

Design of a Concrete Canoe for the ASCE Competition with Washout Improvement and Hydraulic Testing

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Proposal Summary

The concrete canoe project is put together as a response to the American Society of Civil Engineers (ASCE) issuance of a Request for Proposal (RFP) for their yearly competition. This year, the RFP expanded beyond its usual scope due to the influence of COVID-19, allowing more variability in the approach. While the requirements to design a hull, a mix design, and perform a structural analysis remained the same, the construction of the prototype was left as optional for each school. In place of the construction requirement, enhanced focus areas are implemented, letting the project have a broader scope with more creative capabilities. Initially the project aimed for the creation of a full prototype canoe, but due to restrictions on in-person meetings and time constraints present for this process, prototype construction was soon abandoned to focus on other goals. Instead, the focus areas chosen for this project are an environmental concrete washout procedure and hydraulic testing of scale models for several canoe types. Our project features design for a light-weight concrete, environmental management and improvement, higher level structural analysis, in depth project scheduling, and hydraulic testing and analysis, the results of which can be used in future years for ASCE's competition.



Figure 1. ASCE Concrete Canoe Logo

Potential Alternatives

Canoe Building

- Full Build: Create a full 19'6" prototype, provides experience in construction as well as the capability to test a full scale model for effectiveness when rowed
- Partial Build: Build half of a 19'6" prototype, provides experience in construction
- No Build: Develop the cross sections and hull in AutoCAD but do not construct mold or prototype



Figure 2. AutoCAD Generated Canoe Hull

Hull Design Alternatives (Width)

- Narrow: Minimal drag force, emphasizes speed at the cost of maneuverability
- Medium: Attempts to balance speed and maneuverability for racing
- Wide: Stable and more maneuverable, but with more weight and drag

Mold Type (assumes canoe is built)

- Male or Female: A mold in which a minimal slump concrete is placed outside/inside by had to construct a canoe, mold is cross sections cut by CNC router
- Male and Female: Makes use of two molds and a high flow concrete to be poured between the layers, molds are cross sections cut by CNC router
- 3D printed mold: High expense, but gives a smooth finish and low construction effort (would be either male or female)



Figure 3. Female Mold in Construction With Cross Section Method

Concrete Washout (Environmental Improvement)

- Do nothing: Continue using detention to cure leftover concrete and evaporate water
- Filtration: Create a filtration system that will remove aggregate and potentially other solids from washout water
- Filtration and pH treatment: Create a filtration system as well as a treatment plan for pH and dissolved solids left in the washout water



Figure 4. Current Washout Detention in USU Concrete Lab

Alternative Criteria and Decision Matrices

Competition Canoe Building Alternatives				
Decision Factor (0-3 Scale)	Importance	Full Canoe Build	Partial Build	No Build - CAD
Cost	20%	1	2	3
Competition Testing	20%	3	0	2
Enhanced Focus Area	20%	3	0	0
Labor	10%	1	2	3
Transportation	15%	1	1.5	3
Time	15%	1	2	2
Total Score:	3	1.8	1.125	2.05

Concrete Washout Alternatives				
Decision Factor (0-3 Scale)	Importance	No Washout	Filtration Washout	Filtration and pH
Environmental Risk	50%	0	2	3
Cost	25%	3	2	1
Effectiveness	25%	0	2	3
Total Score:	3	0.75	2	2.5

As a project is in its developmental phase, several alternatives within the design need to be discussed and analyzed in order to achieve the best outcome. The alternatives chosen to analyze were different canoe build completion stages, hull design, mold type, and concrete washout. The team came up with three alternatives for each aspect of the project and narrowed them to a final recommended alternative based upon Pugh Matrices. A Pugh Matrix breaks a category down into multiple different aspects of importance concerning the topic, in which all alternatives considered will receive a score.

Hull Design Alternatives				
Decision Factor (0-3 Scale)	Importance	Narrow	Wide	Medium
Strength	35%	1	3	2
Stability	20%	0	3	2
Speed	20%	3	0	2
Cost	15%	3	1	2
Weight	10%	3	0	1.5
Total Score:	3	1.7	1.8	1.95

Mold Type Alternatives				
Decision Factor (0-3 Scale)	Importance	Male or Female	Male and Female	3D Print a Mold
Effectiveness	50%	2	3	2
Cost	20%	3	2	0
Appearance	20%	2	3	3
Labor	10%	1	0	3
Total Score:	3	2.1	2.5	1.9

Selected Alternative

- The no build alternative has the highest score in the Pugh Matrix; however, in the interest of future years gaining experience construction of a full canoe was still attempted
- The intermediate hull has the highest score in the Pugh Matrix, and the assumptions used there were mostly confirmed in hydraulic testing
- The combination male and female mold received the highest score, but due to budget constraints it was decided to only make a female mold
- Filtration and pH balance received the highest score, but due to technical limitations the best solution managed was dilution, which improved pH slightly and helped meet the dissolved solid limit for Logan, Utah

Finalized Designs

Mix Design

- Cementitious Material: Portland Cement and Jim Bridger fly ash
- Aggregates: expanded shale and polystyrene beads
- Fibers: monofilament and fibrillated
- Admixtures: MasterAir and MasterGlenium



Figure 5. Cross Section View of Concrete Test Specimen

Environmental

- Layer 1—13 mm openings for coarse aggregate
- Layer 2—1.3 mm openings for fine aggregate
- Layer 3—Fine strainer for sands
- Layer 4—Stormwater protection for silts and clays
- Dilute after filtration at a 1:1 ratio



Figure 7. CAD Design File of Filter System and Constructed Prototype

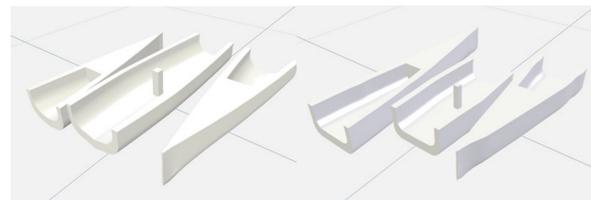


Figure 6. STL Files for Hydraulic Specimens (three pieces to fit on 3D printer)

Hulls Hydraulically Tested

- Narrow Shallow V
- Medium Shallow V
- Wide Shallow V
- Narrow Square
- Narrow Round

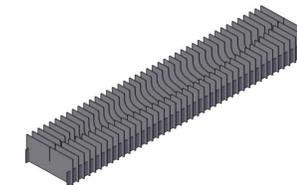


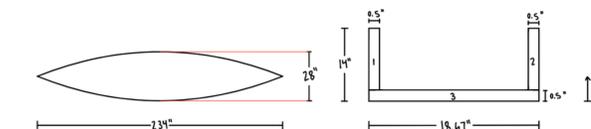
Figure 7. CAD Design File of Female Mold

Construction*

- Female Mold
- Cross sections cut with CNC Router every 6" along hull
- Lay 3/16" plastic secured with caulk
- Cellophane used for smooth finish and covering seams
- Concrete placed by hand

*cancelled due to COVID-19

Calculation and Testing Results



Structural Analysis

Simple Beam Dimensions:

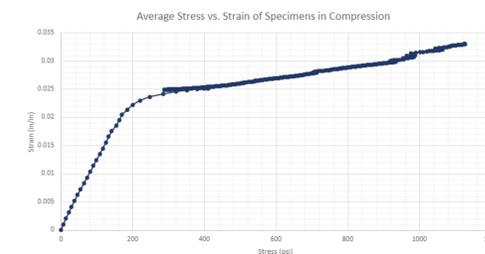
- Channel is 18.67" wide by 14" deep by 234" long
- Thickness is evenly 0.5"

Maximum Expected Shear: 68.74 lbs. at 4.875' and 14.625' along length

Maximum Expected Moment: 223.4 lb*ft at 9.75' along length

Cracking Moment: 16.83 lb*ft

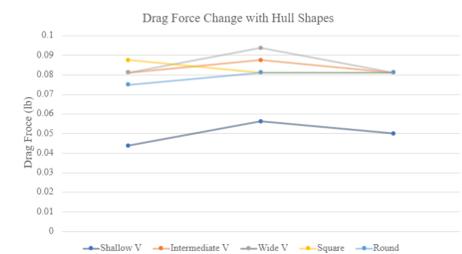
Ultimate Bending Moment: 1424.5 lb*ft



Material testing confirms that mix design can withstand expected shear from structural analysis

Hydraulic Testing

- Narrow Shallow V has least drag
- Wide Shallow V has the highest average drag



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