University of Wisconsin - Madison Concrete Canoe Team

2005 - 2006

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Appendices

Forward at a Glance

Color	Natural Grey
Length	21 ft
Weight	162 lb
Maximum Width	30 in.
Maximum Depth	13 in.
Average Thickness	½ in.
Fiberglass Mesh Reinforcement	4.5 oz/yd^2
Steel Pre-Stress Wire	20 gage
Composite Concrete Mixture	
Unit Weight	41.24 pcf
Flexural Strength	1,060 psi
Structural Concrete Mixture	
Unit Weight	40.32 pcf
Tensile Strength	150 psi
Compressive Strength	855 psi
Dyed Concrete Mixtures	
Unit Weight	42.55 pcf
Tensile Strength	130 psi
Compressive Strength	825 psi
Finishing Concrete Mixture	
Unit Weight	46.71 pcf
Tensile Strength	123 psi
Compressive Strength	923 psi
Dyed Finishing Mixtures	
Unit Weight	47.32 pcf
Tensile Strength	115 psi
Compressive Strength	950 psi

Executive Summary

The University of Wisconsin-Madison is located on a 933 acre campus in the center of downtown Madison between Lake Mendota and Lake Monona. UW-Madison has more than 41,000 students enrolled, including 450 studying civil engineering. The UW-Madison Concrete Canoe Team has competed in the Great Lakes Regional Competition for the past seventeen years and has qualified for the National Competition the past thirteen years. In 2002, the team earned its first top-five finish, followed by national championships in 2003, 2004, and 2005.

The 2006 team employed forward thinking by examining previous methods and challenging them to be more sustainable. *Forward*, this year's entry, was named after Wisconsin's state motto and represents the combination of successful methods from previous teams and innovative changes to move toward more sustainable practices.

Several changes were implemented throughout the creation of *Forward*. A new, versatile hull shape allowed both bow- and stern-initiated turns. The team also created an innovative, mold-less prototype to test hull modifications before mold construction began. Development engineers created concrete mixtures that incorporated several new innovations including a Class C/F hybrid fly ash and aggregates made from recycled glass. A detailed structural analysis allowed engineers to design more efficient ribs and a simplified pre-stress system compared to previous years. *Forward's* construction also utilized an innovative female and male mold system which was both environmentally sensitive and time efficient. Mock-ups confirmed the feasibility of these new mold construction methods. Finally, precast concrete inlays allowed for the creation of sharp, clean lines between colors, which enhanced *Forward's* aesthetics.

Team leadership was facilitated by three experienced team members and several supporting engineers. The abundance of experience enabled knowledge to be passed on to younger team members through increased one-on-one interaction. The management scheme created a motivated and unified team to continue UW-Madison's strong tradition of ingenuity, innovation, and project excellence.

Hull Design

Forward's hull design team recognized a number of areas for improvement over last year's canoe, *Taliesin*. The main goals of the hull design team were to improve maneuverability, increase stability, and reduce frictional resistance. To test modifications, hull engineers established the goal of creating a prototype prior to final hull shape approval. Finally, the hull design team required that design theory from the past several years be maintained while pursuing these goals.

Hull designers maintained *Taliesin's* main features: swede form[1], asymmetrical rocker[2], flat bottom and hard chines[3]. These traits helped last year's paddlers negotiate the critical buoy turns performed during every race. Unfortunately, these features also hindered *Taliesin's* ability to be controlled from the stern.

In order to increase maneuverability, *Forward* was designed to turn around two axes of rotation, thus allowing both bow- and stern-initiated turns. A variable rocker profile was designed by decreasing lateral plane[4] area in the bow and raising it in the stern to improve straight line control and stern-initiated turns. Rocker was also increased from *Taliesin* to enhance overall maneuverability. To further skew the lateral plane, the deadwood[5] portions of the stems were cut away to a greater extent in the bow than the stern (Figure 1) (Winters, 2004).

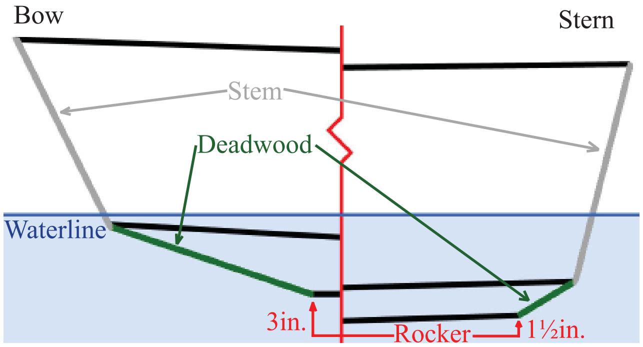

Figure 1: Stem, deadwood, and rocker shown here are the main components of the tips of *Forward*. Notice lateral plane is smaller in the bow than the stern.

A paddler in a stable canoe can focus on technique. To stabilize *Forward* without detracting from hull speed and acceleration, a team of four engineers used the hull design and analysis software Hulls to test chine shapes. During this analysis, other hull features were kept constant to isolate the effects of different chine shapes. The chine geometry that yielded the best stability characteristics was chosen.

Forward's hard chines are similar to those used in the past three years. When the canoe is leaned on edge, the chine acts like a curved keel, enabling the hull to turn itself. The hard chines enhance maneuverability, but tend to increase wetted surface area, which increases friction.

The design team countered the friction associated with hard chines in two ways. First, the largest contributor to overall area, length, was decreased 6in. from *Taliesin's* length to 21ft. Second, the chines were softened in the bow, reducing the section area. Softening the chine helped to minimize wetted surface area at the bow where flow is more laminar and, as a result, frictional resistance is high (Winters, 2004).

The wide range of power input between two and four paddlers was considered in designing *Forward*. The Prismatic Coefficient (PC), a measure of a hull's rate of cross sectional area change, is established by comparing a hull to a flat-sided prism. The PC is an indicator of how efficiently a hull glides and/or accelerates. Typical values range from 0.50 to 0.60 for normal canoe hulls. Hulls with lower values accelerate more easily, while hulls with higher values glide better between strokes (Slade, 1998). Forward's PC varies from 0.53 with two paddlers to 0.58 with four paddlers. This variation allows better acceleration for two-paddler sprints and improved glide for three-paddler endurance races and four-paddler sprints.

After several test sessions in a prototype, veteran paddlers and the design team agreed: *Forward* is a major step in the evolution of hull design at UW-Madison. *Forward* exhibits better acceleration, top speed, turning abilities, and straight line control than previous UW-Madison canoes.

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[1] A hull with its widest point aft of the midpoint.
[2] Amount keel rises at the ends relative to the lowest point on the hull.
[3] Region of hull where bottom transitions into sidewall.
[4] Underwater area of hull seen in side view.
[5] Lateral plane very near bow and stern.

Analysis

The goal of the analysis team was to design a structural system that would allow *Forward* to endure the rigors of the competition with minimal hull thickness and reinforcing materials. Because of the complex shape of the canoe, a three-dimensional analysis was conducted to determine the final structural requirements. Results from this analysis allowed the team to determine rib and pre-stress locations that would reduce areas of high tensile stresses.

SAP® 2000 finite element analysis was used to complete the three-dimensional analysis. Analysis engineers built the model with ½in. by ½in. by ½in. shell elements. Sizing elements in this way ensured precise results and allowed for accurate rib modeling. Model equilibrium was obtained with three boundary conditions: one pin and one roller at the bow, and one roller at the stern.

All five racing scenarios were considered in the development of the structural system. *Forward* was assumed to have a self-weight of 150lb based upon preliminary mixtures, and the design weights for the male and female paddlers were 200lb and 150lb, respectively. Paddler locations for each load case were measured during prototype testing. Each paddler knee was modeled as four point loads spaced 2in. apart. The buoyancy force was based on the design water line for each load case. Analysis engineers iteratively calculated the buoyancy force to generate a reaction force necessary to complete the paddler knee load (Figure 2). This process allowed the canoe to deform realistically, unhindered by artificial restraints needed to achieve overall canoe stability.

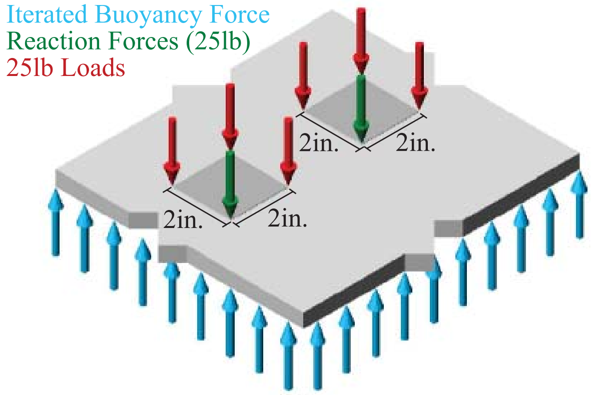


Figure 2: Male paddler boundary conditions at the bow. The dark grey squares represent knee locations.

The analysis aided in determining the required composite strength, as well as the placement and quantity of pre-stress tendons and ribs. Principle stresses revealed that *Forward* required minimum strengths of 167psi in compression and 309psi in tension. Using concrete design principles, the analysis team assumed that the concrete would provide 100% of the compressive resistance and the mesh reinforcement would provide 100% of the tensile resistance.

To determine the effective zone of each pre-stress tendon, a plate was modeled with a single tendon running down the center (Figure 3). In the model, the tendon was tensioned to different values to develop a system that minimized the number of tendons needed. Tendons tensioned to 150lb had an effective zone of 3in. on each side of the tendon, leading the analysis team to place four in the bottom of the hull and one in each gunwale at areas of high stress. The four tendons on the bottom were positioned 5in. inches apart while the other two were positioned 1in. below each gunwale. The final pre-stress orientation reduced tensile stresses by 28%

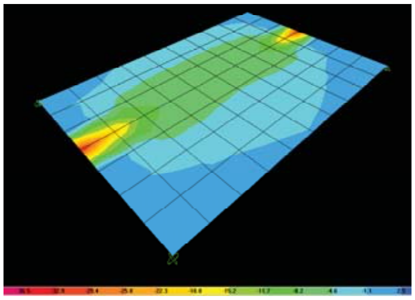


Figure 3: Prestress Effective Zone

Rib locations were determined based on areas of tension on the inside of the canoe and paddler locations for each load scenario. Various rib dimensions were analyzed to determine *Forward's* rib shape. The final rib cross sectional area was reduced by 40% from the 2005 design to ½in. wide by ¾in. tall. The use of transverse pre-stress tendons in the ribs stiffened the walls and bottom through axial compression. Transverse tendons were pre-stressed to 15lb, which, when combined with the ribs, reduced stresses by 32%.

Analysis goals were achieved by designing an accurate structural system with components to reduce stress in essential locations. As a result, the development team was now able to create the final concrete mixtures to be used in *Forward*.

Development and Testing

The primary goal of *Forward's* development team was to create a self-buoyant concrete mixture with an overall composite flexural strength of 309psi. The development team also aimed to create a mixture with sufficient resilience to withstand fatigue from cyclical loading applied during races. Though strength requirements governed mixture design, a subsequent goal was to reduce the density of the concrete mixture compared to *Taliesin's*. In keeping with the theme of sustainability, a final goal was to utilize recycled and by-product materials. To achieve all of these goals, the development team obtained new aggregates and binders and began a systematic development of *Forward's* concrete mixtures.

All test mixtures were cast into cylinders, formed into composite plates, and subjected to compressive and flexural tests at 7 and 28 days (ASTM C39/C39M-05, ASTM C1018-97). Different reinforcing materials were considered, and dyes were incorporated to develop *Forward's* aesthetics.

Aggregate selection was driven by experience from last year's mixture design as well as this year's theme of sustainability. *Taliesin's* main aggregate was manufactured ceramic spheres that needed to be separated into different sizes to meet gradation requirements. This process proved to be an inefficient use of time and materials. To expedite the design process, the development team chose aggregate sources that did not require sieving. Research inspired the use of a new, lightweight glass aggregate made from 99% recycled material compliant with the gradation in its stock condition. The development team then selected binders, admixtures, and fibers to create a concrete mixture that exceeded analysis requirements.

The development team aimed to minimize cement content by maximizing the use of an innovative hybrid Class C/F fly ash and blast furnace slag. The hybrid fly ash has a synergistic effect with the advantage of early strength from the Class C fly ash and long-term strength benefits from the Class F fly ash. This hybrid also promotes reduced permeability of the concrete, which increases *Forward's* durability (Malisch, 2005).

Mixture design began with *Taliesin's* final structural mixture as a baseline. This mixture was then altered to include slag, new aggregates, and air entrainment. The density of initial concrete mixtures was much lower than any of *Taliesin's* mixtures, but did not meet strength requirements. To produce sufficient strengths, the development team used a systematic approach by varying one mixture component at a time to find a balance between aggregate and binder content. Initially, binder ratios were varied to see how strength, density, and workability were affected. The results of this testing, summarized in Table 1 below, led the development team to choose a binder scheme incorporating a high slag content.

Binder Ratios			
	High Cement	High Fly Ash	**High Slag**
Ample Strength	Yes	Yes	**Yes**
Low Density	No	No	**Yes**
Workable	Yes	Yes	**Yes**
Sustainable	No	Yes	**Yes**

Table 1: Binder Ratio Effects

After selecting binder ratios, the development team considered aggregate combinations. Four different sizes of glass spheres were coarsely and finely blended within the limits set by ASTM C33 to develop a suitable composite aggregate source. Coarsely blended mixtures were less dense and more workable when compared to finely blended mixtures, but yielded lower strengths. Strength was gained with an increase in overall binder content in coarsely blended mixtures. Workability and low density were also maintained in these mixtures, leading the development team to choose a coarse aggregate blend.

Admixtures and fibers were incorporated into the mixture to generate a more durable and flexible concrete. Latex and batched water amounts were varied to find a balance between flexural strength, workability, and concrete setting time. Mixtures containing only batched water exhibited very low flexural strengths, while mixtures with large amounts of latex hardened quickly and were unworkable. Based on these results, the development team balanced latex and batched water contents to create a workable yet flexurally sound concrete mixture. Finally, fiber and air entrainment contents were tested. Past experience provided a baseline for fiber content, but the development team had no basis for air entrainment quantities. The development team tried ranges of air entrainment within the manufacturer's recommendations of dosages between ¼ and 4fl oz per 100lb of cementitious materials (fl oz/cwt). Test results led the development team to use 4fl oz/cwt because this quantity decreased density and increased workability without greatly affecting strength.

In an attempt to use a sustainable reinforcing material, natural alternatives such as hemp and wheat fibers were considered. However, these materials did not meet strength requirements and were also too thick to meet competition rule specifications. Carbon mesh was also considered as a possible reinforcing material, but due to the energy-intensive nature of its manufacturing process, the team rejected the material in favor of readily available reinforcement options. In an effort to counteract the necessary use of a non-sustainable material, excess fiberglass mesh from previous years was then considered. Past experience established this mesh as a viable reinforcement option, leading to its selection as *Forward's* primary reinforcement.

The development team tested different orientations of this reinforcement, striving to limit the number of layers used in the canoe. At the bottom of the canoe, where tensile stresses were larger, the development team selected a ½in. hull thickness with three layers of reinforcement throughout the cross section (Figure 4). In the walls, where tensile stresses were lower, the middle layer of reinforcement was removed, which promoted faster construction and better bonding between the layers of concrete in the walls.

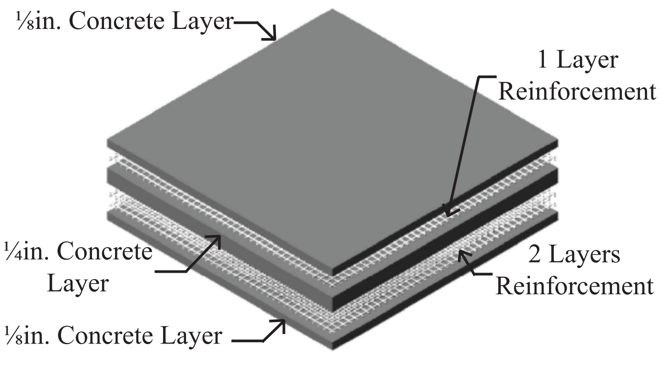


Figure 4: Reinforcement orientation, bottom of the hull

Once the mixture components were chosen, *Forward's* development team altered the water-to-cementitious ratio and cementitious-to-aggregate ratio to achieve a balance between strength, workability, and density. After creating thirty-seven different test mixtures, the development team arrived at the final structural concrete mixture that attained a compressive strength of 855psi and a composite flexural strength of 1,060psi, exceeding structural analysis requirements. Also, at a unit weight of 40.32pcf, the mix was 30% lighter than *Taliesin's* structural mix, leading to a more competitive canoe.

Finally, to enhance *Forward's* aesthetics, dyed mixtures were created using the final structural mixture as a baseline. These mixtures would be used by the construction team to create pre-cast inlay shapes and colored exterior chines. Also, a highly workable, fiberless mixture was developed for use as a finishing mixture. This mixture incorporated a minimal aggregate content to allow for maximum workability to fill voids left on the unfinished surface of *Forward*.

To test the durability of concrete mixtures, a punching shear test was performed on 12in. by 12in. by ½in. composite plates. Four pins supported the corners of the plates, and a crosshead was cyclically applied to the center. A 100lb load was applied to the plate to simulate a static load of one male paddler's knee. The test was then run with the load cycling between 100 and 200lb to model the shift in weight that could occur during the canoe races. To simulate the number of strokes taken during all of the races, the test was run for 1000 cycles. The final structural concrete mixture did not crack during this test, which led the development team to conclude that the mixture was durable enough for the construction of *Forward*.

With the development team's successful completion of a composite concrete section that exceeded the structural analysis requirements and met sustainability goals, construction engineers could now create *Forward*.

Construction

One of the main areas for implementing the theme of sustainability was in mold and prototype construction. Molding procedures from past years employed large volumes of polystyrene, epoxy, fiberglass, and acetone, all of which have adverse environmental impacts. In an effort to reduce the amount of harmful materials used, this year's construction team strived to use as many recycled or by-product materials as possible in prototyping and mold construction.

Forward's flat panel design allowed the construction team to create a prototype without building a mold. To mitigate the prototype's environmental impact, the construction team used plantation-grown plywood, as well as 60% less epoxy and 33% less fiberglass than *Taliesin's* practice canoe. Precise panel shapes were hand plotted and cut with a jig saw. They were then stitched edge to edge with copper wire and covered with one layer of fiberglass and epoxy for rigidity. This construction method is commonly known as "stitch and glue" (Kulczycki, 1993). This intermediate design step allowed the hull design team to verify design goals and make minor modifications prior to mold construction.

To guarantee an accurate hull shape and reduce finishing time, *Forward* was created using an innovative female and male mold system. Placement into a female mold would ensure that the exterior surface of the canoe would accurately match the designed hull shape, giving the expected performance on the water. Also, a smooth and consistent finish would be obtained on the surfaces contacting the mold. Because the individual concrete layers would harden quickly, the team placed the male mold inside the canoe in three- to four-foot sections to generate a consistent finish on workable concrete.

Because this molding method was new to the team, a three-foot mock-up mold was built to test the process. The mock-up produced the expected results, prompting the construction team to accept this new molding method. The construction team also tested the use of tie wires to hold pre-stress wires through the use of a mock-up. The section of the hull with the greatest curve was used for this mock-up to see if 18-gage steel wire could hold pre-stress wires in place during the placement and curing of *Forward*. These mock-up results confirmed the functionality of a tie wire system, allowing mold construction to proceed.

The mold was constructed using twenty-one cross sections cut by hand from reused plywood. These cross sections were nested at 12in. and 6in. offsets on four steel beams, which were reused from old construction tables. The mold skin was made from ¼in. masonite panels, a milling industry by-product made of sawdust. Panels were laid out and cut by hand, then positioned and fastened to the cross sections with a non-toxic construction adhesive. The tie wire system was then fastened through the female mold skin to hold pre-stress in place during the curing process (Section A-A - page 9).

Corresponding male cross sections were hand cut using leftover material from the female cross sections. Masonite was again used to construct a set of male mold panels that were screwed to the male cross sections and sanded to create rounded interior chines. Both molds were covered with an adhesive poly film for mold release. Then, the male mold was cut into sections. Each section was separated into wall panels, chine and bottom panels, and cross sections (Mold Assembly - page 9).

After completing both molds, the focus of the construction team turned to quality control and aesthetics. To gage thickness for the first layer of concrete, ⅛in. ropes were run the length of the female mold. These ropes were positioned to separate the colored chine panel from the bottom and walls (Section A-A - page 9). Similarly, to gage the thickness of the middle layer of concrete, a ¼in. rope was temporarily attached to the second layer of reinforcement in the bottom of the canoe. All team members attended informational sessions prior to placement day to learn assigned tasks and minimize error. Also, to ensure an ideal curing environment for *Forward*, a moisture-controlled humidity tent was constructed. For aesthetic appeal, pre-cast inlay sections were created for the canoe's main logo on the inside of the canoe and team logos on the outside walls.

On placement day, forty team members were divided into mixing and placing teams. Placement teams were further divided into four groups led by experienced team members that were responsible for quality control at each quadrant of the canoe.

Placement began with an ⅛in. layer of concrete followed by two layers of reinforcement. After the reinforcement was worked into the bottom layer of concrete, longitudinal prestress wires were threaded through the tie wires and tensioned. Next, a ¼in. layer of concrete was placed followed by the final layer of reinforcement. Then, the final ⅛in. layer of concrete was placed in 3 to 4ft sections and pieces of the male mold were pressed onto the concrete. Transverse pre-stress wires were then threaded through tie wires at rib locations and tensioned. Finally, ribs were hand-crafted with the use of innovative “rib trowels,” CNC cut by construction team members (Figure 5).

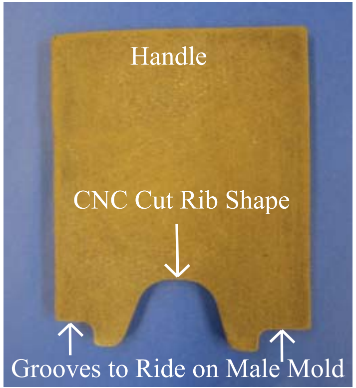


Figure 5: Rib Trowel

After seven days of curing, the male mold was removed from the canoe. Finishing began on the interior of the canoe while the canoe continued to cure inside the female mold. After twenty-eight days, the canoe was flipped and the female mold was removed. To attain a uniformly smooth finish, the team patched and then sanded with 40 to 2000 grit sandpaper. The final step in the finishing process entailed waterproofing *Forward*. The team applied two coats of a penetrating sealer with a sprayer in compliance with the manufacturer’s recommendations.

Project Management

A five person leadership committee was assembled to ensure efficient resource allocation, team communication, and task completion. The primary leadership of the team was delegated to three experienced team members. A construction/hull engineer and a development engineer formed the second level of leadership for the project. Tasks and project progress were discussed through bimonthly meetings and a web-based communication network. All team leaders provided input during the planning process. At the beginning of the project, the primary team leaders identified the specific tasks that would be necessary to complete the project.

Costs and required resources were identified to construct a budget. Anticipated costs were offset by industry and alumni donations, as well as funding from the civil engineering department and the engineering student council. Compared to previous years, the total cost to complete *Forward* was significantly reduced due to the use of recycled and by-product materials.

In an effort to keep the project scope in sight, a project schedule was developed. Previous years’ experiences helped to guide the selection of major milestones, which dictated both the critical path and the necessary supplemental tasks (Table 2). Forty team members devoted a total of 3425 person-hours to complete the project. Of this total, 375 hours were devoted to paddling practice, 2000 to construction, 600 to design and testing, and 450 to meetings and team development.

Milestone	Difference	Explanation
Hull Design	1 Week Early	Efficient Time Usage
Mixture Design	2 Week Delay	Using Many New Materials
Mold Construction	On Schedule	Productive Work Sessions
Placement	On Schedule	Mold Completed on Time

Table 2: Project Milestones

Throughout the design and construction process, a rigorous safety program was an important component of the team working environment. Gloves, dust masks, safety glasses, and proper ventilation were provided at all times. Safety and risk management were discussed at team meetings and during lab experiences.

Effective project management, conscientious material selection, forward thinking, and unprecedented team involvement allowed the team to continue UW-Madison’s tradition of success with *Forward*.

Organizational Chart

Project Manager
Dave Chmielewski
Set project schedule, managed finances, monitored quality assurance, coordinated all engineers.
Involved in all aspects of project.

Project Engineer
Brad Groh
Enforced safety program, organized team meetings, monitored quality assurance, coordinated development engineers.
Involved in all aspects of project.

Project Engineer
Samantha Thompson
Coordinated outreach, monitored quality assurance, coordinated hull and construction engineers.
Involved in all aspects of project.

Development Engineer
Joe Monahan

Developed mixtures, coordinated testing.

Analysis
Jaime Kurten
Ann Thielmann

Testing
Mike Dickey
Jesse Duchow
Jay Hille
Adam Reinbold
Robbie Sivak
Jodi Zwickey

Inlay
Brad Groh
Jaime Kurten
Samantha Thompson

Development Team

Display Stands
Austin Kazda

Display
Nicole Brostowitz
Ivy Harmon
Jodi Zwickey

Cross Section
Kelly Greuel
Austin Kazda
Ann Thielmann
Jodi Zwickey

Aesthetic Display Team

Design Paper
Dave Blodgett
Brad Groh
Jaime Kurten
Samantha Thompson

Oral Presentation
Dave Blodgett
Brad Groh
Ivy Harmon
Jaime Kurten
Joe Monahan
Ann Thielmann
Samantha Thompson

Engineer's Notebook
George Sullivan

Technical Display Team

Fundraising
Jaime Kurten

Hull/Construction Engineer
Dave Blodgett

Designed hull, coordinated prototype and mold construction.

Hull Design
Nicole Brostowitz
Jesse Duchow
Corey Olson

Prototype
Jesse Duchow
Kelly Greuel
Casey Konopacky
Corey Olson
Alex Rexrode

Paddling
Dave Blodgett
Dave Chmielewski
Kelly Greuel
Ivy Harmon
Jaime Kurten
Alex Rexrode

Paddling Team

Mold Construction
Brad Bertram
Kelly Greuel
Ivy Harmon
Corey Olson
Alex Rexrode

Humidity Tent
Arick Groth
Austin Ramme

Placement
Entire Team

Finishing
Entire Team

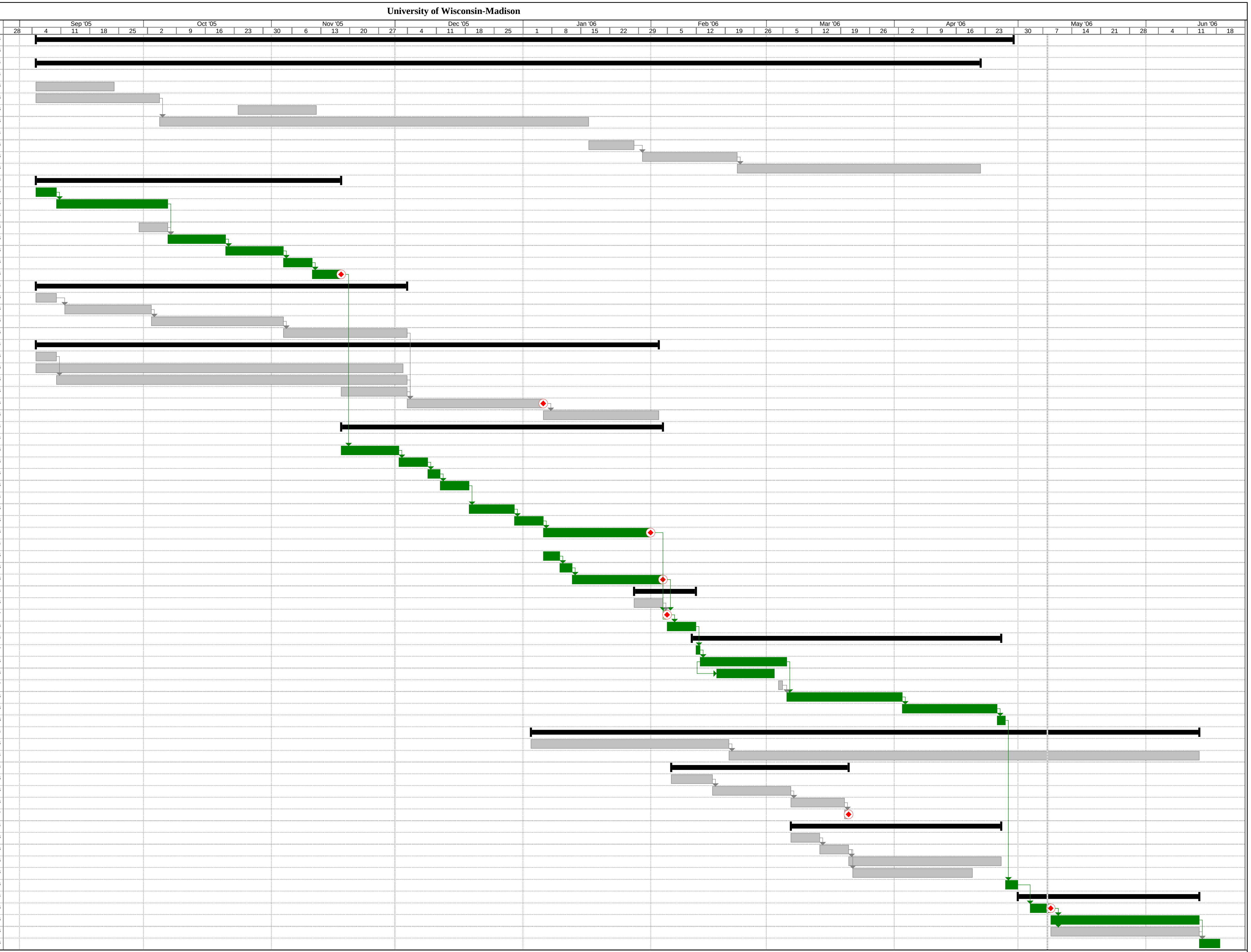
Construction Team

Forward Team

PROJECT SCHEDULE

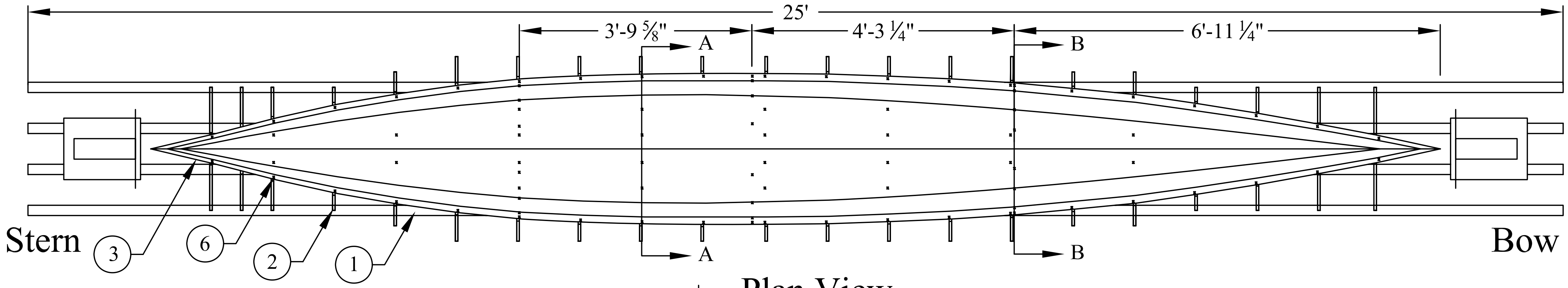
University of Wisconsin-Madison

ID	Task Name	Start	Finish	Duration
1	**Project Duration**	Mon 9/5/05	Sat 4/29/06	235 days
2	Notice to Proceed with Forward	Mon 9/5/05	Mon 9/5/05	0 days
3	**Fundraising**	**Mon 9/5/05**	**Fri 4/21/06**	**227 days**
4	**Fall Semester**	**Mon 9/5/05**	**Mon 1/16/06**	**132 days**
5	1st Polygon Funding Committee Proposal	Mon 9/5/05	Fri 9/23/05	19 days
6	Prepare and Send Donation Letters	Mon 9/5/05	Tue 10/4/05	30 days
7	2nd Polygon Funding Committee Proposal	Mon 10/24/05	Fri 11/11/05	19 days
8	Collect Donations & Send Thank You Letters	Wed 10/5/05	Mon 1/16/06	102 days
9	**Spring Semester**	**Tue 1/17/06**	**Fri 4/21/06**	**95 days**
10	1st Polygon Funding Committee Proposal	Tue 1/17/06	Fri 1/27/06	11 days
11	Contact Companies for Donations	Mon 1/30/06	Tue 2/21/06	23 days
12	Collect Donations & Send Thank You Letters	Wed 2/22/06	Fri 4/21/06	59 days
13	**Hull Design**	**Mon 9/5/05**	**Thu 11/17/05**	**74 days**
14	Preliminary Hull Design	Mon 9/5/05	Fri 9/9/05	5 days
15	HULLS Hull Design	Sat 9/10/05	Thu 10/6/05	27 days
16	**Prototype/Practice Canoe Construction**	**Fri 9/30/05**	**Thu 11/3/05**	**35 days**
17	Material Acquisition	Fri 9/30/05	Thu 10/6/05	7 days
18	Assembly-Prototype	Fri 10/7/05	Thu 10/20/05	14 days
19	Finishing-Prototype	Fri 10/21/05	Thu 11/3/05	14 days
20	Prototype Testing	Fri 11/4/05	Thu 11/10/05	7 days
21	Finalize Hull Design	Fri 11/11/05	Thu 11/17/05	7 days
22	**Analysis**	**Mon 9/5/05**	**Sat 12/3/05**	**90 days**
23	Concepts & Goals of Analysis	Mon 9/5/05	Fri 9/9/05	5 days
24	3-D Model Generation	Mon 9/12/05	Sun 10/2/05	21 days
25	3-D Finite Element Analysis	Mon 10/3/05	Thu 11/3/05	32 days
26	Prestress & Rib Design	Fri 11/4/05	Sat 12/3/05	30 days
27	**Mixture & Reinforcement Design**	**Mon 9/5/05**	**Thu 2/2/06**	**149 days**
28	Concepts & Goals of Mixture Design	Mon 9/5/05	Fri 9/9/05	5 days
29	Material Acquisition	Mon 9/5/05	Fri 12/2/05	89 days
30	Mixture Design: Initial Phase	Sat 9/10/05	Sat 12/3/05	85 days
31	Reinforcement Scheme Design	Fri 11/18/05	Sat 12/3/05	16 days
32	Finalize Structural Mixture & Reinforcement	Sun 12/4/05	Thu 1/5/06	31 days
33	Finishing Mixture Design	Fri 1/6/06	Thu 2/2/06	28 days
34	**Mold Construction**	**Fri 11/18/05**	**Fri 2/3/06**	**76 days**
35	**Construction Mockups**	**Fri 11/18/05**	**Sun 12/18/05**	**31 days**
36	Layout & Construct Mold System	Fri 11/18/05	Thu 12/1/05	14 days
37	Place Concrete & Test Mold System	Fri 12/2/05	Thu 12/8/05	7 days
38	Construct Tie Wire Mockup	Fri 12/9/05	Sun 12/11/05	3 days
39	Place Concrete & Test Tie Wire System	Mon 12/12/05	Sun 12/18/05	7 days
40	**Female Mold Construction**	**Mon 12/19/05**	**Tue 1/31/06**	**42 days**
41	Plot & Cut Cross Sections & Mold Skin Panels	Mon 12/19/05	Thu 12/29/05	10 days
42	Construct Wood Panel Mold	Fri 12/30/05	Thu 1/5/06	6 days
43	Finalize Mold Construction	Fri 1/6/06	Tue 1/31/06	26 days
44	**Male Mold Construction**	**Fri 1/6/06**	**Fri 2/3/06**	**29 days**
45	Hand Cut Cross Sections & Mold Skin Panels	Fri 1/6/06	Mon 1/9/06	4 days
46	Construct Wood Panel Mold	Tue 1/10/06	Thu 1/12/06	3 days
47	Finalize Mold Construction	Fri 1/13/06	Fri 2/3/06	22 days
48	**Placement**	**Sat 1/28/06**	**Sat 2/11/06**	**15 days**
49	Inlay Placement and Curing	Sat 1/28/06	Fri 2/3/06	7 days
50	Forward's Placement Day	Sat 2/4/06	Sat 2/4/06	1 day
51	Cure Concrete	Sun 2/5/06	Sat 2/11/06	7 days
52	**Finishing**	**Sat 2/11/06**	**Wed 4/26/06**	**75 days**
53	Remove Male Mold From Forward	Sun 2/12/06	Sun 2/12/06	1 day
54	Sand-Rough Finish	Mon 2/13/06	Sun 3/5/06	21 days
55	Patch-Imperfections	Fri 2/17/06	Thu 3/2/06	14 days
56	Remove Female Mold From Forward	Sat 3/4/06	Sat 3/4/06	1 day
57	Sand-Intermediate Finish	Mon 3/6/06	Sun 4/2/06	28 days
58	Sand-Final Finish	Mon 4/3/06	Tue 4/25/06	23 days
59	Finalize with Clear Coat & Decals	Wed 4/26/06	Thu 4/27/06	2 days
60	**Paddling**	**Tue 1/3/06**	**Tue 6/13/06**	**162 days**
61	Weight Training	Tue 1/3/06	Sun 2/19/06	48 days
62	Paddling Practice Sessions	Mon 2/20/06	Tue 6/13/06	114 days
63	**Design Paper**	**Mon 2/6/06**	**Mon 3/20/06**	**43 days**
64	Writing Sessions-Rough Draft	Mon 2/6/06	Wed 2/15/06	10 days
65	Critical Review & Revisions	Thu 2/16/06	Mon 3/6/06	19 days
66	Final Draft, Review, & Details	Tue 3/7/06	Sun 3/19/06	13 days
67	Submit Regional Paper	Mon 3/20/06	Mon 3/20/06	1 day
68	**Business Presentation**	**Tue 3/7/06**	**Wed 4/26/06**	**51 days**
69	Concept Generation	Tue 3/7/06	Mon 3/13/06	7 days
70	Writing Sessions	Tue 3/14/06	Mon 3/20/06	7 days
71	Rehearsal & Visuals Development	Tue 3/21/06	Wed 4/26/06	37 days
72	Critical Review & Revisions	Wed 3/22/06	Wed 4/19/06	29 days
73	**Regionals in Madison, WI**	**Fri 4/28/06**	**Sun 4/30/06**	**3 days**
74	**Nationals Preparation**	**Mon 5/1/06**	**Tue 6/13/06**	**44 days**
75	Design Paper Revisions & Submittal	Thu 5/4/06	Mon 5/8/06	5 days
76	Presentation Practice & Improvements	Tue 5/9/06	Tue 6/13/06	36 days
77	Finishing Details	Tue 5/9/06	Tue 6/13/06	36 days
78	**Nationals in Stillwater, OK**	**Wed 6/14/06**	**Sun 6/18/06**	**5 days**

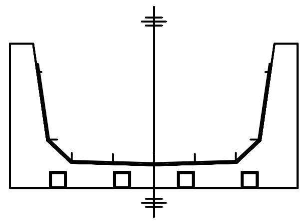


Project: ***Forward***

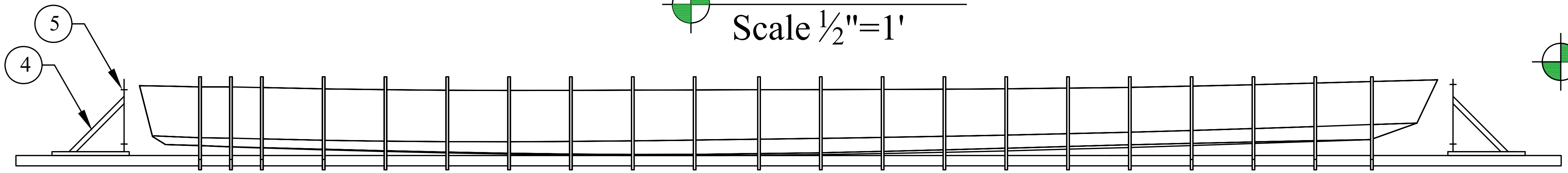
Task	▨	Critical Path	🟩	Milestone	◆	Summary	▬



Plan View
Scale ½"=1'



Rib Cross Section
Scale ½"=1'



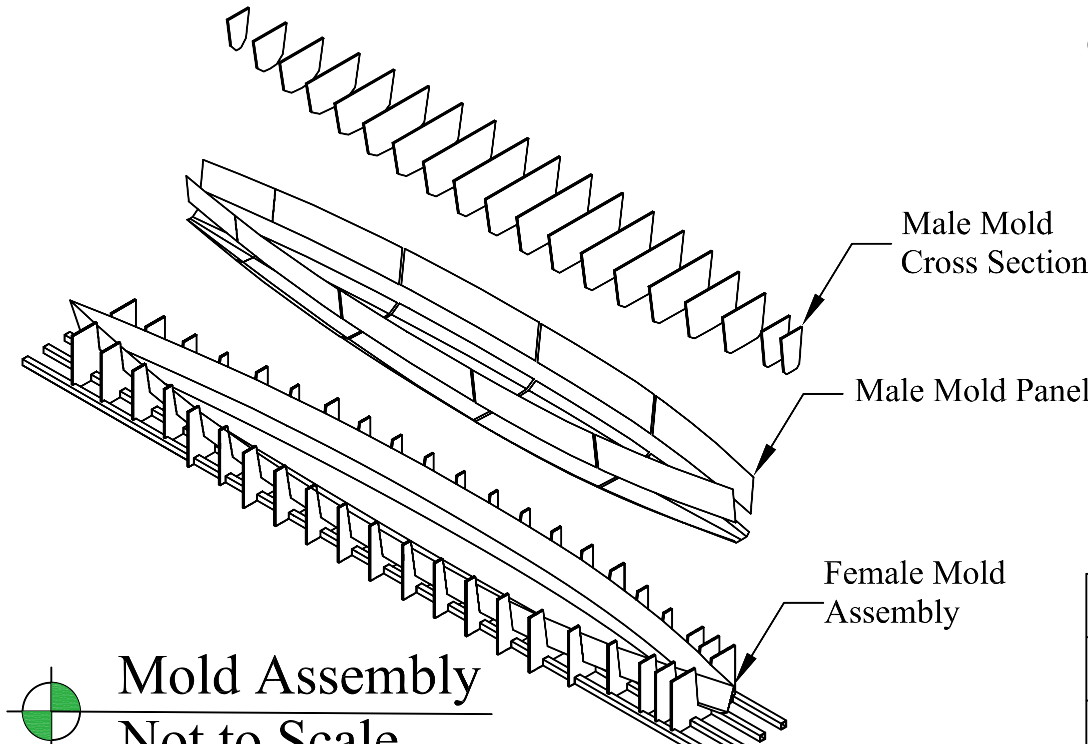
Elevation View
Scale ½"=1'

General Notes:

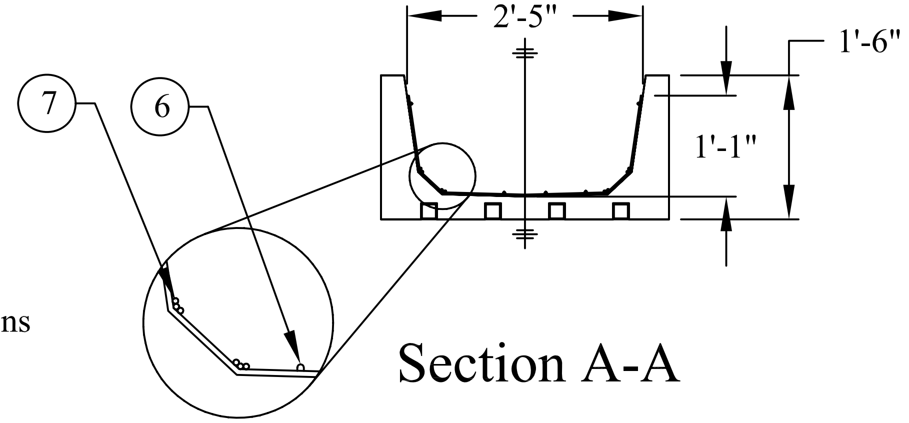
1. Tie wires along the bottom and gunwales are spaced 2' and 1' apart, respectively.

Bill of Materials

No.	Qty.	Description
1	100 LF	2" x 2" Steel Tube
2	80.25 SF	¾" Plywood
3	192 SF	¼" Masonite
4	2 Each	Stanchion
5	6 Each	Turnbuckle
6	14 LF	18 Gage Steel Wire
7	288 LF	⅛" Diameter Rope
8	133 SF	Adhesive Poly-Film
9	1 Each	Construction Adhesive



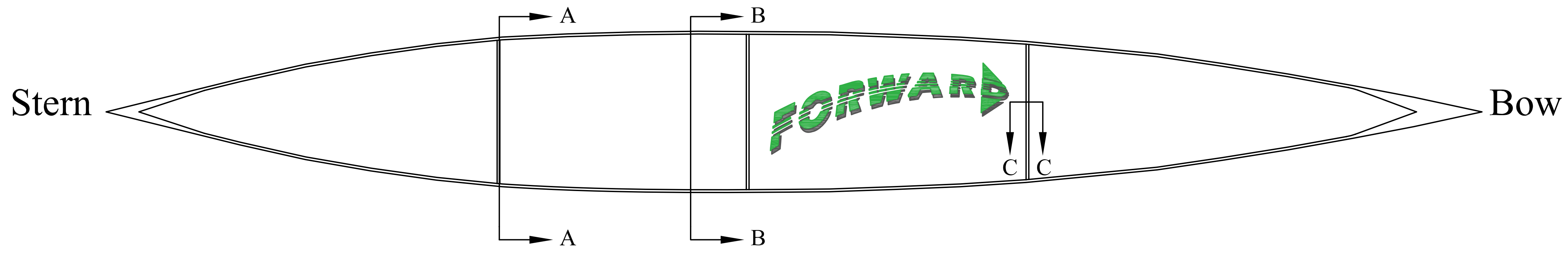
Mold Assembly
Not to Scale



Typical Cross Section
Scale ½"=1'

Project Name:	Forward
Drawing Name:	Mold Design
Date:	May 12, 2006
Sheet Number:	9

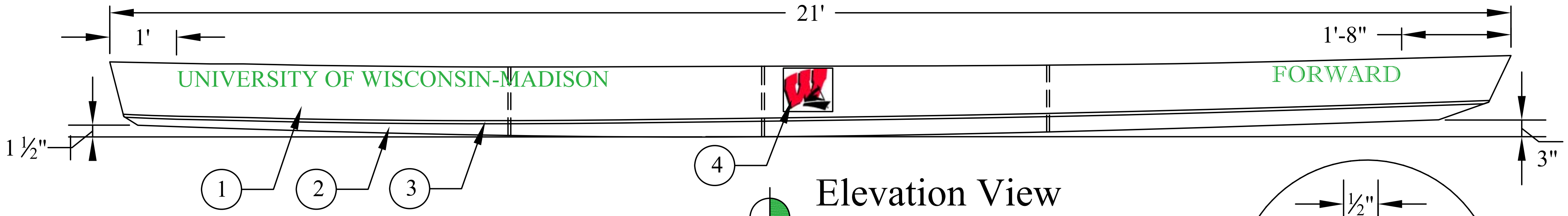
UNIVERSITY OF WISCONSIN MADISON



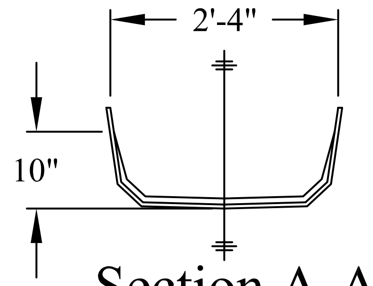
Plan View
Scale ½"=1'

General Notes:

1. The ribs are located at 6'-11 ¼", 11'-2 ½", and 15'-⅛" aft of the bow.
2. Section B-B is at the widest section of the canoe.



Elevation View
Scale ½"=1'

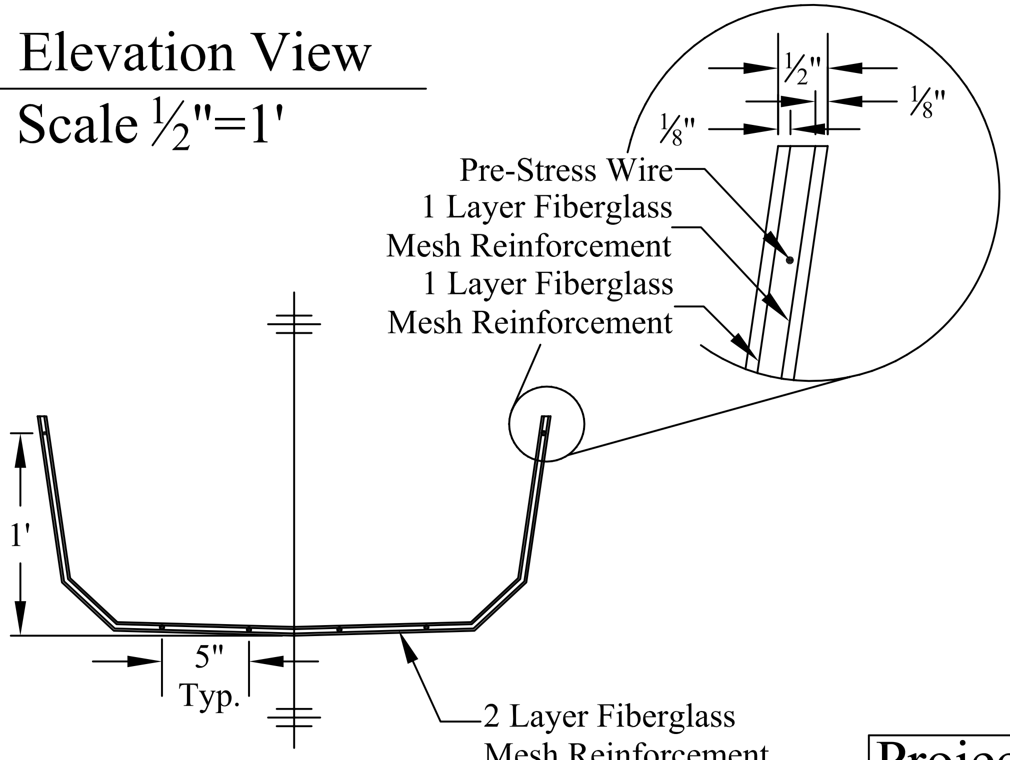


Section A-A

Rib Cross Section
Scale ½"=1'

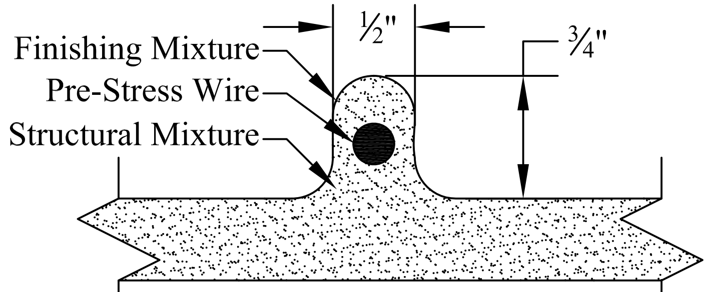
Bill of Materials

No.	Qty.	Description
1	2.37 CF	Structural Concrete Mixture
2	0.19 CF	Dyed Concrete Mixture (Green)
3	0.04 CF	Dyed Concrete Mixture (Black)
4	N/A	Dyed Concrete Mixture (Red)
5	0.17 CF	Finishing Concrete Mixture
6	0.09 CF	Dyed Finishing Mixture (Green)
7	0.02 CF	Dyed Finishing Mixture (Black)
8	N/A	Dyed Finishing Mixture (Red)
9	159 LF	20 Gage Woven Steel Wires
10	168 SF	4.5 Oz/Sq Yd Fiberglass Mesh Reinforcement



Section B-B

Prestress Detail
Not to Scale



Section C-C

Rib Detail
Not to Scale

Project Name:	Forward
Drawing Name:	Hull Design
Date:	May 12, 2006
Sheet Number:	10

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TABLE 3.1.1 - SUMMARY OF MIXTURE PROPORTIONS
MIXTURE DESIGNATION: STRUCTURAL CONCRETE MIXTURE

Batch Size (ft^3): 0.25

		Proportions as Designed		Batched Proportions		Yielded Proportions	
Cementitious Materials	Specific* Gravity	Amount (lb/yd^3)	Volume (ft^3)	Amount (lb)	Volume (ft^3)**	Amount (lb/yd^3)	Volume (ft^3)
1.) Portland Cement Type: III	3.15	241.10	1.23	2.23	11.35	216.04	1.10
2.) Class C/F Fly Ash	2.54	72.98	0.46	0.68	4.26	65.39	0.41
3.) Grade 120 Slag	2.30	158.56	1.10	1.47	10.23	142.08	0.99
Total of All Cementitious Materials		472.64	2.79	4.38	25.84	423.51	2.50
Fibers							
1.) Polypropylene	0.90	5.21	0.09	0.05	0.86	4.67	0.08
Aggregates							
1.) Glass Microspheres Absorption, 0.2% Batched Moisture Content 0.0%	0.20	32.15	2.57	0.30	23.84	28.80	2.31
2.) 1.0mm - 2.0mm Glass Beads Absorption 1-2% Batched Moisture Content 0.0%	0.39	130.76	5.37	1.21	49.73	117.17	4.81
3.) 0.5mm - 1.0mm Glass Beads Absorption 1-2% Batched Moisture Content 0.0%	0.47	122.07	4.16	1.13	38.52	109.38	3.73
4.) 0.25mm - 0.50mm Glass Beads Absorption 1-2% Batched Moisture Content 0.0%	0.59	111.65	3.03	1.03	28.07	100.04	2.72
Total of All Aggregates		396.62	15.14	3.67	140.16	355.39	13.56
Water							
Batched Water	1.00	53.87	0.86	0.50	7.99	48.27	0.77
Free Water from All Aggregates	1.00	0.00	0.00	0.00	0.00	0.00	0.00
Total Water from All Admixtures	1.00	151.27	2.42	1.40	22.44	135.54	2.17
Total Water		205.14	3.29	1.90	30.43	183.81	2.94
Admixtures	% Solids	Amount (fl oz/cwt)	Water‡ in admixture (lb/yd^3)	Amount (fl oz)	Water‡ in admixture (lb)	Amount (fl oz/cwt)	Water‡ in admixture (lb/yd^3)
1.) Air Entrainment	0.0%	3.95		0.17		3.95	
2.) Acrylic Latex	47.0%	874.59	151.27	38.27	1.40	874.59	135.54
Cement-Cementitious Materials Ratio		0.51		0.51			0.51
Water-Cementitious Ratio		0.43		0.43			0.43
Slump, in.		4.00		3.00			3.00
Air Content, %		13.6%		22.2%			22.5%
Density (Unit Weight), lb/ft^3		45.00		40.32			40.32
Gravimetric Air Content, %				22.5%			
Yield, ft^3		27		0.28			27

* For aggregates, specific gravity provided is given by the aggregate supplier

** Volumes are multiplied by a factor of 10^{-3}

‡ Water Content of admixture

TABLE 3.1.2 - SUMMARY OF MIXTURE PROPORTIONS
MIXTURE DESIGNATION: DYED CONCRETE MIXTURES

Batch Size (ft^3): 0.25

		Proportions as Designed		Batched Proportions		Yielded Proportions	
Cementitious Materials	Specific* Gravity	Amount (lb/yd^3)	Volume (ft^3)	Amount (lb)	Volume (ft^3)**	Amount (lb/yd^3)	Volume (ft^3)
1.) Portland Cement Type: III	3.15	235.77	1.20	2.18	11.10	222.93	1.13
2.) Class C/F Fly Ash	2.54	71.37	0.45	0.66	4.17	67.48	0.43
3.) Grade 120 Slag	2.30	155.05	1.08	1.44	10.00	146.61	1.02
Total of All Cementitious Materials		462.18	2.73	4.28	25.27	437.02	2.58
Fibers							
1.) Polypropylene	0.90	5.10	0.09	0.05	0.84	4.82	0.09
Aggregates							
1.) Glass Microspheres Absorption, 0.2% Batched Moisture Content 0.0%	0.20	31.44	2.52	0.29	23.31	29.72	2.38
2.) 1.0mm - 2.0mm Glass Beads Absorption 1-2% Batched Moisture Content 0.0%	0.39	127.87	5.25	1.18	48.63	120.90	4.97
3.) 0.5mm - 1.0mm Glass Beads Absorption 1-2% Batched Moisture Content 0.0%	0.47	119.37	4.07	1.11	37.67	112.87	3.85
4.) 0.25mm - 0.50mm Glass Beads Absorption 1-2% Batched Moisture Content 0.0%	0.59	109.17	2.96	1.01	27.45	103.23	2.80
Total of All Aggregates		387.84	14.80	3.59	137.05	366.73	14.00
Water							
Batched Water	1.00	66.82	1.07	0.62	9.91	63.18	1.01
Free Water from All Aggregates	1.00	0.00	0.00	0.00	0.00	0.00	0.00
Total Water from All Admixtures	1.00	147.92	2.37	1.37	21.94	139.87	2.24
Total Water		214.74	3.44	1.99	31.85	203.05	3.25
Admixtures	% Solids	Amount (fl oz/cwt)	Water‡ in admixture (lb/yd^3)	Amount (fl oz)	Water‡ in admixture (lb)	Amount (fl oz/cwt)	Water‡ in admixture (lb/yd^3)
1.) Air Entrainment	0.0%	3.95		0.17		3.95	
2.) Acrylic Latex	47.0%	874.59	147.92	37.43	1.37	874.59	139.87
3.) Powdered Dye¥	100.0%	2.76	0.00	0.06	0.00	2.76	0.00
Cement-Cementitious Materials Ratio		0.51		0.51			0.51
Water-Cementitious Ratio		0.46		0.46			0.46
Slump, in.		4.00		2.50			2.50
Air Content, %		14.6%		19.4%			19.1%
Density (Unit Weight), lb/ft^3		45.00		42.55			42.55
Gravimetric Air Content, %				19.1%			
Yield, ft^3		27		0.26			27

* For aggregates, specific gravity provided is given by the aggregate supplier

** Volumes are multiplied by a factor of 10^{-3}

‡ Water Content of admixture

¥ Proportions as Designed & Yielded Proportions listed as % of cementitious materials. Batched Proportions listed in lb.

TABLE 3.1.3 - SUMMARY OF MIXTURE PROPORTIONS
MIXTURE DESIGNATION: FINISHING CONCRETE MIXTURE

Batch Size (ft^3): 0.25

		Proportions as Designed		Batched Proportions		Yielded Proportions	
Cementitious Materials	Specific* Gravity	Amount (lb/yd^3)	Volume (ft^3)	Amount (lb)	Volume (ft^3)**	Amount (lb/yd^3)	Volume (ft^3)
1.) Portland Cement Type: III	3.15	309.07	1.57	2.86	14.55	277.62	1.41
2.) Class C/F Fly Ash	2.54	93.56	0.59	0.87	5.46	84.04	0.53
3.) Grade 120 Slag	2.30	203.26	1.42	1.88	13.11	182.58	1.27
Total of All Cementitious Materials		605.89	3.58	5.61	33.12	544.24	3.21
Fibers							
1.) Polypropylene	0.90	0.00	0.00	0.00	0.00	0.00	0.00
Aggregates							
1.) Glass Microspheres Absorption, 0.2% Batched Moisture Content 0.0%	0.20	31.56	2.53	0.29	23.40	28.35	2.27
2.) 1.0mm - 2.0mm Glass Beads Absorption 1-2% Batched Moisture Content 0.0%	0.39	128.37	5.27	1.19	48.82	115.31	4.74
3.) 0.5mm - 1.0mm Glass Beads Absorption 1-2% Batched Moisture Content 0.0%	0.47	119.84	4.08	1.11	37.82	107.65	3.67
4.) 0.25mm - 0.50mm Glass Beads Absorption 1-2% Batched Moisture Content 0.0%	0.59	109.61	2.98	1.01	27.55	98.45	2.67
Total of All Aggregates		389.38	14.86	3.61	137.60	349.75	13.35
Water							
Batched Water	1.00	128.43	2.06	1.19	19.05	115.36	1.85
Free Water from All Aggregates	1.00	0.00	0.00	0.00	0.00	0.00	0.00
Total Water from All Admixtures	1.00	148.50	2.38	1.38	22.03	133.39	2.14
Total Water		276.94	4.44	2.56	41.08	248.76	3.98
Admixtures	% Solids	Amount (fl oz/cwt)	Water‡ in admixture (lb/yd^3)	Amount (fl oz)	Water‡ in admixture (lb)	Amount (fl oz/cwt)	Water‡ in admixture (lb/yd^3)
1.) Air Entrainment	0.0%	0.25		0.01		0.25	
2.) Acrylic Latex	47.0%	669.78	148.50	37.58	1.38	669.78	133.39
Cement-Cementitious Materials Ratio		0.51		0.51			0.51
Water-Cementitious Ratio		0.46		0.46			0.46
Slump, in.		8.00		6.50			6.50
Air Content, %		7.9%		17.0%			17.3%
Density (Unit Weight), lb/ft^3		52.00		46.71			46.71
Gravimetric Air Content, %				17.3%			
Yield, ft^3		27		0.28			27

* For aggregates, specific gravity provided is given by the aggregate supplier

** Volumes are multiplied by a factor of 10^{-3}

‡ Water Content of admixture

TABLE 3.1.4 - SUMMARY OF MIXTURE PROPORTIONS
MIXTURE DESIGNATION: DYED FINISHING MIXTURES

Batch Size (ft^3): 0.25

		Proportions as Designed		Batched Proportions		Yielded Proportions	
Cementitious Materials	Specific* Gravity	Amount (lb/yd^3)	Volume (ft^3)	Amount (lb)	Volume (ft^3)**	Amount (lb/yd^3)	Volume (ft^3)
1.) Portland Cement Type: III	3.15	302.95	1.54	2.81	14.26	275.68	1.40
2.) Class C/F Fly Ash	2.54	91.70	0.58	0.85	5.35	83.45	0.53
3.) Grade 120 Slag	2.30	199.24	1.39	1.84	12.85	181.31	1.26
Total of All Cementitious Materials		593.89	3.51	5.50	32.47	540.44	3.19
Fibers							
1.) Polypropylene	0.90	0.00	0.00	0.00	0.00	0.00	0.00
Aggregates							
1.) Glass Microspheres Absorption, 0.2% Batched Moisture Content 0.0%	0.20	30.93	2.48	0.29	22.94	28.15	2.25
2.) 1.0mm - 2.0mm Glass Beads Absorption 1-2% Batched Moisture Content 0.0%	0.39	125.83	5.17	1.17	47.85	114.50	4.70
3.) 0.5mm - 1.0mm Glass Beads Absorption 1-2% Batched Moisture Content 0.0%	0.47	117.47	4.00	1.09	37.07	106.89	3.64
4.) 0.25mm - 0.50mm Glass Beads Absorption 1-2% Batched Moisture Content 0.0%	0.59	107.43	2.92	0.99	27.01	97.76	2.65
Total of All Aggregates		381.66	14.57	3.53	134.87	347.31	13.26
Water							
Batched Water	1.00	137.33	2.20	1.27	20.37	124.97	2.00
Free Water from All Aggregates	1.00	0.00	0.00	0.00	0.00	0.00	0.00
Total Water from All Admixtures	1.00	145.56	2.33	1.35	21.59	132.46	2.12
Total Water		282.89	4.53	2.62	41.96	257.43	4.12
Admixtures	% Solids	Amount (fl oz/cwt)	Water‡ in admixture (lb/yd^3)	Amount (fl oz)	Water‡ in admixture (lb)	Amount (fl oz/cwt)	Water‡ in admixture (lb/yd^3)
1.) Air Entrainment	0.0%	0.25		0.01		0.25	
2.) Acrylic Latex	47.0%	669.78	145.56	36.83	1.35	669.78	132.46
3.) Powdered Dye¥	100.0%	2.76	0.00	0.07	0.00	2.76	0.00
Cement-Cementitious Materials Ratio		0.51		0.51			0.51
Water-Cementitious Ratio		0.48		0.48			0.48
Slump, in.		8.00		7.50			7.50
Air Content, %		9.0%		17.3%			17.1%
Density (Unit Weight), lb/ft^3		52.00		47.32			47.32
Gravimetric Air Content, %				17.1%			
Yield, ft^3		27		0.27			27

* For aggregates, specific gravity provided is given by the aggregate supplier

** Volumes are multiplied by a factor of 10^{-3}

‡ Water Content of admixture

¥ Proportions as Designed & Yielded Proportions listed as % of cementitious materials. Batched Proportions listed in lb.

Concrete Aggregate: Glass Microspheres

Sample Weight: 315.4 g

Specific Gravity (G_s): 0.20

Fineness Modulus: 0.01

Sieve	Diameter (mm)	Weight Retained (g)	Cumulative Weight Retained (g)	Percent Finer (%)
3/8 inch	9.50	0.0	0.0	100%
No. 4	4.75	0.0	0.0	100%
No. 8	2.36	0.0	0.0	100%
No. 16	1.18	0.0	0.0	100%
No. 30	0.60	0.0	0.0	100%
No. 50	0.30	0.0	0.0	100%
No. 100	0.15	2.9	2.9	99%
P 100	0.00	311.9	314.8	0%

Concrete Aggregate: 1.0mm - 2.0mm Glass Beads

Sample Weight: 312.5 g

Specific Gravity (G_s): 0.39

Fineness Modulus: 3.56

Sieve	Diameter (mm)	Weight Retained (g)	Cumulative Weight Retained (g)	Percent Finer (%)
3/8 inch	9.50	0.0	0.0	100%
No. 4	4.75	0.0	0.0	100%
No. 8	2.36	0.0	0.0	100%
No. 16	1.18	176.9	176.9	43%
No. 30	0.60	132.4	309.4	1%
No. 50	0.30	3.1	312.5	0%
No. 100	0.15	0.0	312.5	0%
P 100	0.00	0.0	312.5	0%

Concrete Aggregate: 0.5mm - 1.0mm Glass Beads

Sample Weight: 309.8 g

Specific Gravity (G_s): 0.47

Fineness Modulus: 2.66

Sieve	Diameter (mm)	Weight Retained (g)	Cumulative Weight Retained (g)	Percent Finer (%)
3/8 inch	9.50	0.0	0.0	100%
No. 4	4.75	0.0	0.0	100%
No. 8	2.36	0.0	0.0	100%
No. 16	1.18	0.0	0.0	100%
No. 30	0.60	206.5	206.5	33%
No. 50	0.30	100.2	306.6	1%
No. 100	0.15	3.2	309.8	0%
P 100	0.00	0.0	309.8	0%

Concrete Aggregate: 0.25mm - 0.50mm Glass Beads

Sample Weight: 315.5 g

Specific Gravity (G_s): 0.59

Fineness Modulus: 1.93

Sieve	Diameter (mm)	Weight Retained (g)	Cumulative Weight Retained (g)	Percent Finer (%)
3/8 inch	9.50	0.0	0.0	100%
No. 4	4.75	0.0	0.0	100%
No. 8	2.36	0.0	0.0	100%
No. 16	1.18	0.0	0.0	100%
No. 30	0.60	0.0	0.0	100%
No. 50	0.30	292.9	292.9	7%
No. 100	0.15	22.6	315.5	0%
P 100	0.00	0.0	315.5	0%

Concrete Aggregate: Composite Aggregate Blend (All Mixtures)

Sample Weight: 500.0 g

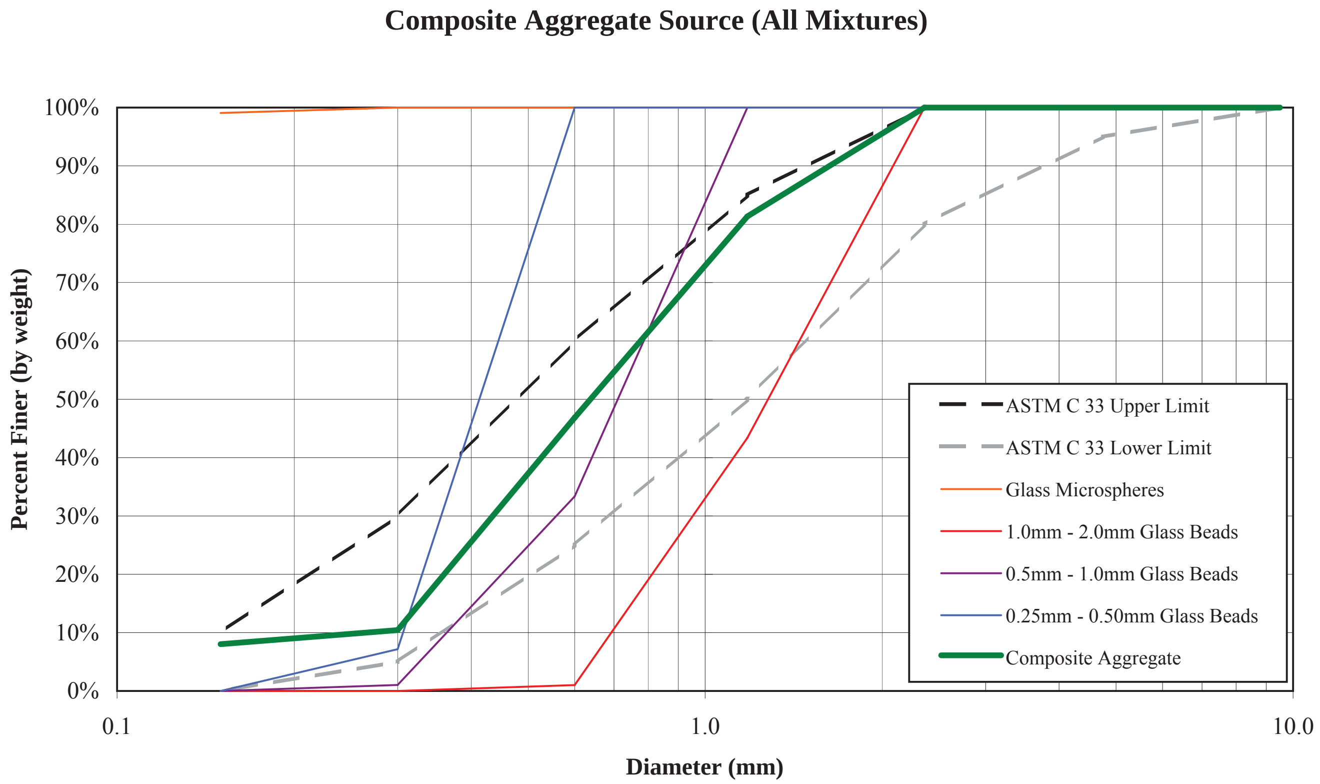
Specific Gravity (G_s): -

Fineness Modulus: 2.53

Aggregate	Oven Dry Weight (g)
1.) Glass Microspheres	40.53
2.) 1.0mm - 2.0mm Glass Beads	164.84
3.) 0.50mm - 1.0mm Glass Beads	153.89
4.) 0.25mm - 0.50mm Glass Beads	140.74

Percent Finer (%)

Sieve	Glass Microspheres	1.0mm - 2.0mm Glass Beads	0.5mm - 1.0mm Glass Beads	0.25mm - 0.50mm Glass Beads	Composite
3/8 inch	100%	100%	100%	100%	100.0%
No. 4	100%	100%	100%	100%	100.0%
No. 8	100%	100%	100%	100%	100.0%
No. 16	100%	43%	100%	100%	81.3%
No. 30	100%	1%	33%	100%	46.8%
No. 50	100%	0%	1%	7%	10.4%
No. 100	99%	0%	0%	0%	8.0%
P 100	0%	0%	0%	0%	0.0%



Note:

Composite Blend is 8% Glass Microspheres, 33% 1.0mm - 2.0mm Glass Beads, 31% 0.5mm - 1mm Glass Beads, 28% 0.25mm - 0.5mm Glass Beads