2014-2015 Concrete Canoe

Dreadnoughtus

HIGH ALTITUDE ENGINEERING:

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[1]

Project Description

- Participate in ASCE Pacific Southwest Region Conference (PSWC)
  - Design, construct, and race a concrete canoe
  - Judged on design paper, oral presentation, final product, and five races
  - Selected theme of dinosaurs
- Last year's Concrete Canoe Team "Spirit" finished 13th out of 18 at PSWC 2014 held in San Diego, California

Project Description

- Limitations of money, personnel, and time
- Maximum dimensions of 22’ length and 36” width
- No hollow cavities or air bladders allowed
- Minimum reinforcement percent open area (POA) of 40%
- No 3D analysis allowed for conference

[2]

Project Management

- Jeremy DeGeyter – Project Manager
- Matt Snyder – Structural Analysis Lead
- Kristin Van Sciver – Concrete Lead
- Cynthia Alvarez – Reinforcement Lead
- Ramon Aguilar – Quality Control and Safety Officer

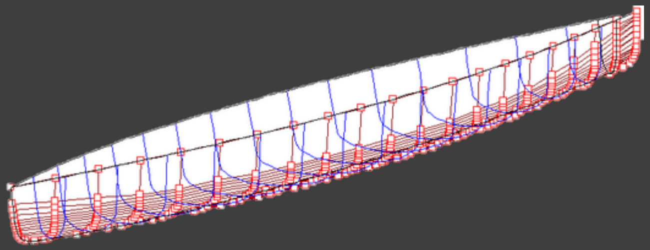
Hull Design

Figure 1: Basic Concrete Canoe Terminology

Hull Design

- Shallow Arch Bottom
- 5-in rocker
- 21-ft long, 27-in wide
- Analyzed through Prolines Software
  - Optimum Speed 5.4 knots (6.2mph)

[4] Figure 2: What is a “Rocker”



[5] Figure 3: Prolines Hull Model

Structural Analysis

- Compressive stress of 340-psi
- Tensile stress of 120-psi
- Max moment of 4-lbin/in
  - Four person loading analysis
  - Transverse direction
- Capacity of 30-lbin/in
  - Based on one layer reinforcement
  - Does not include ribs
- 3-D analysis
  - Verified 2-D Results

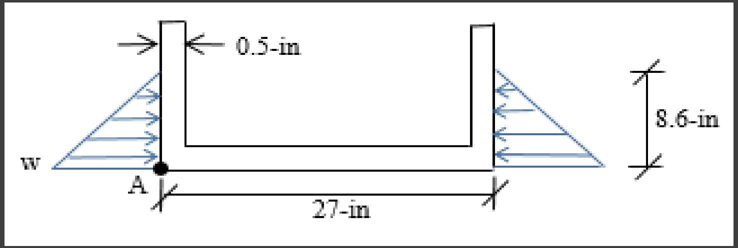


Figure 4: Transverse Free-Body Diagram

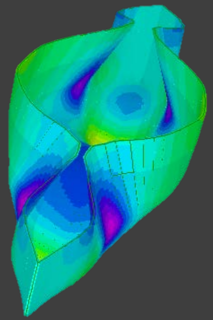


Figure 5: LISA FEA Deflected Shape

Post-Tensioning

- Provides 690-lbs of axial compression to increase flexural cracking load
- Six-7x7 galvanized steel tendons were placed symmetrically about the centroid
- Designed for 115-lbs of tension after calculated losses

Figure 7: Anchorage System

Figure 8: Post-Tensioning Net

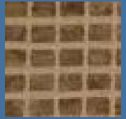
Figure 6: Tensioning System

Pictures taken by Canoe Team

Reinforcement

- Tested four different materials
  - Strength and Elongation
- Selected Parex Glass Fiber Reinforcing Mesh
- Development length tests
  - 6-inch, 4-inch, and 2-inch

Table 1: Reinforcement Alternatives

Material	TriAx Geogrid (TX140) 	Parex Glass Fiber Reinforcing Mesh 	Glasgrid Pavement Reinforcement System 	Dryvit Reinforcing Mesh 
Strength (lb-ft/in)	72	135	181	102
Elongation (in)	0.62	0.08	0.04	0.07

Pictures taken by Cynthia Alvarez

Concrete Mix

- Constituent selection
  - Five lightweight aggregates considered
  - Poraver® P051 and 3M S32 Glass selected
  - EkkoMAXX selected for cementitious binder
- EkkoMAXX
  - Sustainable alternative to Portland cement
  - 100% fly ash based
  - Resistant to chemical attack
  - Reduced shrinkage

Table 2: Aggregate Properties

Material	Poraver®  *[6]*	S32 Glass Bubbles  *[7]*
Size (mm)	0.50 to 1.00	0.105
Specific Gravity	0.44	0.32
Absorption (by Mass)	20%	1%
Isostatic Crush Strength (psi)	290	2000
Volume in Mix	36%	22%

Concrete Mix

- Mix design alternatives
  - Batched 25 different mixes varying proportions of each constituent
  - Tested each for compressive strength and slump
  - After final mix selected, tested for tensile, flexural, shrinkage, and air content

Figure 9: Compressive Test

Figure 10: Tensile Test

Figure 11: Flexural Test

Figure 12: Shrinkage Test

Pictures taken by Canoe Team

Concrete Mix

- Final mix proportions by volume :
  - EkkoMAXX [24%]
  - Poraver (0.5mm-1mm) [36%]
  - 3M Glass Bubbles (S32) [22%]
  - MasterFiber M 100 [<1%]
  - Air - MB-AE 90 AEA [3%]
  - Water [15%]

Table 3: Final Mix Properties

Final Concrete Structural Mix:	
Wet/Dry Unit Weight	65.5/57.4 pcf
28 Day Compressive Strength	2150 psi
28 Day Tensile Strength	225 psi
28 Day Flexural Strength	725 psi
Air Content	2.80%
Shrinkage	0.03%
Slump Flow	7" ± 1"

Mold Construction

Figure 13: Cross-Section Cutout

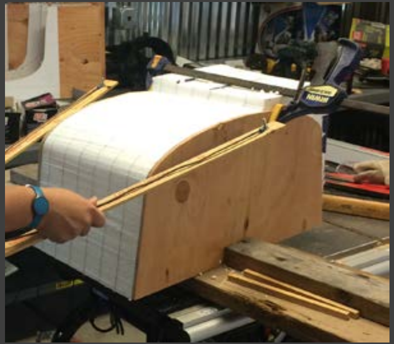


Figure 14: Hot-Wire Cutting Foam

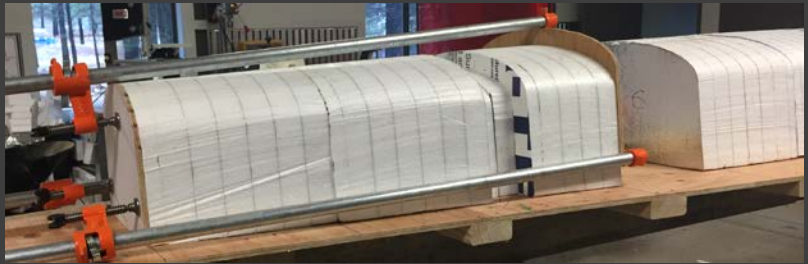


Figure 15: Gluing Cross-Sections

Figure 16: Finished Foam Mold

Pictures taken by Canoe Team

Pour Day

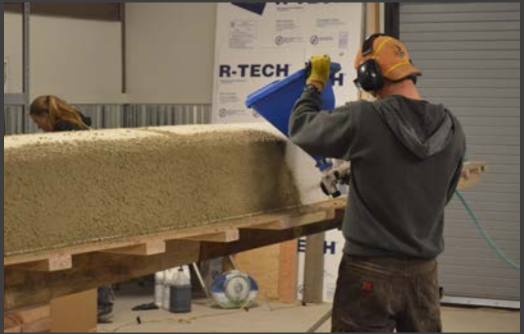


Figure 17: Spraying Concrete Layers

Figure 18: Troweling Concrete Layers


Figure 19: Placing Post-Tensioning


Figure 20: Placing Reinforcement Mesh

Pictures taken by Charlie Wilson

Curing and Finishing

Figure 21: Curing Frame

Figure 22: Curing Tent


Figure 23: Grinding/Polishing


Figure 24: Staining

Final Design

Figure 25: Silicone Rib Mold

Figure 26: Rib in Canoe

Figure 27: 3D Elements in Bulkhead

Figure 28: Arizona Flag Stain

Figure 29: Flagstaff Night Sky Stain

Pictures taken by Canoe Team

Conference Results

- 3rd place overall in Canoe, best NAU finish in 15 years!
- 1st in Final Product
- 3rd in Oral Presentation
- 3rd in Men's Sprint

Figure 30: Collage of Final Product Display

Pictures taken by Charlie Wilson & Canoe Team

Direct Impacts

- Implemented sustainable/reused surplus materials
- Fabricated reusable mold
- Exposure to fumes, particles, and tools
- Renewed interest in Canoe Competition

Figure 31: Group Picture After Race Day

Figure 32: Paddling Practice

Pictures taken by Charlie Wilson

Cost of Design and Implementation

Table 4: Cost of Project

1.0 Personnel	Classification	Hours	Rate, $/hr	Cost
	SENG	325	100	$32,500
	ENG	1006	80	$80,480
	LAB	476	62	$29,512
	INT	1146	52	$59,592
	Total Personnel	**2953**		**$202,084**
2.0 Travel	Lodging/Food	per person	250	$1,250
	Registration	per person	120	$600
	Van Rental	per day	56	$280
	Total Travel			**$2,130**
3.0 Direct Costs	Materials			$6,455
	Total Direct Costs			**$6,455**
4.0 Total				**$210,669**

Presenting…

Dreadnoughtus

Figure 33: Final Dreadnoughtus Setup

Picture taken by Canoe Team

Acknowledgements

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References

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- [2] ASCE, and NCCC. 2015 ASCE National Concrete Canoe Competition Rules & Regulations.
- [3] Figure 1 modified from http://www.realmagick.com/canoe-the-parts-of-a-canoe/ & http://www.oldtowncanoe.com/canoes/recreation/stillwater_14/
- [4] Figure 2 provided from https://reflectionsoutdoors.wordpress.com/category/general-outdoors-2/page/12/
- [5] Figure 3 provided by Matt Snyder
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Questions?