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Canoebis

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Utah State University

Canoebis

by

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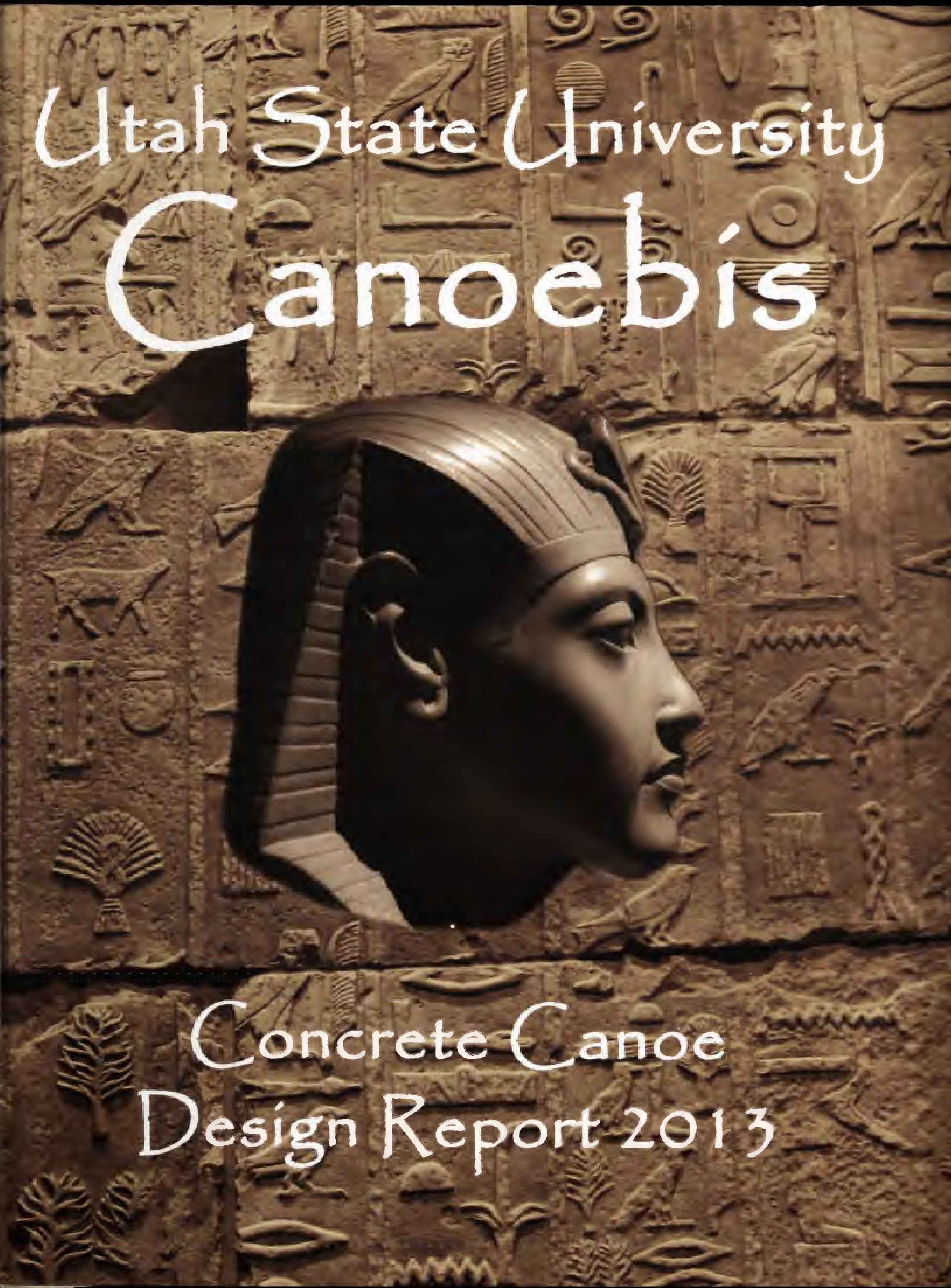

Utah State University
Canoebis

Concrete Canoe Design Report 2013

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Executive Summary

Egyptian mythology is full of legend and mystery. Ra, the Chief God of Ancient Egypt, used a mysterious canoe, named Meseket, to cross the underworld at night (Ions, 1983). Our fabricated legend begins with Aken, Ra's loyal ferryman. When Aken accidentally broke the canoe Meseket, he was left without a vessel to ferry Ra. Without proper materials to fashion another wooden boat, he asked Anubis, the god of embalming for assistance. Together they built a new canoe out of concrete using raw materials from the Egyptian landscape. The 2013 Utah State University Concrete Canoe Team has endeavored to recreate this concrete canoe of legend.

The Agricultural College of Utah was established in Logan, UT in 1888. As the programs offered by the school grew in diversity, the name was changed to Utah State University (USU) in 1957. USU is Utah's land grant institution and is known throughout the world for its groundbreaking research in agriculture, engineering, and science. The university enrolls over 28,000 students, offers 311 degrees, and has the second longest standing undergraduate research program in the country.

The Concrete Canoe Team has a longstanding tradition at USU, initially competing at the regional level in the 1980's. USU is a member of the Rocky Mountain Student Conference. After placing first in the regional competition in 2011 with *Tribute*, the team made their debut appearance at the National Concrete Canoe Competition (NCCC). After placing 16th at the NCCC, the USU team returned to the national competition with *Old Ephraim* in 2012. *Old Ephraim* was the second lightest canoe at the NCCC in 2012 at 108 lbs., and the team placed 18th.

This year, the team is proud to bring *Canoebis* to the Rocky Mountain Student Conference. The result of hours of preparation by the 2013 team, *Canoebis* is the best concrete canoe ever produced at Utah State.

The team focused on developing construction techniques that were labor and time efficient while reducing costs and the project's ecological footprint. The concrete mix used to build *Canoebis* was developed targeting a high strength/weight ratio. This allowed the team to build another extremely lightweight canoe, weighing only 127 lbs. (see canoe specifications in Table 2).

In addition to the structural mix, two separate finishing mixes were applied to *Canoebis* to fill voids and remove imperfections (see concrete properties in table 1).

Table 1: *Canoebis'* concrete properties

Concrete Mix:	Structural Mix (28-day)	Finishing Mix A (14-day)	Finishing Mix B (14-day)
Unit Weight (Wet)	53.2 pcf	74.8 pcf	74.4 pcf
Unit Weight (Dry)	46.7 pcf	65.6 pcf	67.2 pcf
Tensile Strength	270 psi	480 psi	470 psi
Compressive Strength	1,870 psi	2090 psi	2020 psi
Composite Flexural Strength	4,610 psi	N/A	N/A

Table 2: *Canoebis'* specifications

Design Specifications	
Weight	124 lbs
Length	18' 6"
Max. Width	2' 10"
Hull Thickness	0.5"
Concrete Color	Light Brown
Stain Color	Dark Brown and Blue
Reinforcement and Composite Details	
Passive Reinforcement	Fiberglass Mesh
Active Reinforcement	Pre-stressed 1/16" steel cable

In addition to the mix design, the team strove to maximize the stability and maneuverability of *Canoebis*. This is evident in the optimized hull shape. Based on the Wenonah Mixed Cruiser, the world's most popular racing canoe, the design allows a canoe to be extremely stable yet maneuverable. This will enable the team to gain the legendary status *Canoebis* deserves.

Project Management

In late April 2012, while preparing for the 2012 NCCC, a team captain and two co-captains were elected to manage the *Canoebis* team, and the canoe theme was chosen. Completing this process early allowed the captains and returning team members to attend the 2012 NCCC with the 2013 canoe in mind.

In August, the captains met to outline the project schedule and establish the critical path. A duration window was planned for each project task and summary objective. Milestones were established to ensure small adjustments to individual task deadlines did not effect the final completion date. The critical path was defined as the activities and deadlines that had the largest influence on the project completion date. The schedule was acutely adjusted as needed throughout the project, but over 80% of all tasks were completed by the original deadlines (see Table 3 for key milestones and the Project Schedule on pg. 9 for all tasks and the critical path).

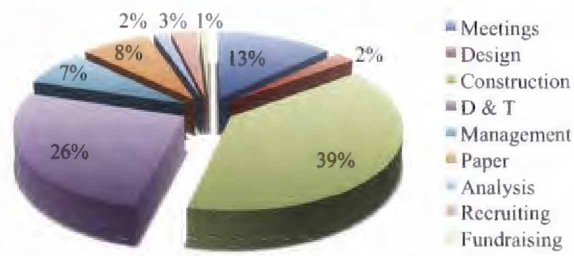
Table 3: Key milestones

Milestone	Delay	Reason
Mold Completion	None	Proper scheduling
Cast Practice Canoe	None	Proper scheduling
Practice Canoe Float Test	1 week	Additional finishing time required
Final Mix Selection	5 days	Additional testing
Cast Final Canoe	None	Proper scheduling

The three captains were given separate responsibilities that covered all aspects of the competition: paddling/general management, design, and construction. The captains then organized three sub-teams (see organization chart on pg. 2). All members were involved with key tasks (casting day, form construction, etc). This allowed the 26-member team (8 veterans, 18 new recruits) to remain focused on the entire project.

Clear and efficient team leadership and effective time management allowed the team to build the best canoe ever from USU. The team has dedicated over 2,600 person-hours to the project and a breakdown of hours is shown in Figure 1.

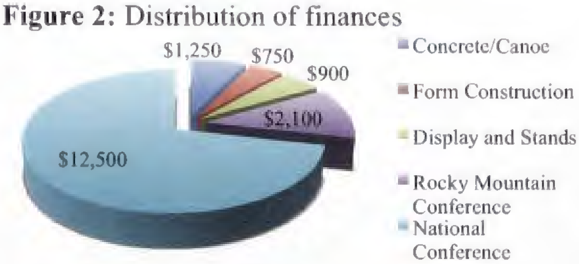
Figure 1: Distribution of team hours



Quality control was extremely important throughout the project, as it not only affects the final product, but the overall budget. The captains assigned individuals to peer-review calculations and measurements for the mix design, analysis, and mold construction. This attention to detail also provided a teaching opportunity for the experienced members to train new members of the team.

The budget for *Canoebis* was set at $17,500. The largest percentage of funds was allocated to travel and registration for the 2013 NCCC. Reusing materials and equipment for the mold construction and canoe finishing, as well as seeking donations for admixtures, aggregates, and cementious materials also lowered the overall project cost. A cost breakdown is shown in Figure 2.

Figure 2: Distribution of finances



Safety was a top priority during all aspects of the project. Proper personal protection equipment was provided to team members at all times, and instructional safety sessions were held before construction and paddling activities. Detailed preparation allowed *Canoebis* to be completed without serious injury or safety violations.

Organization Chart

Team Captain

Mitch Dabling

Paddling Lead/General Management

Paddling Team

Alex Souvall	Michael Budge
Anna Newman	Nikki Tatton
Jacob Crump	Shantell Ostler
Mark Stenquist	Silvia Smith
McKenna Lee	

Trained and practiced for sprint and endurance races

Co-Captain

Tyler Hansen

Construction Lead

Construction Team

Matt Gillespie	Alex Souvall
Forrest Kolle	Anna Newman
Tyson Alder	Jacob Crump
Nate Decker	Mark Stenquist
Robert Carpenter	McKenna Lee
Gilbert Nichols	Michael Budge
Johnny Hansen	Nikki Tatton
Mitch Dabling	Shantell Ostler
Allison Albert	Silvia Smith
Landon Kinney	Kaitlyn Anderson
Nate Fox	Parker McGarvery
Victor Torres	Nate Lowe
Ryan Warren	

Tested and developed concrete mix and constructed canoe

Co-Captain

Allison Albert

Design Lead

Design Team

Landon Kinney	Kaitlyn Anderson
Nate Fox	Parker McGarvery
Victor Torres	Nate Lowe
Ryan Warren	Anna Newman
Shantell Ostler	

Designed overall aesthetics of canoe, cross-section, display, and stands

Hull Design

Due to the fact that the slalom event was omitted from the 2012 competition, last years *Old Ephraim* canoe design intentionally sacrificed maneuverability in favor of a streamlined hull. With the slalom reinstated for the 2013 competition, *Canoebis* is designed to maintain the speed of *Old Ephraim* while adding increased maneuverability.

During early season paddling practice sessions, the team had access to a Wenonah Jensen V-1 Pro professional racing canoe. The canoe handled extremely well, and *Canoebis* is loosely based on the design of the Wenonah model, with a few modifications (see Design Drawing, pg. 10 for detailed canoe dimensions).

The V-1 Pro was designed to obtain high speeds while maintaining controllability (Wenonah, 2012). Wenonah's design only accommodates two paddlers; *Canoebis* features a deeper hull and increased length to account for the larger water displacement that occurs with four occupants during the co-ed sprint race. The bow protrudes higher out of the water than the stern to minimize water from the bow wave entering the canoe at racing speeds. A hard chine (steep angle of the bottom of the hull) near the bow and stern maintains stability, while a soft chine in the center of the canoe provides agility and decreases the wetted area. Design information for *Canoebis* can be found in Table 4.

Table 4: Comparison of canoe specifications

Specification	*Old Ephraim*	*Canoebis*
Length	18' 0"	18' 6"
Bow Depth	1' 2"	1' 6"
Stern Depth	1' 2"	1' 0.2"
Center Depth	1' 2"	1' 0.4"
Max. Width	2' 4"	2' 10"
Weight	108 lbs.	127 lbs.
Prismatic Coefficient	0.842	0.32
Length/Beam Ratio	7.7:1	6.5:1

Figure 3: Detail of gunwale and tension cables

The hull of *Canoebis* is ½-inch thick throughout to minimize weight. The gunwale (upper most line on either side of the hull) is thicker, measuring 1-inch thick by 1.5-inches deep, to reduce the maximum tensile forces. Two pre-tensioned steel cables run through the center of the gunwale to maintain compression in the concrete during racing conditions (see Fig. 3). This gunwale design directs tensional forces away from the centerline of the hull to prevent fracture.

The effect of a ship's width on top speed is related to the length. Generally, increased beam width (the maximum width of a vessel) results in greater stability. If complimented with a long hull length and narrow bow/stern, high top speeds can be maintained. The ideal length to beam ratio is from 5.6:1 to 6.6:1 (Stevens, 1889). *Canoebis*' length-to-beam ratio is 6.5:1, which produces a very stable, yet quick, design.

Structural Analysis

The chosen hull design was evaluated using two-dimensional structural analysis techniques to determine the maximum stresses that *Canoebis* would experience. Two analysis methods were used. The first was a simplified analysis that determined the loading scenario that generated the largest maximum moment (and in turn the largest stresses) on the canoe. The loading cases examined were: transportation, two women paddlers, two men paddlers, and four total paddlers for the co-ed sprint. Transportation of the canoe was determined to create negligible stress as the canoe is fully supported along its length. All loading cases included a factor of safety applied to the paddler's weights (200 lbs. for men, 150 lbs. for women) to account for dynamic loading while paddling. The critical loading case was determined to be two men in the canoe and generated a maximum moment of 423 lb-ft. (see Table 5).

Table 5: Loading cases investigated

Loading Case	Max. Moment
Two Men	423 lb-ft.
Two Women	317 lb-ft.
Two Men and Two Women (Co-Ed)	342 lb-ft.
Transportation	Negligible

Each simplified loading case was analyzed by applying point loads for each paddler on the top of a beam the same length as the canoe. A uniformly distributed load along the bottom length of the beam represented the buoyancy force of the water on the canoe.

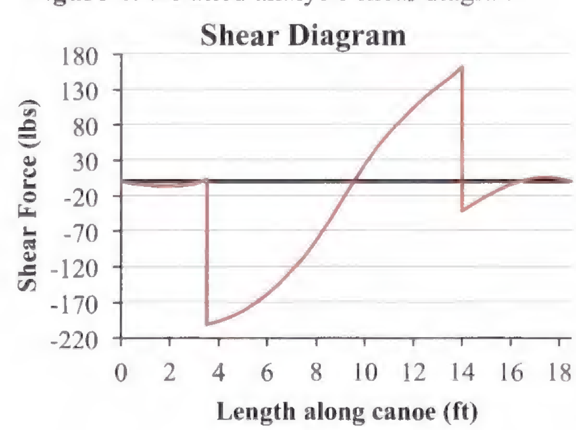
The maximum tensile and compressive stresses were then calculated using the critical two men loading condition. The analysis indicated the tensile requirements of the concrete would far exceed the required compressive strength. This was consistent with previous team's experience, and the construction team created a concrete mix that exceeded the critical tensile loading strength requirements.

After the critical loading case was determined, and estimates of the maximum stresses were obtained using a simple analysis, a more detailed analysis was completed. For this model, the buoyancy force of the water was applied as a distributed variable load. The area of water displaced by the canoe and two men load case was calculated every six inches along *Canoebis*' hull. These area values were then multiplied by the unit weight of water to create uniform distributed loads at 6-inch intervals along the bottom of the hull. Point loads at appropriate racing positions were applied as representations of the paddlers, and a uniform distributed load was placed to represent the weight of the canoe.

Shear force at each interval was then calculated (See Fig. 4). By analyzing the shear diagram, the locations of extreme moment were located where the shear force equaled zero. The location of maximum moment was found to be 9.54 ft. from the bow of *Canoebis*. The moment at this location was calculated and used to obtain the maximum stress on a cross-section at that location based on flexure.

The tension cables in the gunwale were treated as discrete forces at the neutral axis combined with a moment to account for their eccentricity. While the construction design for Canoebis specified a jacking tension of 100 lbs to be applied to each cable, the analysis only modeled each cable as a 50 lb load to account for short and long-term losses. The moment created by the detailed loading case was then applied to the cross-section, and the maximum tensile stress at the top of the gunwale and maximum compression stress at the bottom of the gunwale were calculated.

Figure 4: Detailed analysis shear diagram



The detailed analysis results, compared with the measured tensile and compressive strength of the concrete used for *Canoebis*, are presented in Table 6. The concrete used in *Canoebis* exceeds the analysis.

Table 6: Maximum stresses

Stress	*Canoebis'* Concrete	Required
Max. Tensile	267 psi	180 psi
Max. Compressive	1,872 psi	95 psi

Development and Testing

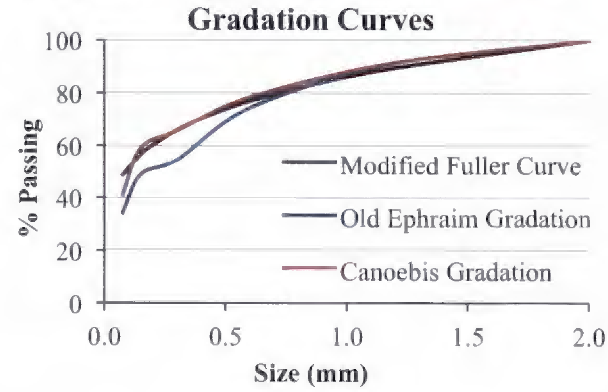
The mix design used for *Old Ephraim* was Utah State's most successful concrete to date. Because of the high strength/weight ratio and workability, it was chosen as the baseline for improvement. The primary goal for the new mix design was to develop a concrete that maintained a low unit weight. The team also pushed to create a stronger mix to cope with the projected increased maximum stresses from the new hull design. Secondary goals included improving the workability of the mix and maintaining sustainability.

Innovation

Early on in testing, new aggregates were integrated in the mix to increase compressive strength. Starting from the baseline mix, the K37 microspheres [specific gravity (SG) = 0.37; Crush Strength (CS) = 3,000 psi] were replaced with iM16K (SG = 0.46; CS =16,500 psi) and iM30K (SG = 0.6; CS = 28,000 psi) glass bubbles (3M, 2008; 2010; 2013). This increased the average specific gravity of our microsphere aggregates by 52%, but because it increased the average compressive strength by 732%, the replacement was desirable.

Increased strength was also achieved by designing the aggregate proportions to match a modified version of the gradation curve for maximum density proposed by Fuller and Thompson (1906). An optimal gradation would minimize the voids between the aggregates, providing a more cohesive mix and greater strength. The aggregate proportions were initially adjusted according to the standard Fuller Curve. This provided a concrete mix that was too coarse to be used, so the team modified the Fuller Curve to compensate for finer aggregates. This produced a gradation that resulted in a very workable mix. This gradation increased the compressive strength by 37%, while only increasing the total aggregate weight by 6.4% compared to last year's mix. A comparative graph between the gradations used for *Old Ephraim* and *Canoebis* against the modified Fuller curve is shown in Figure 5.

Figure 5: Gradation vs. modified fuller curve



Improved concrete tensile capacity was obtained by adding fibrous material to the structural mix. Old Ephraim's two fiber sizes were 8 and 130 deniers. The team added two additional sizes of PVA fibers, 20 and 40 deniers, to provide a greater range. Because fibers of similar size tend to clump together, this range allowed the concrete to have more fibers without sacrificing workability. Tensile strength was increased by 50% over last year's mix.

Striving to minimize voids in the aggregate gradation resulted in a stiffer, denser concrete mix. This made it difficult to entrain air using the standard method of mixing. A new mixing technique was used to reach the desired air content. First, the water, air entrainer, and other admixtures were added to the cementitious material and mixed at high speeds for several minutes (see Fig. 6). This long mixing time ensured air was thoroughly entrained in the slurry. The

Figure 6: Mixing cementious material

aggregates were then slowly added to the slurry during a constant mixing process. This method allowed the concrete to be very workable and achieve a zero-inch slump (ASTM C143, 2012c) with a 4.38% air content.

Adding admixtures further enhanced the workability of the mix. Admixtures were tested independently to determine the correct dosage for the overall mix. The team used a higher dosage of air entrainer compared to *Old Ephraim*'s concrete mix. This ensured the mix would obtain a high enough air content to achieve the desired unit weight. A high range water reducer and super-plasticizer were also added to retard the setting time and improve the workability of the concrete.

The team stored all aggregates at their saturated surface-dry (SSD) state to increase workability time and ensure a consistent mix. An aggregate at SSD has reached its absorption potential without excess water clinging to the surface, which means it will not contribute or absorb any free water to the mix (NPCA, 2010). First, the dry aggregates were premeasured into manageable batches. The amount of water required for aggregate absorption was calculated and thoroughly mixed into each batch. The individual batches were then sealed until ready to mix. Ensuring the aggregates were SSD prior to the final mixing meant that they would not absorb the water required by the cement. This helped maintain a consistent workability level throughout the casting process.

Sustainability

In an effort to keep our mix design sustainable, *Canoebis* was built using recycled aggregates, such as Poraver© and CW300 cenospheres. Poraver© uses crushed recycled glass to create their product. Cenospheres are created from a byproduct of burning coal. Both of these processes require no new raw materials and reduce the impact on landfills. The team also used fly ash, an industrial byproduct of combustion, as a main component of the cementitious material. The use of fly ash as a substitute for Portland cement increased the strength and workability of the mix while reducing the environmental impact of *Canoebis*. The production of Portland cement is a major contributor to worldwide CO_2 emissions (Mehta, 2004). By replacing Portland cement with fly ash at a 5:8 ash/cement ratio, the team used an available resource that would otherwise take up space in a landfill and reduced the use of a product with a large carbon footprint.

Test Results

Test cylinders were cast and tested according to ASTM standards (see Fig. 7) with each new mix to help the team track improvements. These cylinders were used to calculate the compressive strength (ASTM C39, 2012a), tensile strength (ASTM C496, 2011), the unit weight, and air content. Test beams were cast to measure the composite flexural strength, using a modified third-point load test (ASTM C78, 2010). Over 15 mix designs were developed before the selection of a final structural mix for *Canoebis*. The final properties of the structural mix used in *Canoebis*, compared to the requirements found by analysis and *Old Ephraim*'s concrete properties are displayed in Table 7.

Figure 7: Compressive strength test

Table 7: Comparison of concrete properties

Property	*Old Ephraim*	*Canoebis*
Comp. Strength	1368 psi	1872 psi
Tensile Strength	178 psi	267 psi
Unit Weight	49.95 pcf	53.18 pcf
Air Content	8.86 %	4.38%

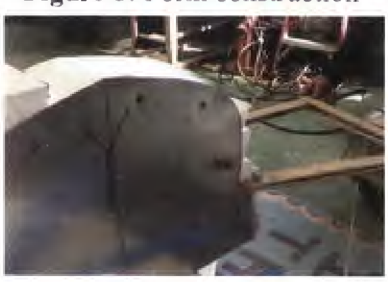
Construction

Canoebis' drastically different hull design presented many challenges to the construction team. Building upon past experience, the team was able to develop new techniques for building the mold, ensuring casting day efficiency, and maintaining tension on the steel cables in the gunwale throughout the curing process. These innovations allowed the construction of *Canoebis* to be quick and sustainable while increasing the quality of the final product.

Form Construction

The form for *Canoebis* was constructed by placing 6-inch thick pieces of low density Styrofoam between tin cross-sections, using a hotwire to cut the shape, and forming a male mold (see Fig. 8). Styrofoam was selected because it is inexpensive, strong enough to support the concrete, lightweight, and easy to shape. When the foam mold was complete, the team covered the foam in plaster to fill in the seams and uneven spots. The plaster was then sanded to a smooth finish.

Figure 8: Form construction



A three-dimensional inlay was carved using a Dremel© tool (see Fig. 9). This was a new technique for the team, as *Old Ephraim*'s inlay pieces were cast separate from the main body of the canoe and attached during the finishing process. Carving the inlay directly into the form allowed the canoe and inlay to be cast simultaneously without a bonding layer. This resulted in a much stronger inlay for *Canoebis*.

Figure 9: Detail of inlay

To finish the mold, a Styropoxy© layer was applied to the foam. This epoxy coat protected the form by ensuring water from the concrete didn't dissolve the plaster form. It also facilitates the removal of the form from the canoe after the concrete has cured.

Casting

In less than two hours, a group of 29 team members and volunteers cast *Canoebis*. All concrete materials were premeasured as individual batches prior to casting day to ensure efficiency and quality control.

The concrete for *Canoebis* was applied by hand in two even ¼-inch lifts. In accordance with the design, two steel cables with anchors spaced every three feet were placed in the gunwales and tensioned to 100 lbs. These cables were maintained in tension using a spring scale throughout the curing process. Fiberglass geo-fabric mesh was placed between the two concrete lifts as passive reinforcement. Wooden cross-sections were used to gauge the concrete thickness without damaging the cast concrete (see Fig. 10). After curing for 21 days, *Canoebis* was manually removed from the mold by cutting out the foam.

Figure 10: Wooden cross-sections

Finishing

After *Canoebis* was separated from the form the finishing process began. Multiple iterations of sanding and finishing mix application were used to fill all voids and remove imperfections. The final sanding process used 2,000-grit sandpaper to create a polished look. Two coats of decorative concrete stain were applied. A high-gloss sealer was applied followed with further sanding, up to 5,000-grit, creating a smooth and polished finish. Figure 11 shows the final product and team at the 2013 Rocky Mountain Student Conference.

Figure 11: *Canoebis* team photo

Practice Canoe

Each year, the USU Concrete Canoe Team builds two canoes. The paddling team uses the first "practice canoe" during training. Construction methods for this canoe followed the same pattern as the competition canoe (see Fig. 12). This allows the team to learn what processes and procedures need to be improved for the final product. It also gives the opportunity for new members of the team to learn what is required for the construction process.

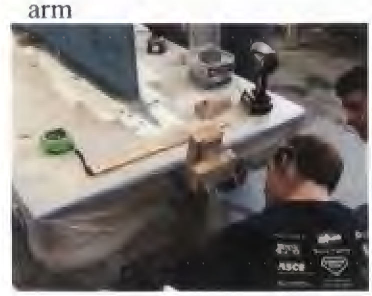
Figure 12: Construction of practice canoe

Innovation

During the construction of the practice canoe, it was apparent that a new method of maintaining tension in the gunwale cables was necessary. The cables relaxed during the curing process and the necessary tension was not being applied. As an innovative way to fix the problem a pulley/lever-arm tensioning system was developed. The cables were stretched down one side of the canoe, guided through two pulleys, and positioned back down the other side of the mold (see Fig. 13). Spacers were used to maintain the appropriate distance between the cables and the mold. At the other end of the canoe, the cables were connected to a wooden lever (see Fig. 14). This lever arm was connected to a spring scale and anchored to the table. This system allowed for a constant, measurable, tension to be applied in the cable while *Canoebis* cured.

Figure 13: Detail of pulley tension system

Figure 14: Detail of lever arm

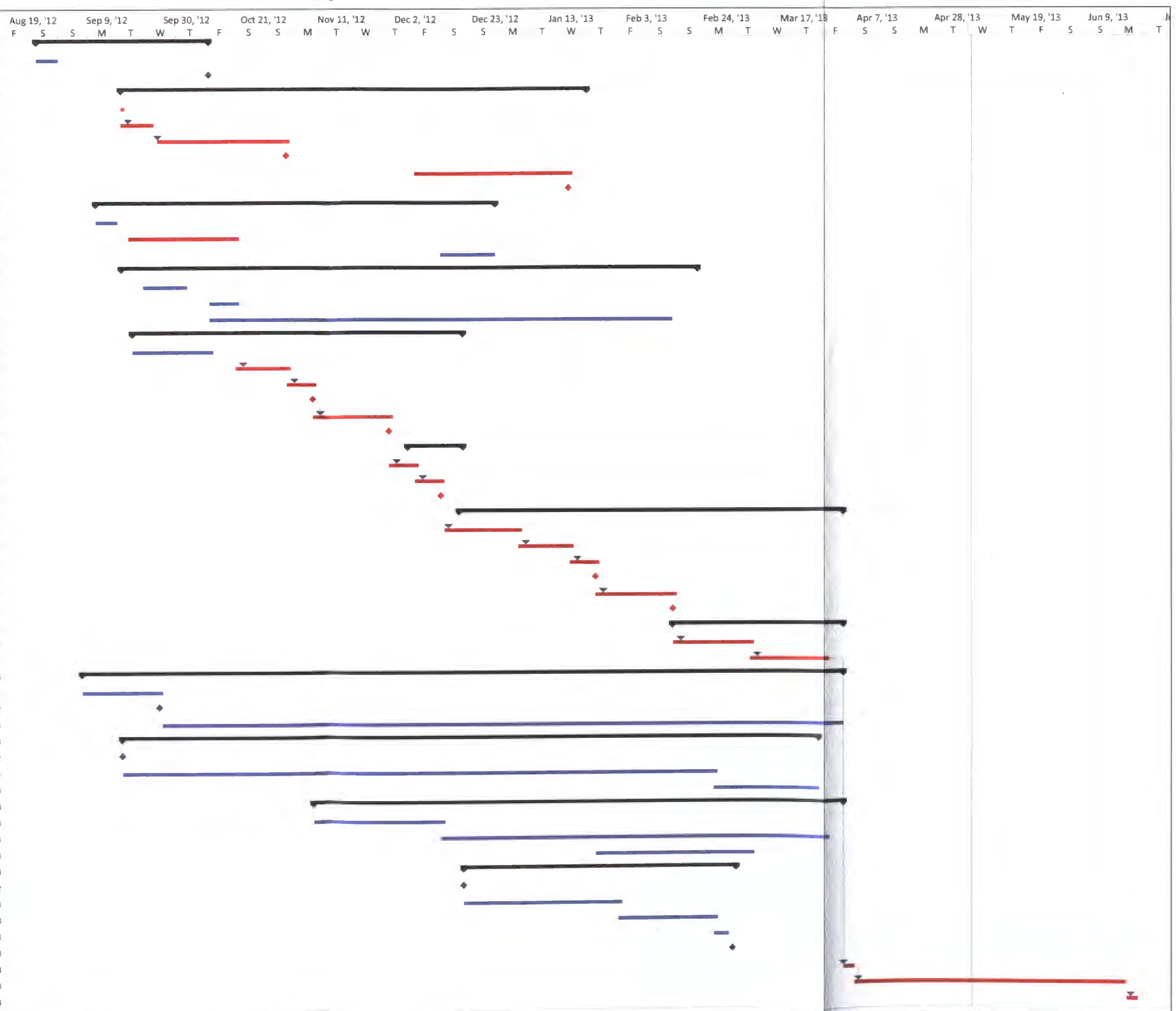


Sustainability

To make the construction process of *Canoebis* sustainable many items and materials were reused or recycled from previous years. The table that held the mold was built using recycled wood. Leftover aggregates from the construction of *Old Ephraim* were used in the concrete mix for this year's practice canoe. Concrete stain and sealant leftover from previous projects were used to save the cost of buying new stain, and decrease environmental impact. The foam used for the mold of the practice canoe was recycled to construct the stands and display. The reuse of these materials saved money and provided an opportunity to reduce the project waste.

Canoebis Project Schedule

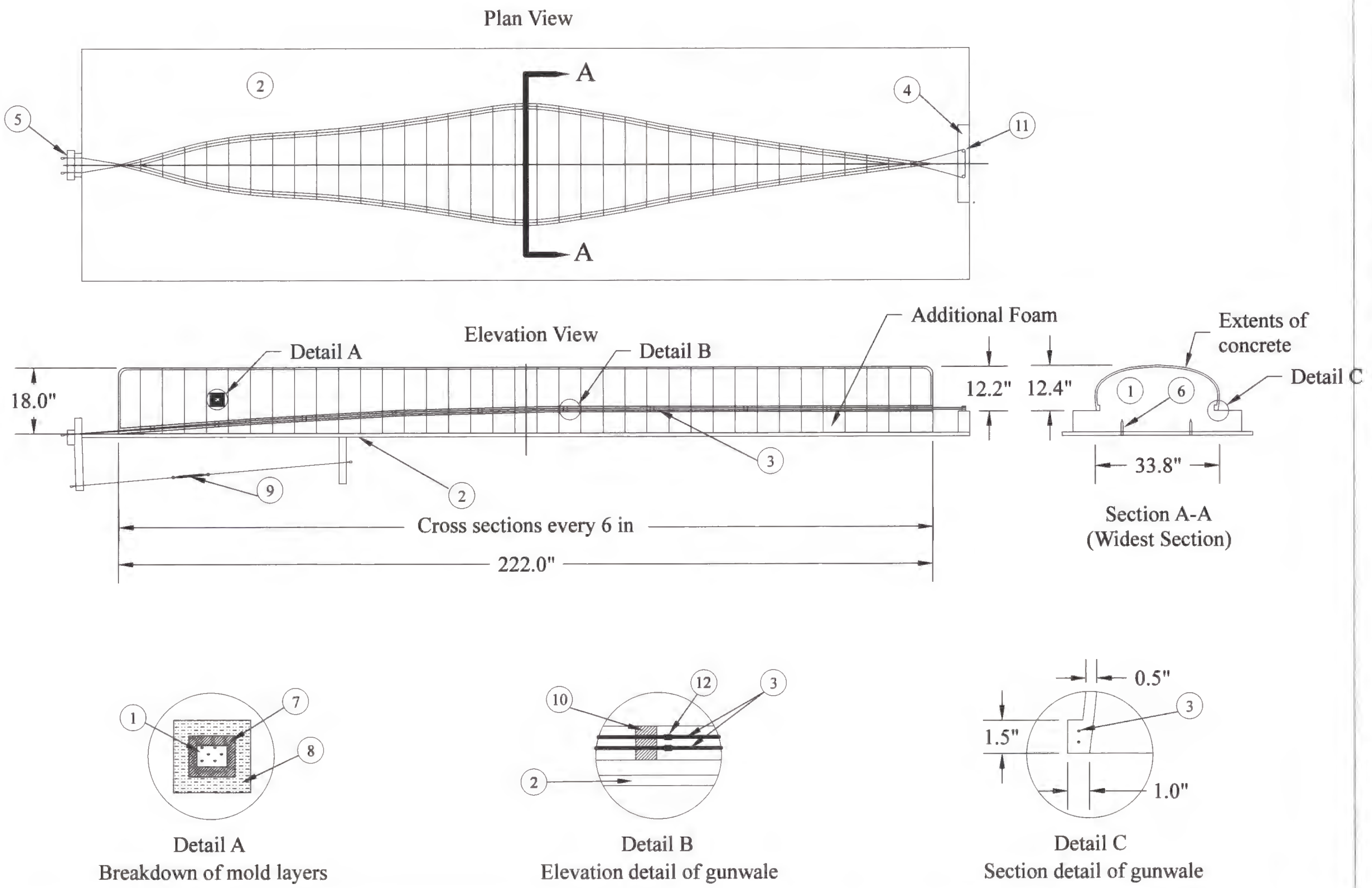
ID	Task Name	Baseline Start	Baseline Finish	Actual Start	Actual Finish
1	**Project start**	**Mon 8/27/12**	**Sat 10/13/12**	**Mon 8/27/12**	**Sat 10/13/12**
2	Recruiting	Mon 8/27/12	Sat 9/1/12	Mon 8/27/12	Sat 9/1/12
3	Lab clean up and resurfacing	Sat 10/13/12	Sat 10/13/12	Sat 10/13/12	Sat 10/13/12
4	**Mix design**	**Wed 9/19/12**	**Sat 1/19/13**	**Wed 9/19/12**	**Thu 1/24/13**
5	Set mix design goals	Wed 9/19/12	Wed 9/19/12	Wed 9/19/12	Wed 9/19/12
6	Develop initial mix design	Wed 9/19/12	Thu 9/27/12	Wed 9/19/12	Thu 9/27/12
7	Initial mix design and testing iterations	Sat 9/29/12	Sat 11/3/12	Sat 9/29/12	Sat 11/3/12
8	Mix design ready for canoe 1	Sat 11/3/12	Sat 11/3/12	Sat 11/3/12	Sat 11/3/12
9	Final mix design and tesing iterations	Sat 12/8/12	Sat 1/19/13	Sat 12/8/12	Tue 1/22/13
10	Final mix design ready	Sat 1/19/13	Sat 1/19/13	Thu 1/24/13	Thu 1/24/13
11	**Hull design**	**Wed 9/12/12**	**Sat 12/29/12**	**Wed 9/12/12**	**Sat 12/29/12**
12	Research hull shapes	Wed 9/12/12	Mon 9/17/12	Wed 9/12/12	Mon 9/17/12
13	AutoCAD model	Fri 9/21/12	Sat 10/20/12	Fri 9/21/12	Sat 10/20/12
14	Adjust drawings if needed	Sat 12/15/12	Sat 12/29/12	Sat 12/15/12	Sat 12/29/12
15	**Analysis**	**Wed 9/19/12**	**Fri 2/15/13**	**Wed 9/19/12**	**Fri 2/22/13**
16	Determine loading scenarios	Tue 9/25/12	Sat 10/6/12	Wed 9/19/12	Sat 10/6/12
17	Complete preliminary analysis	Sat 10/13/12	Sat 10/20/12	Sat 10/13/12	Sat 10/20/12
18	Complete detailed analysis for report	Sat 10/13/12	Fri 2/15/13	Sat 10/13/12	Fri 2/22/13
19	**Construction (canoe 1)**	**Sat 9/22/12**	**Sat 12/15/12**	**Sat 9/22/12**	**Thu 12/20/12**
20	Gather materials	Sat 9/22/12	Sat 10/13/12	Sat 9/22/12	Sat 10/13/12
21	Form construction	Sat 10/20/12	Sat 11/3/12	Sat 10/20/12	Sat 11/3/12
22	Final preparations	Sat 11/3/12	Sat 11/10/12	Sat 11/3/12	Sat 11/10/12
23	Casting day	Sat 11/10/12	Sat 11/10/12	Sat 11/10/12	Sat 11/10/12
24	Curing	Sat 11/10/12	Sat 12/1/12	Sat 11/10/12	Sat 12/1/12
25	Pull from form	Sat 12/1/12	Sat 12/1/12	Sat 12/1/12	Sat 12/1/12
26	**Finishing (canoe 1)**	**Thu 12/6/12**	**Sat 12/15/12**	**Thu 12/6/12**	**Thu 12/20/12**
27	Sanding/finishing mix	Sat 12/1/12	Sat 12/8/12	Thu 12/6/12	Sat 12/8/12
28	Staining/sealing	Sat 12/8/12	Sat 12/15/12	Sat 12/8/12	Thu 12/20/12
29	Float test	Sat 12/15/12	Sat 12/15/12	Thu 12/20/12	Thu 12/20/12
30	**Construction (canoe 2)**	**Sun 12/16/12**	**Sat 3/30/13**	**Thu 12/20/12**	**Wed 4/3/13**
31	Gather materials	Sun 12/16/12	Sat 1/5/13	Thu 12/20/12	Sat 12/29/12
32	Form construction	Sat 1/5/13	Sat 1/19/13	Sat 1/5/13	Sat 1/19/13
33	Final preparations	Sat 1/19/13	Sat 1/26/13	Sat 1/19/13	Sat 1/26/13
34	Casting day	Sat 1/26/13	Sat 1/26/13	Sat 1/26/13	Sat 1/26/13
35	Curing	Sat 1/26/13	Sat 2/16/13	Sat 1/26/13	Sat 2/16/13
36	Pull from form	Sat 2/16/13	Sat 2/16/13	Sat 2/16/13	Sat 2/16/13
37	**Finishing (canoe 2)**	**Sat 2/16/13**	**Sat 3/30/13**	**Sat 2/16/13**	**Wed 4/3/13**
38	Sanding/finishing mix	Sat 2/16/13	Sat 3/9/13	Sat 2/16/13	Wed 3/20/13
39	Staining/sealing	Sat 3/9/13	Sat 3/30/13	Wed 3/20/13	Wed 4/3/13
40	**Conditioning**	**Sat 9/8/12**	**Sat 3/23/13**	**Sat 9/6/12**	**Wed 4/3/13**
41	Initial recruiting/practice	Sat 9/8/12	Sat 9/29/12	Sat 9/8/12	Sat 9/29/12
42	Tryouts	Sat 9/29/12	Sat 9/29/12	Sat 9/29/12	Sat 9/29/12
43	Practice paddling/team workouts	Sun 9/30/12	Wed 4/3/13	Sun 9/30/12	Wed 4/3/13
44	**Fundraising**	**Wed 9/19/12**	**Wed 3/27/13**	**Wed 9/19/12**	**Wed 3/27/13**
45	Set fundraising goals	Wed 9/19/12	Wed 9/19/12	Wed 9/19/12	Wed 9/19/12
46	Contact companies	Wed 9/19/12	Wed 2/27/13	Wed 9/19/12	Wed 2/27/13
47	Order T-shirts	Wed 2/27/13	Wed 3/27/13	Wed 2/27/13	Wed 3/27/13
48	**Display**	**Sat 11/10/12**	**Sat 3/30/13**	**Sat 11/10/12**	**Wed 4/3/13**
49	Themed stands	Sat 11/10/12	Sat 12/15/12	Sat 11/10/12	Mon 4/1/13
50	Cutaway section	Sat 12/15/12	Sat 3/30/13	Sat 1/5/13	Mon 4/1/13
51	Display table	Sat 1/26/13	Sat 3/9/13	Sat 1/26/13	Wed 4/3/13
52	**Design paper**	**Fri 12/21/12**	**Wed 3/20/13**	**Fri 12/21/12**	**Mon 3/4/13**
53	Sections due for initial review	Fri 12/21/12	Fri 12/21/12	Fri 12/21/12	Fri 12/21/12
54	Final draft	Fri 12/21/12	Fri 2/1/13	Fri 12/21/12	Fri 2/1/13
55	Peer review	Fri 2/1/13	Wed 2/27/13	Sat 2/23/13	Wed 2/27/13
56	Final editing	Wed 2/27/13	Sat 3/2/13	Wed 2/27/13	Mon 3/4/13
57	Submission	Mon 3/4/13	Mon 3/4/13	Mon 3/4/13	Mon 3/4/13
58	**Rocky Mountain Conference**	**Thu 4/4/13**	**Sat 4/6/13**	**Thu 4/4/13**	**Sat 4/6/13**
59	Prepare for 2013 NCCC	Sun 4/7/13	Wed 6/19/13	Sun 4/7/13	Wed 6/19/13
60	**2013 NCCC**	**Thu 6/20/13**	**Sat 6/22/13**	**Thu 6/20/13**	**Sat 6/22/13**



Project: Canoebis
Date: Thu 5/9/13

Summary — Task — Critical Tasks — Milestone ◆

Canoebis Design Drawing



Canoebis Design Drawing

Form Bill of Materials

Item No.	Qty	Description
1	84	Cu ft. of expanded polyurethane foam
2	6	4 ft X 8 ft particle board (2 layers)
3	85	Ft of 1/16 in. wound steel cable
4	2	Wood anchor block
5	8	Steel washers
6	111	Screws
7	48	lbs. drywall compound
8	2	Gallons of Styropoxy
9	1	Tension scale
10	20	Cable guide blocks
11	2	Pulleys
12	20	Cable anchors

Notes:
1. Build wood base
2. Cut 37 foam sections according to individual dimensions (insufficient room to show all detail on this drawing)
3. Secure foam sections together & secure to wood using screws and glue
4. Apply drywall compound to fill cracks in foam and sand smooth.
5. Apply two coats of styropoxy
6. Place tension cables
7. Anchor cables to end block and apply tension to 100 lbs. using scale.

UtahStateUniversity

Drawn by: Michael Budge

Checked by: Mitch Dabling

Date: 2/12/13

Appendix A: References

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Appendix B: Mixture Proportions

Mixture ID: Structural Mix					Design Proportions (Non SSD)		Actual Batched Proportions		Yielded Proportions	
Y_D	Design Batch Size (ft³):		0.25							
Cementitious Materials				SG	Amount (lb/yd³)	Volume (ft³)	Amount (lb)	Volume (ft³)	Amount (lb/yd³)	Volume (ft³)
CM1	White Portland Cement			3.15	256.36	1.304	2.37	0.012	264.40	1.345
CM2	VCAS			2.60	64.09	0.395	0.59	0.004	66.10	0.407
CM3	Fly Ash			2.15	159.80	1.191	1.48	0.011	164.81	1.228
CM4	Xypex C-500			2.40	19.75	0.132	0.18	0.001	20.37	0.136
	Total Cementitious Materials:				**500.00**	**3.022**	**4.63**	**0.028**	**515.68**	**3.117**
Fibers										
F1	PVA RSC15			1.30	4.00	0.049	0.04	0.000	4.13	0.051
F2	PVA RECS 100			1.30	4.00	0.049	0.04	0.000	4.13	0.051
F3	PVA RFS 400			1.30	4.00	0.049	0.04	0.000	4.13	0.051
F4	PVA RF4000			1.30	4.00	0.049	0.04	0.000	4.13	0.051
	Total Fibers:				**16.00**	**0.197**	**0.15**	**0.002**	**16.50**	**0.203**
Aggregates										
A1	Cenospheres	Abs:	15%	0.35	91.80	4.203	0.85	0.039	94.68	4.335
A2	K20	Abs:	1%	0.20	49.00	3.926	0.45	0.036	50.54	4.049
A2	IM16K	Abs:	10%	0.46	27.00	0.941	0.25	0.009	27.85	0.970
A3	IM30K	Abs:	9%	0.60	75.06	2.005	0.69	0.019	77.41	2.068
A4	Poraver .25-.5	Abs:	20%	0.88	85.78	1.562	0.79	0.014	88.47	1.611
A5	Poraver .5-1	Abs:	20%	0.71	107.23	2.420	0.99	0.022	110.59	2.496
A6	Poraver 1.0-2.0	Abs:	20%	0.53	64.34	1.945	0.60	0.018	66.35	2.006
	Total Aggregates:				**500.20**	**17.003**	**4.63**	**0.157**	**515.89**	**17.536**
Water										
W1	Water for CM Hydration			1.00	300.00	4.808	2.78	0.045	309.41	4.958
	W1a. Water from Admixtures				13.71		0.13		14.14	
	W1b. Additional Water				286.29		2.65		295.26	
W2	Water for Aggregates, SSD			1.00	75.18		0.70		77.54	
	Total Water :				**375.18**	**4.808**	**3.47**	**0.045**	**386.95**	**4.958**
Solids Content of Latex, Dyes and Admixtures in Powder Form										
P1	Pigment 1 (Powder Form)			4.50	0.82	0.003	0.01	0.000	0.85	0.003
	Total Solids of Admixtures:				**0.82**	**0.003**	**0.01**	**0.000**	**0.85**	**0.003**
Admixtures				% Solids	Dosage (fl oz/cwt)	Water in Admixture (lb/yd³)	Amount (fl oz)	Water in Admixture (lb)	Dosage (fl oz/cwt)	Water in Admixture (lb/yd³)
Ad1	polyheed 997	10.6	*lb/gal*	48.00	32.00	6.89	1.48	0.064	33.0	7.11
Ad2	glenium 3030	8.7	*lb/gal*	20.00	9.00	2.45	0.42	0.023	9.3	2.52
Ad3	Bonding Adhesive	9.2	*lb/gal*	26.00	0.00	0.00	0.00	0.000	0.0	0.00
Ad4	Micro-Air	7.9	*lb/gal*	11.40	16.00	4.37	0.74	0.041	16.5	4.51
	Water from Admixtures:					**13.71**		**0.127**		**14.14**
Cement-Cementitious Materials Ratio					0.513		0.513		0.513	
Water-Cementitious Materials Ratio					0.600		0.600		0.600	
Slump, Slump Flow, *in.*					0.00		0.00		0.00	
M	Mass of Concrete, *lbs*				1392.21		12.89		1435.86	
V	Absolute Volume of Concrete, *ft³*				25.033		0.232		25.818	
T	Theorectical Density, *lb/ft³*				55.62		55.62		55.62	
D	Design Density, *lb/ft³*				51.56					
D	Measured Density, *lb/ft³*						53.180		53.180	
A	Air Content, *%*				7.29		4.38		4.38	
Y	Yield, *ft³*				27		0.242		27	
Ry	Relative Yield						0.970			

	Mixture ID: Finishing Mix A				Design Proportions (Non SSD)		Actual Batched Proportions		Yielded Proportions	
Y_D	Design Batch Size (ft^3):		0.1							
	Cementitious Materials			SG	Amount (lb/yd^3)	Volume (ft^3)	Amount (lb)	Volume (ft^3)	Amount (lb/yd^3)	Volume (ft^3)
CM1	White Portland Cement			3.15	725.53	3.691	2.69	0.014	724.07	3.684
CM2	VCAS			2.60	140.53	0.866	0.52	0.003	140.25	0.864
CM3	Fly Ash			2.15	173.26	1.291	0.64	0.005	172.91	1.289
CM4	Xypex C-500			2.40	43.67	0.292	0.16	0.001	43.58	0.291
	Total Cementitious Materials:				**1082.99**	**6.140**	**4.01**	**0.023**	**1080.81**	**6.128**
	Fibers									
F1	PVA RSC15			1.30	0.00	0.000	0.00	0.000	0.00	0.000
F2	PVA RECS 100			1.30	0.00	0.000	0.00	0.000	0.00	0.000
F3	PVA RFS 400			1.30	0.00	0.000	0.00	0.000	0.00	0.000
F4	PVA RF4000			1.30	0.00	0.000	0.00	0.000	0.00	0.000
	Total Fibers:				**0.00**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**
	Aggregates									
A1	Cenospheres	Abs:	15%	0.35	23.80	1.090	0.09	0.004	23.75	1.088
A2	K20	Abs:	1%	0.20	0.00	0.000	0.00	0.000	0.00	0.000
A3	IM16K	Abs:	10%	0.46	46.70	1.627	0.17	0.006	46.61	1.624
A4	IM30K	Abs:	9%	0.60	0.00	0.000	0.00	0.000	0.00	0.000
A5	K1	Abs:	1%	0.13	46.70	5.987	0.17	0.022	46.61	5.975
A6	Poraver .5-1	Abs:	20%	0.71	0.00	0.000	0.00	0.000	0.00	0.000
A7	Poraver 1.0-2.0	Abs:	20%	0.53	0.00	0.000	0.00	0.000	0.00	0.000
	Total Aggregates:				**117.20**	**8.704**	**0.43**	**0.032**	**116.96**	**8.686**
	Water									
W1	Water for CM Hydration			1.00	600.49	9.623	2.22	0.036	599.28	9.604
	W1a. Water from Admixtures				609.20		2.26		607.98	
	W1b. Additional Water				-8.71		-0.03		-8.69	
W2	Water for Aggregates, SSD			1.00	8.71		0.03		8.69	
	Total Water :				**609.20**	**9.623**	**2.26**	**0.036**	**607.97**	**9.604**
	Solids Content of Latex, Dyes and Admixtures in Powder Form									
ad 1	Bonding Adhesive			2.04	212.50	1.668	0.79	0.006	212.08	1.665
P1	Pigment 1 (Powder Form)			4.50	0.70	0.002	0.00	0.000	0.70	0.002
	Total Solids of Admixtures:				**213.20**	**1.671**	**0.79**	**0.006**	**212.77**	**1.667**
	Admixtures			% Solids	Dosage (fl oz/cwt)	Water in Admixture (lb/yd^3)	Amount (fl oz)	Water in Admixture (lb)	Dosage (fl oz/cwt)	Water in Admixture (lb/yd^3)
Ad1	polyheed 997	10.6	*lb/gal*	48.00	5.77	2.69	0.23	0.010	5.76	2.68
Ad2	glenium 3030	8.7	*lb/gal*	20.00	2.88	1.70	0.12	0.006	2.88	1.69
Ad3	Bonding Adhesive	9.2	*lb/gal*	26.00	1050.00	604.82	42.12	2.240	1047.89	603.60
Ad4	Micro-Air	7.9	*lb/gal*	11.40	0.00	0.00	0.00	0.000	0.00	0.000
	Water from Admixtures:					**609.20**		**2.256**		**607.98**
	Cement-Cementitious Materials Ratio				0.670		0.670		0.670	
	Water-Cementitious Materials Ratio				0.554		0.554		0.554	
	Slump, Slump Flow, *in.*				8.00		8.00		8.00	
M	Mass of Concrete, *lbs*				2022.59		7.49		2018.52	
V	Absolute Volume of Concrete, ft^3				26.138		0.097		26.086	
T	Theorectical Density, lb/ft^3				77.38		77.38		77.38	
D	Design Density, lb/ft^3				74.91					
D	Measured Density, lb/ft^3						74.760		74.760	
A	Air Content, %				3.19		3.39		3.39	
Y	Yield, ft^3				27		0.100		27	
Ry	Relative Yield						1.002			

Mixture ID: Finishing Mix B				Design Proportions (Non SSD)		Actual Batched Proportions		Yielded Proportions	
Y_D	Design Batch Size (ft³):	0.1							
Cementitious Materials			SG	Amount (lb/yd³)	Volume (ft³)	Amount (lb)	Volume (ft³)	Amount (lb/yd³)	Volume (ft³)
CM1	White Portland Cement		3.15	670.00	3.409	2.48	0.013	653.99	3.327
CM2	VCAS		2.60	130.00	0.801	0.48	0.003	126.89	0.782
CM3	Fly Ash		2.15	160.00	1.193	0.59	0.004	156.18	1.164
CM4	Xypex C-500		2.40	40.00	0.267	0.15	0.001	39.04	0.261
	Total Cementitious Materials:			**1000.00**	**5.670**	**3.70**	**0.021**	**976.11**	**5.534**
Fibers									
F1	PVA RSC15		1.30	0.00	0.000	0.00	0.000	0.00	0.000
F2	PVA RECS 100		1.30	0.00	0.000	0.00	0.000	0.00	0.000
F3	PVA RFS 400		1.30	0.00	0.000	0.00	0.000	0.00	0.000
F4	PVA RF4000		1.30	0.00	0.000	0.00	0.000	0.00	0.000
	Total Fibers:			**0.00**	**0.000**	**0.00**	**0.000**	**0.00**	**0.000**
Aggregates									
A1	Cenospheres	Abs: 15%	0.35	22.00	1.007	0.08	0.004	21.47	0.983
A2	K20	Abs: 1%	0.20	0.00	0.000	0.00	0.000	0.00	0.000
A3	IM16K	Abs: 10%	0.46	44.00	1.533	0.16	0.006	42.95	1.496
A4	IM30K	Abs: 9%	0.60	0.00	0.000	0.00	0.000	0.00	0.000
A5	k1	Abs: 1%	0.13	44.00	5.641	0.16	0.021	42.95	5.506
A6	Poraver .5-1	Abs: 20%	0.71	0.00	0.000	0.00	0.000	0.00	0.000
A7	Poraver 1.0-2.0	Abs: 20%	0.53	0.00	0.000	0.00	0.000	0.00	0.000
	Total Aggregates:			**110.00**	**8.181**	**0.41**	**0.030**	**107.37**	**7.986**
Water									
W1	Water for CM Hydration		1.00	695.08	11.139	2.57	0.041	678.48	10.873
	W1a. Water from Admixtures			703.22		2.60		686.42	
	W1b. Additional Water			-8.14		-0.03		-7.95	
W2	Water for Aggregates, SSD		1.00	8.14		0.03		7.95	
	Total Water :			**703.22**	**11.139**	**2.60**	**0.041**	**686.42**	**10.873**
Solids Content of Latex, Dyes and Admixtures in Powder Form									
ad 1	Bonding Adhesive		2.04	242.94	1.907	0.90	0.007	237.13	1.862
P1	Pigment 1 (Powder Form)		4.50	0.70	0.002	0.00	0.000	0.68	0.002
	Total Solids of Admixtures:			**243.64**	**1.910**	**0.90**	**0.007**	**237.82**	**1.864**
Admixtures			% Solids	Dosage (fl oz/cwt)	Water in Admixture (lb/yd³)	Amount (fl oz)	Water in Admixture (lb)	Dosage (fl oz/cwt)	Water in Admixture (lb/yd³)
Ad1	polyheed 997	10.6 *lb/gal*	48.00	16.00	6.89	0.59	0.026	15.6	6.73
Ad2	glenium 3030	8.7 *lb/gal*	20.00	9.00	4.89	0.33	0.018	8.8	4.78
Ad3	Bonding Adhesive	9.2 *lb/gal*	26.00	1300.00	691.44	48.15	2.561	1268.9	674.92
Ad4	Micro-Air	7.9 *lb/gal*	11.40	0.00	0.00	0.00	0.000	0.0	0.00
	Water from Admixtures:				**703.22**		**2.60**		**686.42**
	Cement-Cementitious Materials Ratio			0.670		0.670		0.670	
	Water-Cementitious Materials Ratio			0.695		0.695		0.695	
	Slump, Slump Flow, *in.*			1.00		1.00		1.00	
M	Mass of Concrete, *lbs*			2056.86		7.62		2007.72	
V	Absolute Volume of Concrete, *ft³*			26.900		0.100		26.257	
T	Theorectical Density, *lb/ft³*			76.46		76.46		76.46	
D	Design Density, *lb/ft³*			76.18					
D	Measured Density, *lb/ft³*					74.360		74.360	
A	Air Content, %			0.37		2.75		2.75	
Y	Yield, *ft³*			27		0.102		27	
Ry	Relative Yield					1.024			

Appendix C: Bill of Materials

Material	Quantity	Units	Unit Cost	Total Price
Concrete Materials				
White Portland Cement	21.84	lbs	$0.50	$10.92
VCAS	5.46	lbs	$0.64	$3.49
Fly Ash	13.61	lbs	$0.21	$2.86
Xypex C-500	1.68	lbs	$9.58	$16.09
Cenoshperes	7.82	lbs	$4.28	$33.50
K1 Microshperes	0.43	lbs	$10.00	$4.30
K20 Microspheres	4.17	lbs	$9.50	$39.62
IM16K	2.30	lbs	$28.09	$64.61
IM30K	6.39	lbs	$23.78	$151.92
Poraver (0.25-0.5)	7.31	lbs	$9.14	$66.81
Poraver (0.5-1)	9.13	lbs	$10.72	$97.87
Poraver (1-2)	5.48	lbs	$11.72	$64.23
Polyheed 997	13.63	fl oz	$0.05	$0.75
Glenium 3030	3.83	fl oz	$0.13	$0.50
Micro-air	4.37	fl oz	$0.03	$0.14
Pigment	0.07	lbs	$2.00	$0.14
Quikrete Bonding Adhesive	1.00	gal	$14.00	$14.00
Fibers PVA RSC15	0.33	lbs	$14.00	$4.66
Fibers PVA RECS 100	0.33	lbs	$15.00	$5.00
Fibers PVA RFS 400	0.33	lbs	$15.00	$5.00
Fibers PVA RF4000	0.33	lbs	$20.00	$6.66
Reinforcement				
Material	Quantity	Units	Unit Cost	Total Price
Fiberglass Mesh	110	sq ft	$2.65	$291.50
Steel Cables	85	ft	$0.06	$5.10
Aluminum Stops	20	pieces	$0.62	$12.40
Finishing				
Material	Quantity	Units	Unit Cost	Total Price
Concrete Stain	5	gal	$25.96	$129.80
Sealer	1	gal	$14.00	$14.00
Form				
Material	Quantity	Units	Unit Cost	Total Price
Styrofoam Mold, Complete	1	mold	$350.00	$350.00
Final Product				
Total Cost for Canoebis				$1,395.86