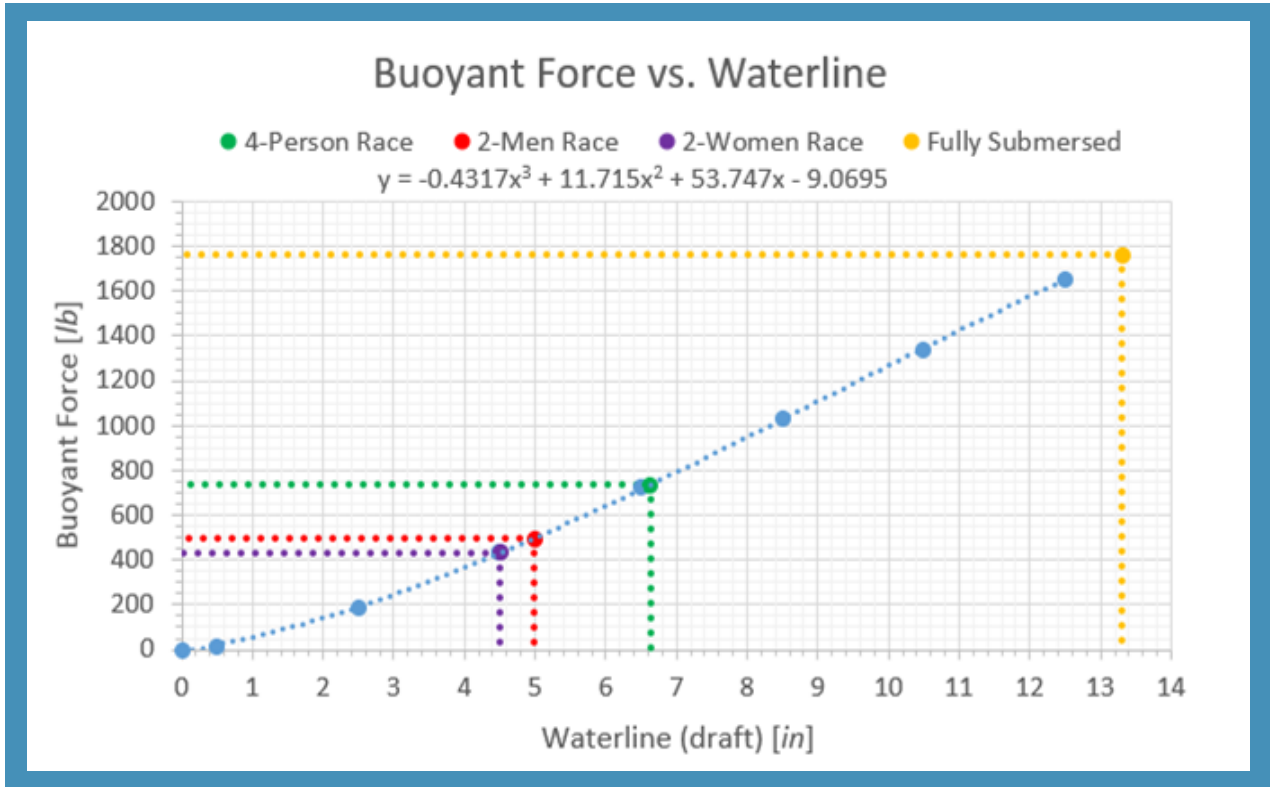


Figure 4: Buoyant Force vs. Waterline Comparison

Structural Analysis

- Structural Analysis
  - Hull Capacity vs Demand:
    - 1”x1”x.5” Panels: 1715.9 psi (425.24 psi)
    - WT-Shape Ribs: 5290.6 psi (425.24 psi)
    - Transverse Cross-Section:
      - Tension Face: 917.5 psi (145.7 psi)
      - Compression Face: 1319.5 psi (151.7 psi)

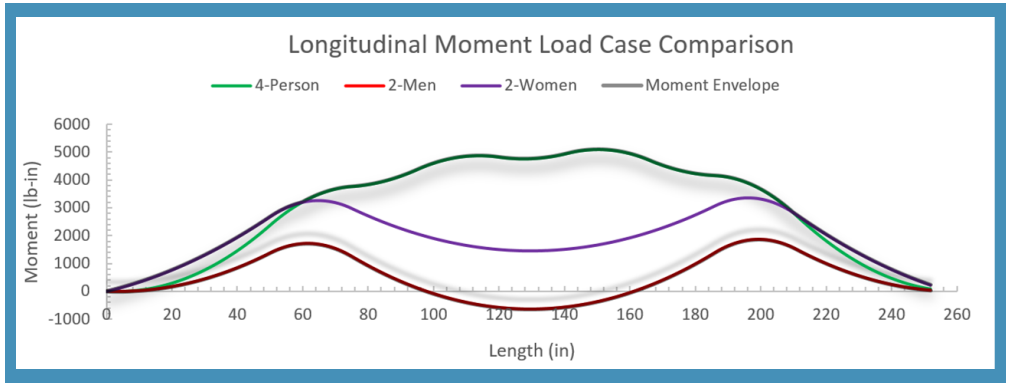


Figure 5: Longitudinal Moment Comparison

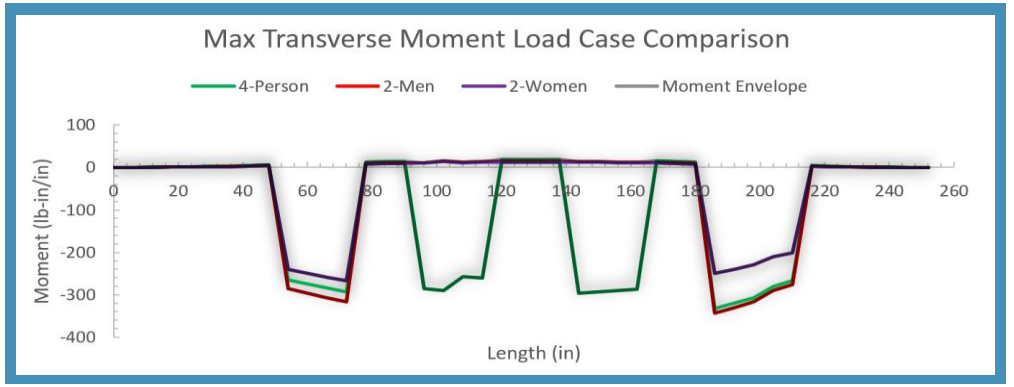


Figure 6: Transverse Moment Comparison

POLARIS

Concrete Mix Design

Concrete Constituents (% volume)

- EkkoMaxx Fly Ash: 21.2%
- Poraver (0.5-1mm): 36.0%
- 3M Glass Bubbles (K20 & S32): 23.7%
- BASF Black Liquid Pigment: 2.9%
- MB AE 90 Air Entrainer: 0.1%
- Water: 10.5%
- Additives: 5.6%
- BASF Master Fibers

Table 1: Structural Mix Properties	
Dry Unit Weight	59 pcf (<62.4 pcf)
28-day Compressive Strength	1950 psi
28-day Tensile Strength	190 psi
28-day Flexural Strength	1230 psi

Figure 7: Compression Test

Figure 8: Tensile Test

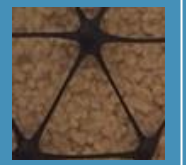
Figure 9: Flexural Test

POLARIS

Reinforcement

- Selected primary reinforcement from five different materials
  - Strength and elongation
  - SpiderLath Fiberglass Mesh
  - Tensile Strength: 756 lb.
  - Elongation: 0.25 in
  - Percent Open Area: 62.6%

Table 2: Reinforcement Alternatives

Material	SpiderLath Fiberglass Mesh [6]	Dryvit Reinforcing Mesh [7]	TriAx Geogrid [8]	Parex Glass Fiber Reinforcing Mesh [9]	Glasgrid Pavement Reinforcing System [10]
					
Strength (lb)	756	102	72	135	181
Elongation (in)	0.25	.07	0.62	.08	.04

Reinforcement Overlap

- Created composite samples of reinforcement and concrete
- Represented placement of reinforcement in canoe
- Tested overlap lengths of 2 in., 4 in., and 6 in.
- All overlap lengths worked
  - Chose 4 in. to be conservative

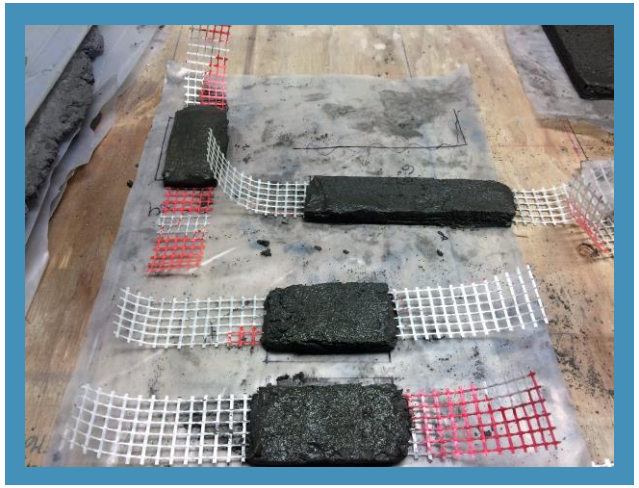


Figure 10: Overlap Samples

Figure 11: Overlap Test

Figure 12: Reinforcement Placement

Post-Tensioning

- System composed of six 1/16” galvanized steel cables placed symmetrically about the centroid
- Cables tensioned to 95 lbs., resulting in 57 lbs. of tension after losses
  - Total axial compression: 342 lbs.
  - Aids in reducing large cracks

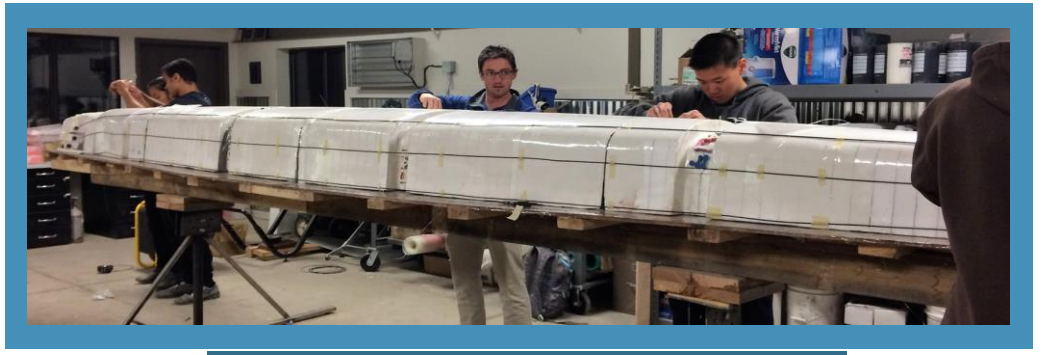


Figure 13: Post Tensioning System

Figure 14: Anchorage System

Figure 15: Post Tensioning Canoe

Canoe Pour and Curing

Figure 16: Spray 1/8" Concrete onto Mold

Figure 17: Apply Reinforcement over Ribs & Center

Figure 18: Apply Post-Tensioning

Figure 19: Apply Reinforcement

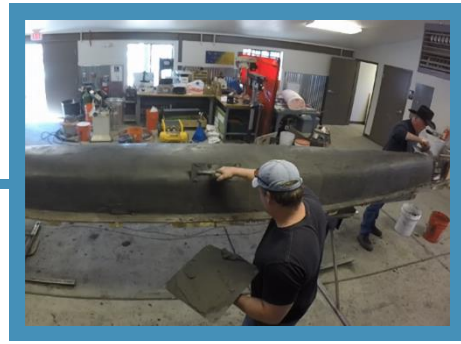


Figure 20: Trowel Final Layer of Concrete

Figure 21: Construct Curing Structure

Figure 22: Moisture Cure for 21-days

Finishing

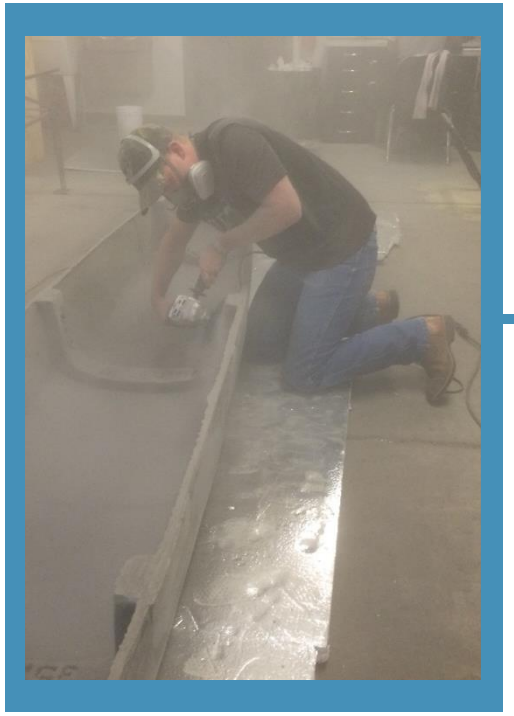


Figure 23: Dry Sand Canoe

Figure 24: Wet Sand Canoe

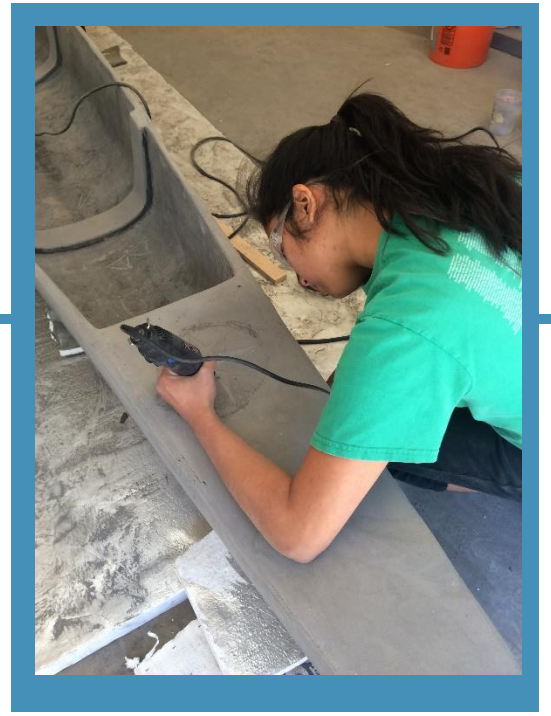


Figure 25: Carve and Etch Concrete

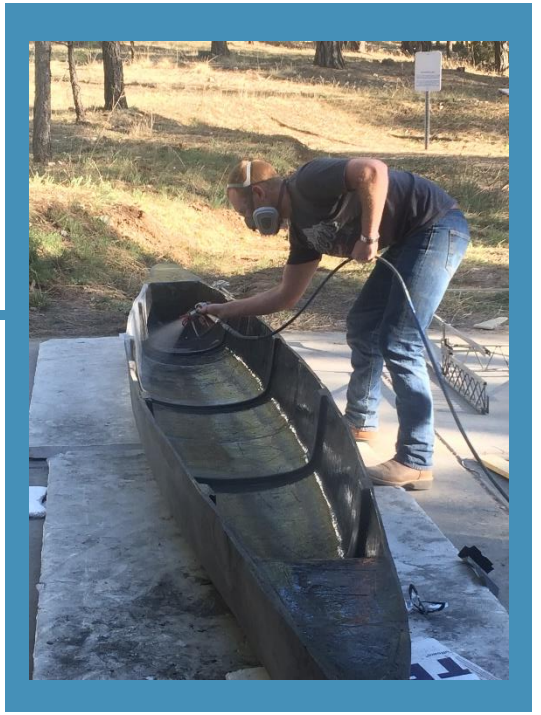


Figure 26: Seal Canoe

Final Product

Figure 27: Completed Ribs

Figure 28: Stern Design

Figure 29: 3D Element

Figure 30: Bow Design

Conference Results

- 6th place overall finish
- 3rd place for design paper
- 4th place for final product
- 13th place for racing
- 15th place for oral presentation

Figure 31: Canoe at Conference

Figure 32: Team Photo

Figure 33: Conference Display

Figure 34: Canoe Cutaway Section

Schedule

Table 3: Scheduled versus Actual Completion Date

Task	Scheduled Completion Date	Actual Completion Date
1.0 Project Management		
1.1 Safety Training	9/11/2015	9/11/2015
1.2 ASCE Competiton Rule Review	10/2/2015	10/2/2015
1.3 Budgeting, Fundraising and Scheduling	Ongoing	Ongoing
2.0 Testing and Analysis		
2.1 Reinforcement Selection	12/11/2015	12/11/2015
2.2 Concrete Mix Design Selection	1/15/2016	2/1/2016
2.3 Concrete-Reinforcement Composite Testing	1/31/2016	2/27/2016
2.4 Structural Verification	1/29/2016	2/6/2016
3.0 Construction		
3.1 Renovate canoe mold, coffin	1/18/2016	1/18/2016
3.2 Pour Day Prep	2/10/2016	2/11/2016
3.3 Pour Day	2/12/2016	2/12/2016
3.4 Canoe Sanding/ Finishing	3/19/2016	3/28/2016
4.0 ASCE Pacific Southwest Conference		
4.1 Internal Design Report Due	2/15/2016	2/23/2016
4.2 Final Design Report Due	3/2/2016	3/2/2016
5.0 CENE 486: Capstone Deliverables		
5.1 50% Design Report	3/10/2016	3/10/2016
5.2 Final Deliverables	5/12/2016	5/12/2016

Key

Completed On-Time
Completed Late

Cost

Table 4: Actual Cost of Engineering Services

1.0 Personnel

Classification	Billing Rate	Quantity	Unit	Cost
SENG	$95 /hr	295	hr	$28,025
ENG	$64 /hr	260	hr	$16,640
LAB	$35 /hr	225	hr	$7,875
INT	$13 /hr	80	hr	$1,040
AA	$33 /hr	235	hr	$7,755
		Total Cost		$61,335

2.0 Travel

Item	Billing Rate	Quantity	Unit	Cost
Conference Registration	$150 /person	7	people	$1,050
Lodging/ Food	$250 /person	7	people	$1,750
Mileage	$0.56 /mile	940	miles	$526
		Total Cost		$3,326

3.0 Expenditures

Item	Price	Quantity	Cost
Materials	$4,850	Lump Sum	$4,850
Equipment	$1,500	Lump Sum	$1,500
		Total Cost	$6,350

Total Project Cost	$71,011
Total Proposed Cost	$76,943

Saved almost $6,000

- ~ $4,000 in Personnel
- ~ $1,000 in Travel
- ~ $1,000 in Expenditures

Impacts

Institutional Impacts

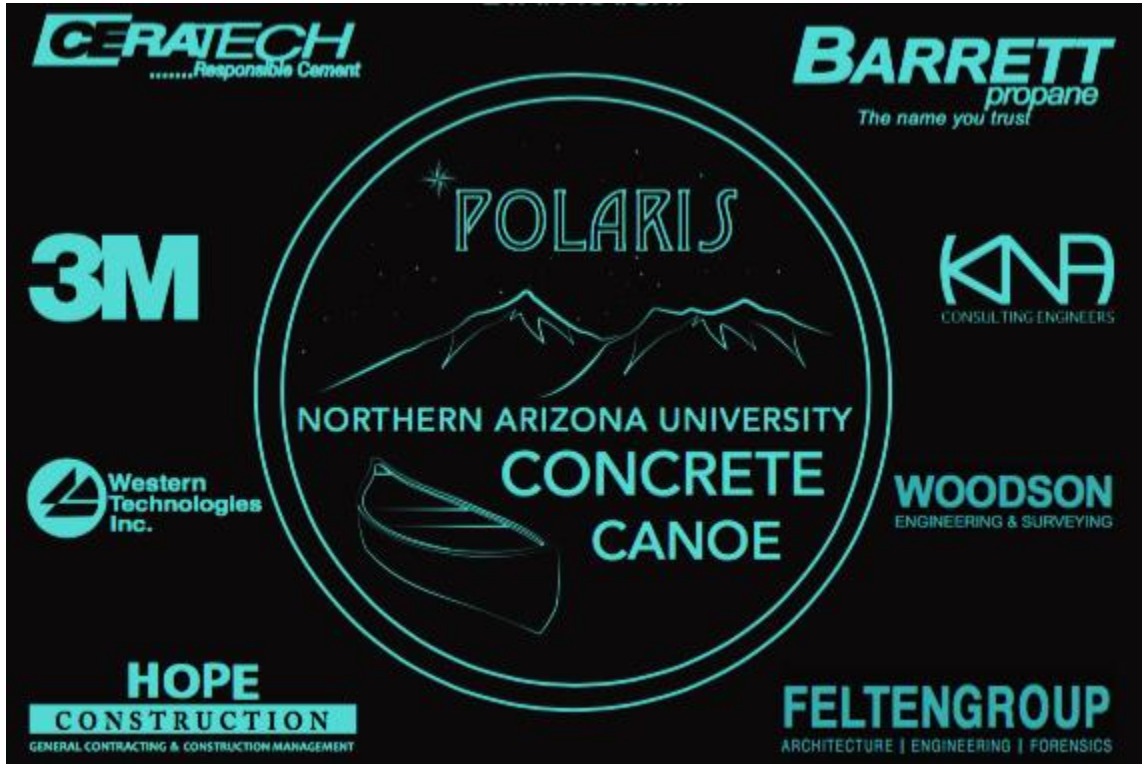
- Provides civil engineering students hands-on practical experience and improves leadership skills
- Knowledge and lessons learned for future NAU teams
- NAU Civil Engineering Department

Broader Impacts

- Use of CeraTech's EkkoMaxx cement – 100% sustainable material
- Increases awareness among students, educators, and professionals of concrete technology and innovation

Acknowledgements

Mark Lamer
Thomas Nelson
Gary Slim
Robin Tuchscher
Chris Hazel
Gina Boschetto
Dillion Corrington
Stephanie Crocker
Hudson & Ann Kekaula
Kaipo Kekaula
Jimmie McConnell
Wendy McConnell



Melkesian Family
Kaichi Family
Tommy Perkins
Jeremy DeGeyter
Cynthia Alvarez
Henry and Glenna Wong
Hank and Merle Miyamoto
Zach Crimmins
Paige Reilly
Ian Connair
Brando Gutierrez

References

[1] ASTM (2004). “Compressive Strength of Cylindrical Concrete Specimens”, C 39/C 39M-01, West Conshohocken, PA.

[2] ASTM (2011). “Standard Performance Specification for Hydraulic Cement.” C1157/C1157M-11, West Conshohocken, PA.

[3] ASTM (2010). “Standard Specification for Fiber-Reinforced Concrete.” C1116/C1116M-10a, West Conshohocken, PA.

[4] ASTM (2016). “Standard Test Method for Flexural Strength of Concrete (Using Simple Beam with Third-Point Loading)”, C78 / C78M-15b, West Conshohocken, PA.

[5] CeraTech (2012). CeraTech EkkoMAXX™: General Product Information and Specifications. URL: http://www.ceratechinc.com/Content/PDFs/ekkomaxx%20Green%20Concrete%20MSDS.pdf> (Sep. 9, 2015). Web.

[6] SpiderLath URL:http://compositesandarchitecture.com/?p=3212

[7] Photo taken by 2014-2015 Concrete Canoe Team

[8] Photo taken by 2014-2015 Concrete Canoe Team

[9] Photo taken by 2014-2015 Concrete Canoe Team

[10] Photo taken by 2014-2015 Concrete Canoe Team

THANK YOU

Presenting:

POLARIS