California Polytechnic State University, San Luis Obispo

Big Sur

Concrete Canoe Design Report 2008

Table of Contents

Big Sur Specifications

Total Weight ....174 lbs
Length .... 19' 10"
Maximum Width ....29"
Maximum Depth ....14"
Average Thickness ....0.50"
Color ....White
Reinforcement:
Fiberglass, carbon fiber, steel cable

Structural Concrete Properties

Unit Weight .... 53.5 pcf
Compressive Strength ....2090 psi
Tensile Strength ....375 psi

Middle Concrete Properties

Unit Weight .... 46.0 pcf
Compressive Strength ....1320 psi
Tensile Strength ....160 psi

Composite Flexural Strength ....1290 psi
Note: Strengths reported are 28 day

Executive Summary

California Polytechnic State University, often referred to as "Cal Poly," is a four-year public university located in San Luis Obispo, California. The school is home to seven distinct colleges and numerous award-winning programs, all of which practice the university-wide "learn by doing" philosophy. In 2008, Cal Poly was named the best public undergraduate-masters university in the Western United States for the 15th consecutive year. The Civil Engineering Department also ranked as the second best public non-doctoral program in the nation [U.S. News and World Report 2007].

Cal Poly competes against 16 other universities in the Pacific Southwest Region (PSWR). The school has had a strong showing at the regional level, placing first in the canoe event eight of the last ten years. More recently, the canoes *Katana* (2006) and *MC Escher* (*MCE*) (2007) placed 2nd and 5th respectively at the national competition. *MCE* also earned the ACI Award for Excellence in Design for its elaborate tile mosaic inlay.

Over the past two years at the national competition, the team placed 1st and 2nd in final product, 1st in a co-ed sprint, and 6th in presentation. This year's captains aspired to continue the traditions established by previous teams, while refining all aspects of the project. The team focused on constructing a final product worthy of the last two years, reducing the overall weight for racing, and improving the presentation and paper.

A general theme of California landmarks was chosen with an emphasis on Big Sur, a beautiful coastal region north of San Luis Obispo. The canoe was named Big Sur in honor of this area. A mosaic with 148 unique tiles was built and placed inside the hull, and a detailed motif was stained on the outside of Big Sur. An innovative feature of this canoe was a dual mold release system that significantly reduced sanding and shrinkage cracks. These features helped the team build an attractive canoe that improved over previous Cal Poly entries.

A lighter canoe was achieved by designing a cutting edge low unit weight concrete. An all glass sphere aggregate gradation, varied mixing techniques, and the addition of polyvinyl alcohol fibers contributed to a 33% reduction in concrete unit weight and an overall decrease in weight of 61 lbs from *MCE*.

This year's goals were met through hard work, dedication and collaboration among the seven team captains. New friends were made, new skills and life lessons learned, and everyone gained the experience of working as part of a team. Overall, this year was a success in all measures of the word.

Hull Design

The first step of the design process required research of hull characteristics and the comparison and evaluation of previous canoe performance. *MCE* was chosen as the base hull shape because of its race performance and similar dimensional requirements.

The primary hull design goal was to create a canoe with higher initial stability than *MCE* because of several inexperienced paddlers on this year's team. A secondary goal was to find a balance between tracking and maneuverability to improve race times.

The main factor contributing to the stability of canoes is the shape of the hull. Curved bottom canoes have high secondary stability and feel more stable as the canoe begins to move [CanoeRoots 2003]. Flat bottomed canoes have higher initial stability with greater righting arms (Figure 1) and are generally favored by less experienced paddlers.

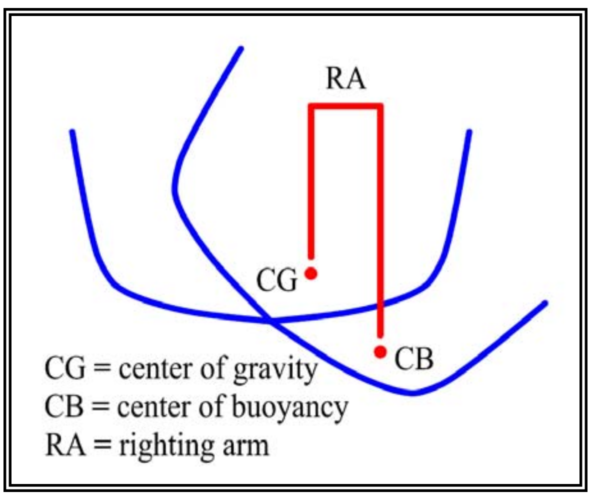


Figure 1: Righting Arm Diagram

The hull design from *MCE* was altered to give Big Sur a flatter hull providing higher initial stability without sacrificing all the benefits of a curved hull.

The secondary goal of balancing maneuverability and tracking was utilized to increase turning speeds while not hindering the ability to maintain a straight path. These characteristics are inversely proportional, but both are directly related to rocker size and waterline length. A small rocker improves tracking and reduces wave drag, while a large rocker increases maneuverability and turning speed [Holtrop 2004]. An effort was made to increase the slalom course turning speed by changing the bow rocker from 3" to 4" as seen in Table 1. The stern rocker was sized at 2.25", the same as *MCE*. A soft chine was chosen to increase tracking, creating a compromise between tracking and maneuverability.

Straight-line speed was considered to be largely dependent on length to beam (L/B) ratio and wetted surface area [Winters 1998]. The length and width were relatively fixed by the rule requirements, so the L/B ratio did not play an active role in design. Two factors that contributed to wetted surface area were weight and hull width. The limited width and variable paddler load cases created a wetted surface area that hull design had little control over.

The hull shape was tested after construction of the practice canoe. Paddlers felt the initial stability was not adequate, therefore, the hull bottom was widened by 2", creating a flatter surface with higher initial stability.

The hull was designed using ProLines7™. This program allowed for accurate design without drawing individual lines. The hull shape was easily exported into SolidWorks™ for milling and then to ABAQUS™ for analysis.

Table 1: Canoe Specifications

	Big Sur	MCE
Length	19'10"	19'11"
Maximum Beam	29"	28"
Maximum Height	14"	14.30"
Splash Guard	4"	4"
Bow Rocker	4"	3"
Stern Rocker	2.25"	2.25"
Cross Section		

Analysis

The goal of the analysis team was to provide the maximum compressive and tensile stresses on the canoe to the mix design team. This was accomplished by modeling Big Sur in the finite element program ABAQUS™.

Analyzing the stresses required an assumption about the modulus of elasticity to make the analysis feasible. Making this assumption was difficult because the cross-section included layers of mesh and concrete that behaved differently than the individual components. The composite modulus of elasticity varied in compression, tension, and in differing orientations. The value was calculated based on the deflection of a simply supported composite plate under multiple loads. The plate and loads were modeled in ABAQUS™ and the modulus of elasticity was varied until the theoretical and experimental displacements matched. This produced a reasonable modulus of elasticity of 730 ksi.

Importing the hull shape from SolidWorks™ to ABAQUS™ allowed the canoe to be modeled as a 3/8" shell with a Poisson ratio of 0.16 and the above mentioned modulus of elasticity. An elastic foundation was applied to the exterior surface of the canoe to model the boundary conditions for the races.

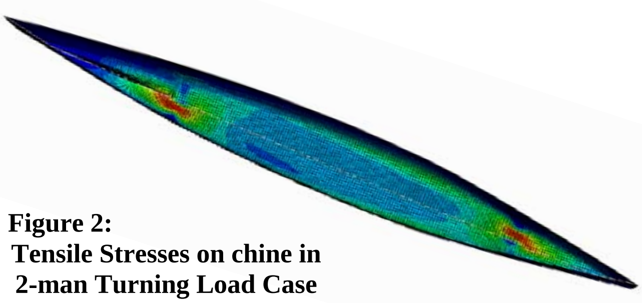


Figure 2:
Tensile Stresses on chine in 2-man Turning Load Case

Paddlers were modeled as pressure forces applied over a square area approximately 12" by 6". The net force for males was 225 pounds and for females was 150 pounds in all cases. The turning load cases were analyzed by shifting two thirds of an individual paddler's weight to one side based on paddler input.

A computerized mesh with a relative seed size of 1" was applied to the canoe based on a mesh convergence study with the four person load case. After the initial four person load case was run, eleven additional load cases were analyzed and are summarized in Table 2.

Table 2: Load Case Descriptions

Load Case	Description
Transport	Simply supported at the ends
Stands	2 pressure supports 40" and 200" from the bow
2 Person (male/female)	2 paddlers 67" and 200" from the bow
3 Person (male/female)	3 paddlers 67", 119", and 200" from the bow
4 Person	2 male paddlers at 67" and 200" with 2 female paddlers at 108" and 156" from the bow
Turning (5 cases)	Same as previous cases, front and rear paddlers leaning in opposite directions

The two man turning load case produced the highest compressive stress of 505 psi and the highest tensile stress of 285 psi. This load created the worst case scenario for several reasons, the major reason being the additional torque on the canoe. The additional torque comes from paddlers shifting their weight in opposite directions, thereby increasing the stress concentrations on the chine (Figure 2). The stresses in the three man and four person turning cases were lower because the paddler weights in the middle of the canoe negated some of the effects of the torque. Overall, the resulting stresses were higher than last year's design, but the results were well within reasonable expectations. The results from the two man turning load case were set as a goal for the mix design team to achieve.

Swamp test results from the practice canoe indicated the need for bulkheads even though the unit weight of the concrete was less than water. Bulkheads were designed as non-structural elements for Big Sur with a length based on past experience.

Development and Testing

The primary goal of the mix design team was to design a structurally adequate concrete with a unit weight lower than water. Secondary goals were the workability, color and crack resistance of the concrete. Achieving these goals required the mix design team to focus on testing mix component properties, mixing time and rate, and composite mixtures. A total of 45 mixes were tested to find the best combination of unit weight and strength.

The structural mix and reinforcement scheme from last year's canoe, *MCE*, was used as a baseline because of the proven strength and white color. *MCE*'s mix featured Type I portland white cement, slag, and a pozzolan (VCAS micronHS). The aggregate gradation was comprised of expanded shale and glass spheres. Admixtures included shrinkage reducer, superplasticizer, and latex for added flexibility.

The reinforcement scheme from *MCE* had two layers of fiberglass and one layer of carbon fiber mesh. The fiberglass mesh had an open area of 60.1%, while the carbon fiber was 62.5%. The same scheme was used for Big Sur because of the success in integrating tiles and reinforcement.

Initial testing concentrated on the types and ratios of cementitious materials and gradation of aggregates. Fly ash, slag, and VCAS were the cementitious materials researched and tested while Type I portland white cement and a baseline aggregate gradation remained constant. Unit weight, color, compressive strength (ASTM C 109), tensile strength (ASTM C 496), and flexural strength (ASTM C 947) were evaluated during the process. Fly ash was eliminated due to its dark grey color. The percentages of slag and VCAS were varied systematically with an upper bound of 40% cement replacement. Higher percentages of slag yielded higher 7-day strengths, but higher unit weights. Specimens with a higher percentage of VCAS had reduced 7-day strengths, higher 28-day strengths and a lower unit weight. A combination of 60% cement, 28% VCAS, and 12% slag proved to be the best combination of 28-day strengths and unit weight.

Figure 3: Tile Plate Testing

A concurrent step in the design process established aggregate material properties used to test various gradations. Glass spheres have been an integral part of the aggregate gradation for multiple canoes, but issues have developed in determining the particle size, specific gravity, and absorption. A sieve analysis on each glass sphere diameter range provided individual gradation curves used in the overall gradation of aggregates. After the particle size was

Table 3: Concrete and Composite Plate Properties

	MCE Structural Mix	Big Sur Structural Mix	Big Sur Middle Mix	Big Sur Composite Plate
Unit Weight	74.0 pcf	53.5 pcf	46.0 pcf	N/A
Compressive Strength (28-day)	2740 psi	2090 psi	1320 psi	N/A
Tensile Strength (28-day)	640 psi	375 psi	160 psi	645 psi
Flexural Strength (28-day)	N/A	N/A	N/A	1290 psi
ABAQUS™ Compressive Strength	108 psi	505 psi	205 psi	N/A
ABAQUS™ Tensile Strength	100 psi	285 psi	95 psi	285 psi

determined, a pycnometer was used to find the specific gravity of fine aggregates per ASTM C 128. The pycnometer was modified by gluing a fine wire mesh at the base of the lid keeping the glass spheres fully submerged in water. The rate of absorption was determined by taking readings at specified time intervals. An absorption rate of 6% by mass was used based on the results at 20 minutes. This matched the time that the concrete density was tested and provided a reasonable absorption rate.

A better understanding of the material properties allowed the team to design accurate aggregate proportions. Batches were made varying the quantities of expanded shale and glass spheres. Expanded shale was eliminated from testing because gradations containing only glass spheres produced low unit weights and adequate 7-day compressive strengths. The team created two different gradations: one for finished surfaces, and one for the middle layer. The finished surface gradation contained smaller aggregate providing higher strengths and a smoother finish. Coincidentally, this mix also proved to have the best workability. The middle layer contained a coarser aggregate gradation utilizing the lighter, larger spheres and removing the heavier 0.1-0.3 mm glass spheres.

After cementitious materials and aggregate gradations were established, further testing included fibers and admixtures. Multiple sizes of polypropylene and polyvinyl alcohol (PVA) fibers were tested to increase tensile strength, increase flexural strength, and reduce cracking. PVA fibers of 8 mm length were chosen because of increased strength and limited impact on workability. The PVA fiber dosage matched the manufacturer's recommendation of 2 lb/yd^3.

MCE's mix provided the basis for the admixtures for Big Sur. A superplasticizer was used to increase the workability of the concrete without sacrificing strength. The dosage was less than the manufacturer's recommendation because the mixes had sufficient workability with a water to cementitious materials ratio of 0.28. The use of PVA fibers aided in crack control, and allowed a lower than recommended dosage of shrinkage reducer. Styrene butadiene latex was added to improve the flexural strength of the concrete. The dosage was less than the recommendation in ACI 548.3R because the recommended value hindered workability.

Table 4: Admixture Dosages

Admixture	Dosage (fl.oz/cwt)	Recommendation (fl.oz/cwt)
ADVA 100	6.69	10.0
Eclipse Plus	12.64	16.0
Latex	410.20	570.0

Additional color pigments were tested for appearance in the structural mix for use in precast tile construction. The pigments used in *MCE* were chosen for Big Sur because of their vibrant colors. A total of sixteen colors were created by varying the amounts of pigments in each mix.

The final step in the concrete testing process was varying mixing rate and time to achieve the desired air content. Precision mixing with a KitchenAid® mixer allowed the team to create concrete with different air contents. The middle layer, with lower stresses, was designed with higher air content to reduce weight. The structural surface layers had lower air contents to increase strengths and aid in finishing.

The final composite section featured the structural mix on the bottom layer followed by a layer of carbon fiber and fiberglass mesh. The middle layer was worked through the reinforcement to bind with the first layer. Precast tile reinforcement was included in the top layer, with the structural mix applied flush to the tiles. The precast nature of the tiles created multiple cold joints. Testing of a tile plate resulted in strengths consistent with a control plate. These results and previous experience helped determine that the cold joints were not a major concern.

Although the final canoe design includes bulkheads, the primary goal of reaching a unit weight lower than water was achieved. The mix met the structural requirements from analysis and also had the desired workability for construction.

Construction

The construction team's goals were to maintain consistent hull shape, decrease initial surface roughness, integrate a tile mosaic, and implement effective quality control measures. These goals helped achieve a sleek, light weight canoe with numerous decorative features.

Consistent hull shape and decreased surface roughness were achieved through the use of a female mold along with a new mold release technique. A female mold was required for hand placement of the precast tile mosaic. The mold was constructed of expanded polystyrene foam blocks because they were inexpensive and easy to mill using a computer numerically controlled (CNC) machine. The foam unit weight was increased from last year's 1 pcf to 2 pcf, which created a finer surface and a notable reduction in mold imperfections. A total of six blocks were used, limiting the number of transitions and decreasing the inconsistencies in the hull shape. The blocks were individually milled and sanded to remove small ridges left by the CNC machine.

Plaster and paint were initially considered for the mold liner and release agent. However, the application of these materials resulted in a less consistent surface and increased labor. The construction team discussed an alternative solution to avoid these issues. Desirable mold liner qualities were uniform application, foam protection, and a smooth final surface. Various materials were tested for these characteristics on sample cross sections. A polyurethane coating was chosen because it protected the foam and provided a hard surface to place concrete on. Multiple release agents including oil, latex, wax, and contact paper were tested with the polyurethane lining. Contact paper was chosen because it provided a glossy finish and allowed the canoe to release from the contact paper or the paper to release from the lining.

Several steps were taken to implement this dual mold release system. Individual blocks were sprayed with a uniform polyurethane coating and glued together to complete the hull shape. A wooden support frame was built around the blocks to prevent them from shifting on the construction table. After the blocks were connected, contact paper was applied, providing a smooth finished surface (Figure 4). The dual release system reduced the finishing time without sacrificing consistency.

Figure 4: Dual Mold Release System

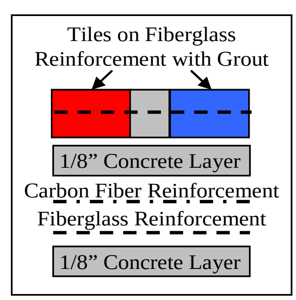
Tile mosaic design started in September with the use of Adobe Illustrator™. The California landmark theme was incorporated into the design through 148 tiles. After a design was created, the tile mosaic construction process began. A single layer of 1/16" craft foam was cut out and placed on the underside of a previous canoe, which provided a casting surface similar to the hull of Big Sur. A layer of fiberglass mesh was then placed on top of the foam followed by a double layer of cut out foam, providing the finished thickness. Concrete was placed and vibrated through the mesh two weeks prior to canoe construction. This time frame allowed the concrete tile mosaic to gain strength for placement.

Figure 5: Tile Construction

Foam tile mold

Individual concrete tile

Finished tile mosaic



Final cross section

Construction quality control began with preparation for construction day. The foam was removed from the tile mosaic and the spaces were cleaned for unobstructed placement of concrete. Control over final thickness of the canoe was important to reduce weight and keep a consistent inside hull shape. Wooden blocks were extended 1/2" from the inside of the mold at 11" intervals serving as final thickness gauges. The spacing of the blocks provided sufficient length for a trowel to finish the inside of the canoe.

On construction day, team captains supervised the quality control of mixing, placing, and finishing. Construction captains instructed student volunteers on proper placing techniques before placing the first concrete layer. The initial layer was checked for thickness using marked toothpicks and 1/8" steel cable to achieve a uniform layer. After placing the initial layer, fiberglass and carbon fiber reinforcement were set inside the hull, followed by the second concrete layer. A steel cable was placed 1" below the top edge of the canoe and provided additional strength. The tile mosaic with reinforcement was then grouted in place with the final layer of concrete. Designated experienced volunteers troweled the final canoe surface, while others vibrated concrete through the tile spacing.

Figure 6: Concrete Placement

After construction, wet burlap and plastic were placed over the canoe for curing. Interior sanding and staining were completed with the canoe in the mold. The canoe was de-molded after four weeks and the outside surface was sanded. Following the manufacturer's recommendations, two coats of stain and sealer were applied to the outside of Big Sur. The final canoe featured a consistent, smooth hull shape, an integrated tile mosaic, and elaborate stain designs, creating a canoe that exceeded expectations.

PROJECT MANAGEMENT

A project manager, two construction captains and four mix design captains determined the scope for Big Sur. The organizational structure was based on multiple years experience. Weekly meetings ensured that tasks were equally distributed, completed on time, and maintained high quality.

Expected costs were tabulated to create the budget. Funding was comprised of industry, individual, and university donations. The majority of the budget was allocated to the construction and mix design teams for procurement of materials with individual expenditures approved at the weekly meetings.

The project schedule consisting of a critical path and support tasks was based on past experience to meet the three major milestones of the project. The milestones were to build a practice canoe, build a final canoe, and to attend the PSWR Conference.

The tasks were finished after 3800 person-hours spent on the project by the leadership team and additional volunteers. The total person-hours were comprised of 900 for design, 800 for testing, 1600 for construction, and 500 for paddling.

Captains actively enforced safety precautions according to MSDS sheets and ensured that all safety equipment was available and used. Possible risks were minimized through a team evaluation which determined the safest course of action.

The hard work and dedication of the leadership team allowed a high quality project to be completed on time and under budget.

Table 5: Project Milestones

Milestone	Variance	Reason
Fabricate Practice Canoe	1 week late	Schedule conflict with CNC machinist
Fabricate Final Canoe	None	Efficient work completed
Attend PSWR Conference	None	Effective time management

Organization Chart

Project Manager

Jason Marshall
Led fundraising effort, procured materials, and ensured project was on schedule

Simon Burnworth

Eric Johnson

Oscar Alcala

Jason Kump

Nicole Palatinus

James Elsberry

Mix Design Captains
Tested individual components and designed concrete mixtures

Construction Captains
Designed mold form, provided quality control for canoe thickness

Hull Design
Nicole Palatinus

Structural Analysis
Jason Marshall

Technical Paper
Nicole Palatinus

Engr. Notebook
Simon Burnworth

Presentation
Eric Johnson
Jason Marshall

Paddlers
Nic Capuchino
Yunling Chow
James Elsberry
Nicole Palatinus
Brian Shalk
Sheila Shideh
Gary Welling

Mix Design Assistants
Nic Capuchino
Nicole Essex
Megan Leroy
Kevin Nylander
Katie Spangler
Jarrod Villanueva

Cementitious Materials
Simon Burnworth
Nicole Palatinus

Aggregate Gradation
Eric Johnson
Jason Kump

Admixtures
Simon Burnworth

Canoe Fabrication
All Captains
~50 Volunteers

Trowel Finishing
Oscar Alcala
James Elsberry
John Layous
Brian Shalk

Tile Construction
All Captains

Graphic Artist
Kenny Sing

Staining
Nicole Palatinus

Cross Section
Oscar Alcala
Jason Kump

Display Table
James Elsberry
Jason Marshall

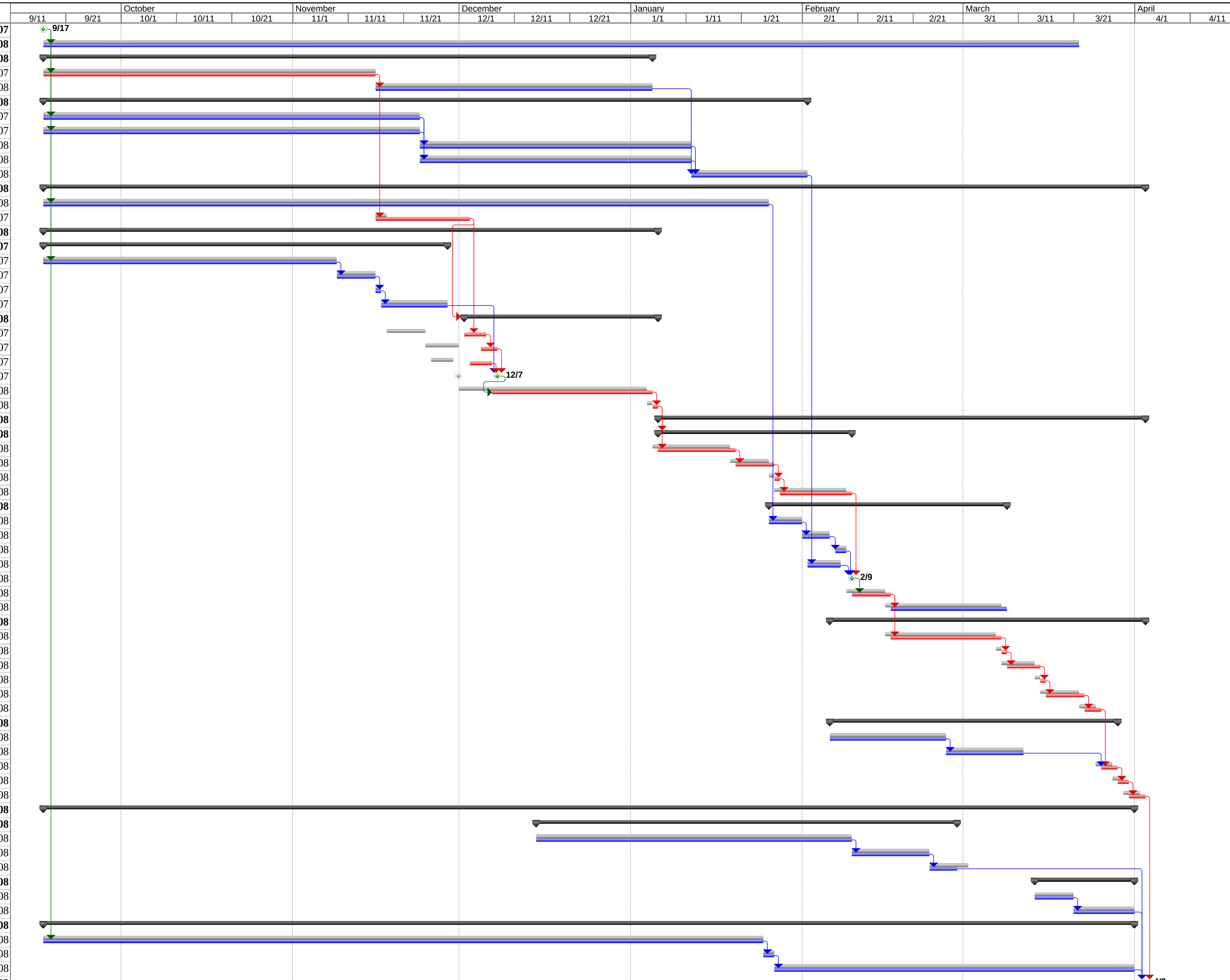
Stands
Oscar Alcala
Simon Burnworth

Cart Repair
James Elsberry
Gary Welling

Bulkheads
Oscar Alcala
Jason Kump

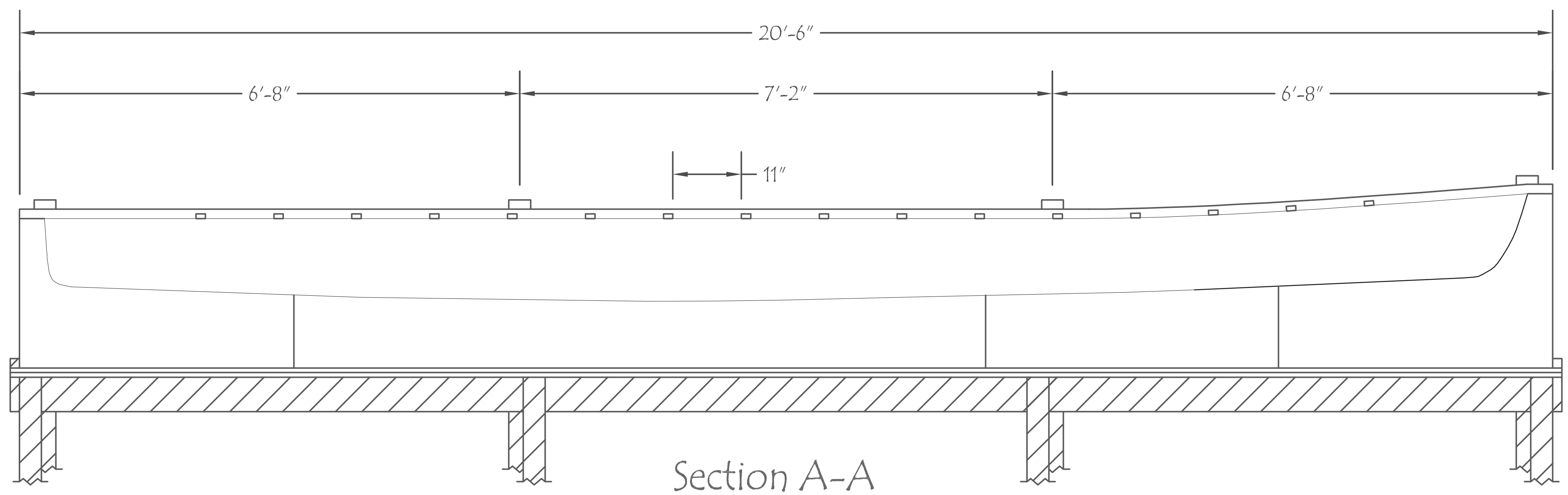
Cal Poly--San Luis Obispo Big Sur Concrete Canoe Project Schedule

ID	Task Name	Baseline Start	Baseline Finish	Start	Finish
1	**Start Construction of Big Sur**	**Mon 9/17/07**	**Mon 9/17/07**	**Mon 9/17/07**	**Mon 9/17/07**
2	**Fundraising**	**Mon 9/17/07**	**Sat 3/22/08**	**Mon 9/17/07**	**Sat 3/22/08**
3	**Hull Design and Analysis**	**Mon 9/17/07**	**Fri 2/29/08**	**Mon 9/17/07**	**Sat 1/5/08**
4	Hull Design	Mon 9/17/07	Fri 11/16/07	Mon 9/17/07	Fri 11/16/07
5	Finite Element Analysis	Fri 11/16/07	Sat 1/5/08	Fri 11/16/07	Sat 1/5/08
6	**Mix Design**	**Mon 9/17/07**	**Sat 2/2/08**	**Mon 9/17/07**	**Sat 2/2/08**
7	Design Aggregate Gradation	Mon 9/17/07	Sat 11/24/07	Mon 9/17/07	Sat 11/24/07
8	Design Cementitious Materials	Mon 9/17/07	Sat 11/24/07	Mon 9/17/07	Sat 11/24/07
9	Design Fibers and Admixtures	Sat 11/24/07	Sat 1/12/08	Sat 11/24/07	Sat 1/12/08
10	Design Mixing Rate and Time	Sat 11/24/07	Sat 1/12/08	Sat 11/24/07	Sat 1/12/08
11	Final Composite Plate Testing	Sat 1/12/08	Sat 2/2/08	Sat 1/12/08	Sat 2/2/08
12	**Construction**	**Mon 9/17/07**	**Wed 4/2/08**	**Mon 9/17/07**	**Wed 4/2/08**
13	Test Mold Releases	Mon 9/17/07	Sat 1/26/08	Mon 9/17/07	Sat 1/26/08
14	Mill Mold	Fri 11/16/07	Sun 11/18/07	Fri 11/16/07	Sun 12/2/07
15	**Practice Canoe Fabrication**	**Mon 9/17/07**	**Sat 1/5/08**	**Mon 9/17/07**	**Sat 1/5/08**
16	**Practice Tile Mosaic**	**Mon 9/17/07**	**Thu 11/29/07**	**Mon 9/17/07**	**Thu 11/29/07**
17	Design in Adobe Illustrator	Mon 9/17/07	Fri 11/9/07	Mon 9/17/07	Fri 11/9/07
18	Prepare Tile Foam Mold	Fri 11/9/07	Fri 11/16/07	Fri 11/9/07	Fri 11/16/07
19	Build Mosaic	Fri 11/16/07	Sat 11/17/07	Fri 11/16/07	Sat 11/17/07
20	Cure Mosaic	Sat 11/17/07	Thu 11/29/07	Sat 11/17/07	Thu 11/29/07
21	**Practice Canoe Preparation**	**Sun 11/18/07**	**Sat 1/5/08**	**Sun 12/2/07**	**Sat 1/5/08**
22	Apply Temp. Mold Release	Sun 11/18/07	Sun 11/25/07	Sun 12/2/07	Wed 12/5/07
23	Attach Temp. Depth Gauges	Sun 11/25/07	Sat 12/1/07	Wed 12/5/07	Fri 12/7/07
24	Dry Batch Concrete	Mon 11/26/07	Fri 11/30/07	Sun 12/2/07	Thu 12/6/07
25	Fabricate Practice Canoe	Sat 12/1/07	Sat 12/1/07	Fri 12/7/07	Fri 12/7/07
26	Cure Practice Canoe	Sat 12/1/07	Fri 1/4/08	Fri 12/7/07	Fri 1/4/08
27	Demold Practice Canoe	Fri 1/4/08	Sat 1/5/08	Fri 1/4/08	Sat 1/5/08
28	**Final Canoe Fabrication**	**Sat 1/5/08**	**Wed 4/2/08**	**Sat 1/5/08**	**Wed 4/2/08**
29	**Tile Mosaic**	**Sat 1/5/08**	**Sat 2/9/08**	**Sat 1/5/08**	**Sat 2/9/08**
30	Finalize Design	Sat 1/5/08	Sat 1/19/08	Sat 1/5/08	Sat 1/19/08
31	Cut Foam for Inlay	Sat 1/19/08	Sat 1/26/08	Sat 1/19/08	Sat 1/26/08
32	Build Mosaic	Sat 1/26/08	Sun 1/27/08	Sat 1/26/08	Sun 1/27/08
33	Cure Mosaic	Sun 1/27/08	Sat 2/9/08	Sun 1/27/08	Sat 2/9/08
34	**Final Canoe Preparation**	**Sat 1/26/08**	**Sat 3/8/08**	**Sat 1/26/08**	**Sat 3/8/08**
35	Apply Final Mold Release	Sat 1/26/08	Fri 2/1/08	Sat 1/26/08	Fri 2/1/08
36	Rebuild Mold	Fri 2/1/08	Wed 2/6/08	Fri 2/1/08	Wed 2/6/08
37	Attach Depth Gauges	Wed 2/6/08	Fri 2/8/08	Wed 2/6/08	Fri 2/8/08
38	Dry Batch Concrete	Sat 2/2/08	Fri 2/8/08	Sat 2/2/08	Fri 2/8/08
39	Fabricate Final Canoe	Sat 2/9/08	Sat 2/9/08	Sat 2/9/08	Sat 2/9/08
40	Initial Cure	Sat 2/9/08	Sat 2/16/08	Sat 2/9/08	Sat 2/16/08
41	Continued Cure	Sat 2/16/08	Sat 3/8/08	Sat 2/16/08	Sat 3/8/08
42	**Finish Work Construction**	**Wed 2/6/08**	**Wed 4/2/08**	**Wed 2/6/08**	**Wed 4/2/08**
43	Sand Interior	Sat 2/16/08	Fri 3/7/08	Sat 2/16/08	Fri 3/7/08
44	Demold Canoe	Fri 3/7/08	Sat 3/8/08	Fri 3/7/08	Sat 3/8/08
45	Rough Sand Exterior	Sat 3/8/08	Fri 3/14/08	Sat 3/8/08	Fri 3/14/08
46	Build Bulkheads	Fri 3/14/08	Sat 3/15/08	Fri 3/14/08	Sat 3/15/08
47	Cure Bulkheads	Sat 3/15/08	Sat 3/22/08	Sat 3/15/08	Sat 3/22/08
48	Final Sand Exterior	Sat 3/22/08	Tue 3/25/08	Sat 3/22/08	Tue 3/25/08
49	**Stain Canoe**	**Wed 2/6/08**	**Fri 3/28/08**	**Wed 2/6/08**	**Fri 3/28/08**
50	Design Stencils	Wed 2/6/08	Wed 2/27/08	Wed 2/6/08	Wed 2/27/08
51	Order Stencils and Stains	Wed 2/27/08	Wed 3/12/08	Wed 2/27/08	Wed 3/12/08
52	Apply Stencils and Stains	Tue 3/25/08	Fri 3/28/08	Tue 3/25/08	Fri 3/28/08
53	Seal Canoe	Fri 3/28/08	Sun 3/30/08	Fri 3/28/08	Sun 3/30/08
54	Apply Lettering	Sun 3/30/08	Wed 4/2/08	Sun 3/30/08	Wed 4/2/08
55	**Prepare for Conference**	**Mon 9/17/07**	**Tue 4/1/08**	**Mon 9/17/07**	**Tue 4/1/08**
56	**Technical Paper**	**Sat 12/15/07**	**Sun 3/2/08**	**Sat 12/15/07**	**Fri 2/29/08**
57	Write Rough Draft	Sat 12/15/07	Sun 2/10/08	Sat 12/15/07	Sun 2/10/08
58	Edit	Sun 2/10/08	Sun 2/24/08	Sun 2/10/08	Sun 2/24/08
59	Print	Sun 2/24/08	Sun 3/2/08	Sun 2/24/08	Fri 2/29/08
60	**Technical Presentation**	**Fri 3/14/08**	**Tue 4/1/08**	**Fri 3/14/08**	**Tue 4/1/08**
61	Write Presentation	Fri 3/14/08	Fri 3/21/08	Fri 3/14/08	Fri 3/21/08
62	Edit and Practice	Fri 3/21/08	Tue 4/1/08	Fri 3/21/08	Tue 4/1/08
63	**Paddling Practice**	**Mon 9/17/07**	**Tue 4/1/08**	**Mon 9/17/07**	**Tue 4/1/08**
64	Practice	Mon 9/17/07	Fri 1/25/08	Mon 9/17/07	Fri 1/25/08
65	Tryouts	Fri 1/25/08	Sun 1/27/08	Fri 1/25/08	Sun 1/27/08
66	Practice	Sun 1/27/08	Tue 4/1/08	Sun 1/27/08	Tue 4/1/08
67	**Attend PSWR Conference**	**Wed 4/2/08**	**Wed 4/2/08**	**Wed 4/2/08**	**Wed 4/2/08**

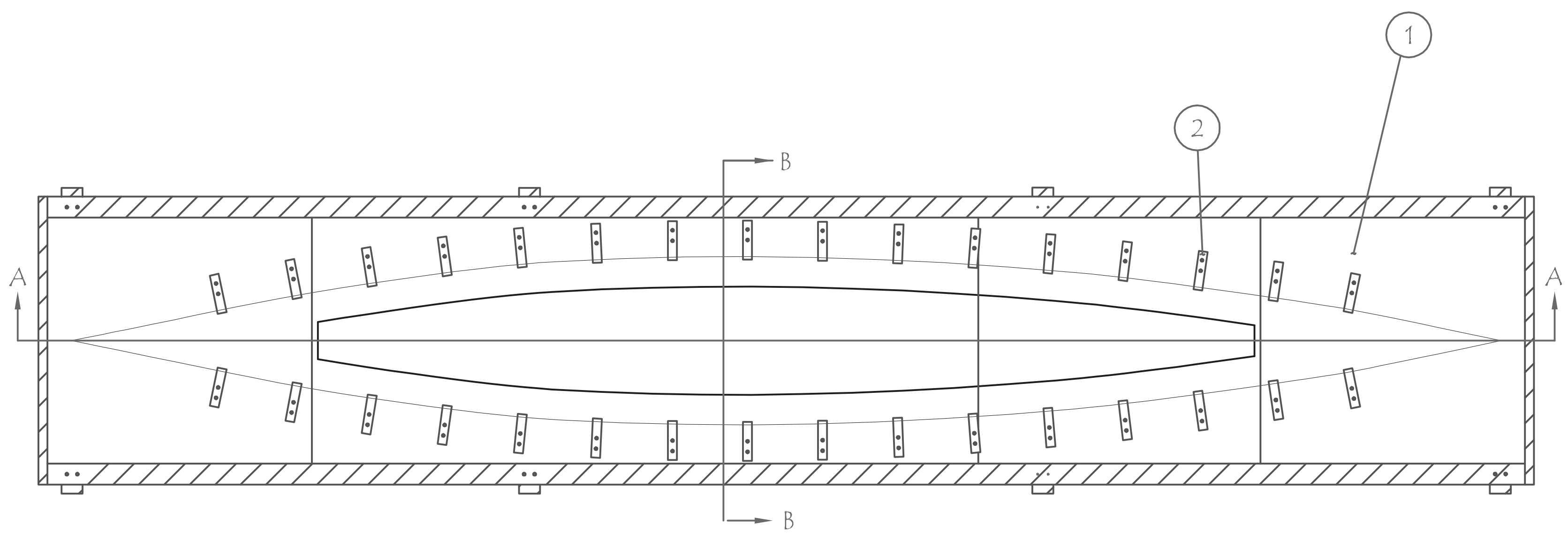


Project: Big Sur Project Schedule
Date: Tue 5/6/08

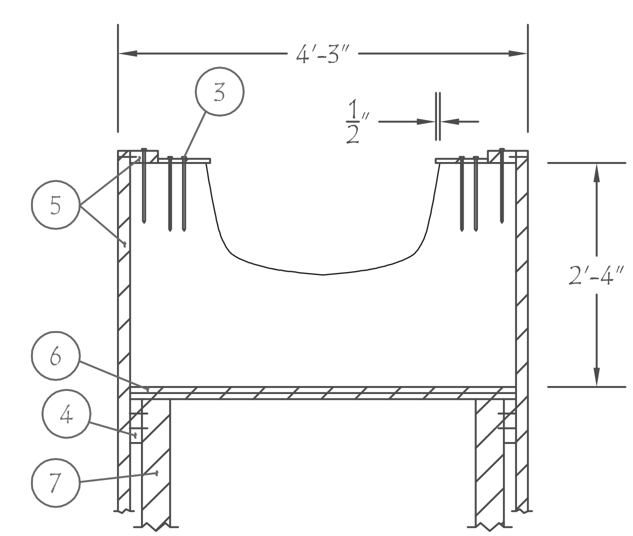
Task Progress | Critical Task Progress | Baseline | Milestone | Baseline Milestone | Summary



Section A-A
ELEVATION VIEW
SCALE 1″ = 2′



PLAN VIEW
SCALE 1″ = 2′-6″



Section B-B
TYPICAL CROSS SECTION
SCALE 1″ = 2′

Formwork
BIG SUR
Cal Poly, SLO
Concrete Canoe 2008

MATERIALS:

No.	Qty.	Description
1.	6	Milled styrofoam
2.	32	1″x2″x8″ Gauge
3.	80	9″ Nail
4.	58 lf	2″x6″ Pine stud
5.	71 lf	2″x4″ Pine stud
6.	6	4′x8′x $\frac{5}{8}$″ OSB
7.	11 lf	4″x4″ Table legs

GENERAL NOTES:

1. Mold covered in $\frac{1}{8}$″ layer of polyurethane.
2. Contact paper placed onto polyurethane prior to fabrication.
3. 1″x2″x8″ Thickness gauges spaced 11″ apart along gunwale.

Drawn by: JSE	Date: 05.02.08
Checked by: NKP	page 9

APPENDIX A — REFERENCES

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APPENDIX B— MIXTURE PROPORTIONS

Mixture: Structural Concrete
Batch Size (ft^3): 0.050

		Non-SSD Proportions as Designed		**Actual 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. ASTM C150 Portland Cement Type I	3.15	448.09	2.28	0.83	4.22	448.09	2.28
2. ASTM C989 Slag Grade 120	2.93	89.38	0.49	0.17	0.90	89.38	0.49
3. ASTM C618 Pozzolan	2.60	208.55	1.29	0.39	2.38	208.55	1.29
Total of All Cementitious Materials		746.03	4.05	1.38	7.50	746.03	4.05
Fibers							
1. Nycon PVA	1.30	2.00	0.02	0.00	0.05	2.00	0.02
Aggregates							
1. Siscor Glass Spheres Ø 1.0-2.0 mm Absorption, 6% Batched Moisture Content, 0%	0.39	44.09	1.81	0.08	3.35	44.09	1.81
2. Siscor Glass Spheres Ø 0.5-1.0 mm Absorption, 6% Batched Moisture Content, 0%	0.47	119.17	4.06	0.22	7.52	119.17	4.06
3. Siscor Glass Spheres Ø 0.25-0.50 mm Absorption, 6% Batched Moisture Content, 0%	0.59	178.76	4.86	0.33	8.98	178.76	4.86
4. Siscor Glass Spheres Ø 0.1-0.3 mm Absorption, 6% Batched Moisture Content, 0%	0.90	35.75	0.64	0.07	1.18	35.75	0.64
5. K1 Microspheres Ø 0.13 mm Absorption, 1% Batched Moisture Content, 0%	0.13	9.53	1.18	0.02	2.17	9.53	1.18
Total of All Aggregates		387.31	12.54	0.72	23.20	387.31	12.54
Water							
Batched Water^	1.00	77.46	1.24	0.14	2.30	77.46	1.24
Total Water Added for Aggregate Absorptior	1.00	22.76	0.36	0.04	0.67	22.76	0.36
Total Water from All Admixtures§	1.00	128.87	2.07	0.24	3.82	128.87	2.07
Total Water		229.10	3.67	0.42	6.79	229.10	3.67
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. Superplasticizer; Density, 9.20 lb/gal	32.00	6.69	2.43	0.09	0.00	6.69	2.43
2. Shrinkage Reducer; Density, 8.11 lb/gal	6.00	12.64	5.60	0.17	0.01	12.64	5.60
3. Latex; Density, 10.84 lb/gal	40.00	410.20	120.84	5.66	0.22	410.20	120.84
Cement-Cementitious Materials Ratio		0.60		0.60		0.60	
Water-Cementitious Materials Ratio		0.28		0.28		0.28	
Flow (flow table), Slump, Slump Flow, in.		3		3		3	
Air Content, %		21.5		21.5		21.5	
Density (Unit Weight), lb/ft^3		53.5		53.5		53.5	
Gravimetric Air Content, %				21.5			
Yield, ft^3		27.0		0.050		27.0	

* *For aggregates provide ASTM C 127 oven-dry bulk specific gravity.*

^ *Excluding water added for aggregate absorption.*

‡ *Water content of admixture.*

§ *If impact on water-cementitious materials ratio is less than 0.01 enter zero.*

*** Reported volumes are equal to actual volumes multiplied by 10^3*

Mixture: Middle Layer
Batch Size (ft^3): 0.056

Cementitious Materials	Specific* Gravity	Non-SSD Proportions as Designed: Amount (lb/yd^3)	Non-SSD Proportions as Designed: Volume (ft^3)	Actual Batched Proportions: Amount (lb)	Actual Batched Proportions: Volume** (ft^3)	Yielded Proportions: Amount (lb/yd^3)	Yielded Proportions: Volume (ft^3)
1. ASTM C150 Portland Cement Type I	3.15	401.98	2.05	0.83	4.22	401.98	2.05
2. ASTM C989 Slag Grade 120	2.93	80.18	0.44	0.17	0.90	80.18	0.44
3. ASTM C618 Pozzolan	2.60	187.09	1.15	0.39	2.38	187.09	1.15
Total of All Cementitious Materials		669.26	3.64	1.38	7.50	669.26	3.64
Fibers							
1. Nycon PVA	1.30	2.00	0.02	0.00	0.05	2.00	0.02
Aggregates							
1. Siscor Glass Spheres Ø 1.0-2.0 mm; Absorption, 6%; Batched Moisture Content, 0%	0.39	128.29	5.27	0.26	10.87	128.29	5.27
2. Siscor Glass Spheres Ø 0.5-1.0 mm; Absorption, 6%; Batched Moisture Content, 0%	0.47	85.53	2.92	0.18	6.01	85.53	2.92
3. Siscor Glass Spheres Ø 0.25-0.50 mm; Absorption, 6%; Batched Moisture Content, 0%	0.59	64.15	1.74	0.13	3.59	64.15	1.74
4. K1 Microspheres Ø 0.13 mm; Absorption, 1%; Batched Moisture Content, 0%	0.13	12.83	1.58	0.03	3.26	12.83	1.58
Total of All Aggregates		290.80	11.51	0.60	23.74	290.80	11.51
Water							
Batched Water^	1.00	75.91	1.22	0.16	2.51	75.91	1.22
Total Water Added for Aggregate Absorption	1.00	16.81	0.27	0.03	0.56	16.81	0.27
Total Water from All Admixtures§	1.00	115.61	1.85	0.24	3.82	115.61	1.85
Total Water		208.33	3.34	0.43	6.88	208.33	3.34

Admixtures	% Solids	Non-SSD: Amount (fl oz/cwt)	Non-SSD: Water‡ in Admixture (lb/yd^3)	Actual Batched: Amount (fl oz)	Actual Batched: Water‡ in Admixture (lb)	Yielded: Amount (fl oz/cwt)	Yielded: Water‡ in Admixture (lb/yd^3)
1. Superplasticizer; Density, 9.20 lb/gal	32.00	6.69	2.18	0.09	0.00	6.69	2.18
2. Shrinkage Reducer; Density, 8.11 lb/gal	6.00	12.64	5.02	0.17	0.01	12.64	5.02
3. Latex; Density, 10.84 lb/gal	40.00	410.20	108.41	5.66	0.22	410.20	108.41

	Non-SSD Proportions as Designed	Actual Batched Proportions	Yielded Proportions
Cement-Cementitious Materials Ratio	0.60	0.60	0.60
Water-Cementitious Materials Ratio	0.29	0.29	0.29
Flow (flow table), Slump, Slump Flow, in.	4	4	4
Air Content, %	28.3	28.3	28.3
Density (Unit Weight), lb/ft^3	46.0	46.0	46.0
Gravimetric Air Content, %		28.3	
Yield, ft^3	27.0	0.056	27.0

* *For aggregates provide ASTM C 127 oven-dry bulk specific gravity.*

^ *Excluding water added for aggregate absorption.*

‡ *Water content of admixture.*

§ *If impact on water-cementitious materials ratio is less than 0.01 enter zero.*

*** Reported volumes are actual volumes multiplied by 10^3*

Mixture: Pigmented Concrete (Option 1)
Batch Size (ft^3): 0.050

Cementitious Materials	Specific* Gravity	Non-SSD Proportions as Designed: Amount (lb/yd^3)	Non-SSD Proportions as Designed: Volume (ft^3)	Actual Batched Proportions: Amount (lb)	Actual Batched Proportions: Volume** (ft^3)	Yielded Proportions: Amount (lb/yd^3)	Yielded Proportions: Volume (ft^3)
1. ASTM C150 Portland Cement Type I	3.15	447.12	2.27	0.83	4.22	447.12	2.27
2. ASTM C989 Slag Grade 120	2.93	89.19	0.49	0.17	0.90	89.19	0.49
3. ASTM C618 Pozzolan	2.60	208.10	1.28	0.39	2.38	208.10	1.28
Total of All Cementitious Materials		744.40	4.05	1.38	7.50	744.40	4.05
Fibers							
1. None							
Aggregates							
1. Siscor Glass Spheres Ø 1.0-2.0 mm; Absorption, 6%; Batched Moisture Content, 0%	0.39	44.00	1.81	0.08	3.35	44.00	1.81
2. Siscor Glass Spheres Ø 0.5-1.0 mm; Absorption, 6%; Batched Moisture Content, 0%	0.47	118.91	4.05	0.22	7.52	118.91	4.05
3. Siscor Glass Spheres Ø 0.25-0.50 mm; Absorption, 6%; Batched Moisture Content, 0%	0.59	178.37	4.84	0.33	8.98	178.37	4.84
4. Siscor Glass Spheres Ø 0.1-0.3 mm; Absorption, 6%; Batched Moisture Content, 0%	0.90	35.67	0.64	0.07	1.18	35.67	0.64
5. K1 Microspheres Ø 0.13 mm; Absorption, 1%; Batched Moisture Content, 0%	0.13	9.51	1.17	0.02	2.17	9.51	1.17
Total of All Aggregates		386.47	12.52	0.72	23.20	386.47	12.52
Water							
Batched Water^	1.00	91.56	1.47	0.17	2.72	91.56	1.47
Total Water Added for Aggregate Absorption	1.00	22.71	0.36	0.04	0.67	22.71	0.36
Total Water from All Admixtures§	1.00	129.57	2.08	0.24	3.85	129.57	2.08
Total Water		243.84	3.91	0.45	7.24	243.84	3.91

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. Superplasticizer; Density, 9.20 lb/gal	32.00	6.69	2.43	0.09	0.00	6.69	2.43
2. Shrinkage Reducer; Density, 8.11 lb/gal	6.00	12.64	5.59	0.17	0.01	12.64	5.59
3. Latex; Density, 10.84 lb/gal	40.00	410.20	120.58	5.66	0.22	410.20	120.58
4. Pigment; Density, 15.00 lb/gal	59.00	2.72	0.98	0.04	0.00	2.72	0.98

	Non-SSD Proportions as Designed	Actual Batched Proportions	Yielded Proportions
Cement-Cementitious Materials Ratio	0.60	0.60	0.60
Water-Cementitious Materials Ratio	0.30	0.30	0.30
Flow (flow table), Slump, Slump Flow, in.	4	4	4
Air Content, %	20.8	20.8	20.8
Density (Unit Weight), lb/ft^3	54.0	54.0	54.0
Gravimetric Air Content, %		20.8	
Yield, ft^3	27.0	0.050	27.0

* *For aggregates provide ASTM C 127 oven-dry bulk specific gravity.*
^ *Excluding water added for aggregate absorption.*
‡ *Water content of admixture.*
§ *If impact on water-cementitious materials ratio is less than 0.01 enter zero.*
*** Reported volumes are equal to actual volumes multiplied by 10^3*

Mixture: Pigmented Concrete (Option 2)
Batch Size (ft^3): 0.050

		Non-SSD Proportions as Designed		Actual 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. ASTM C150 Portland Cement Type I	3.15	446.41	2.27	0.83	4.22	446.41	2.27
2. ASTM C989 Slag Grade 120	2.93	89.04	0.49	0.17	0.90	89.04	0.49
3. ASTM C618 Pozzolan	2.60	207.77	1.28	0.39	2.38	207.77	1.28
Total of All Cementitious Materials		743.22	4.04	1.38	7.50	743.22	4.04
Fibers							
1. None							
Aggregates							
1. Siscor Glass Spheres Ø 1.0-2.0 mm Absorption, 6% Batched Moisture Content, 0%	0.39	43.93	1.81	0.08	3.35	43.93	1.81
2. Siscor Glass Spheres Ø 0.5-1.0 mm Absorption, 6% Batched Moisture Content, 0%	0.47	118.73	4.05	0.22	7.52	118.73	4.05
3. Siscor Glass Spheres Ø 0.25-0.50 mm Absorption, 6% Batched Moisture Content, 0%	0.59	178.09	4.84	0.33	8.98	178.09	4.84
4. Siscor Glass Spheres Ø 0.1-0.3 mm Absorption, 6% Batched Moisture Content, 0%	0.90	34.43	0.61	0.06	1.14	34.43	0.61
5. K1 Microspheres Ø 0.13 mm Absorption, 1% Batched Moisture Content, 0%	0.13	9.50	1.17	0.02	2.17	9.50	1.17
Total of All Aggregates		384.67	12.47	0.71	23.16	384.67	12.47
Water							
Batched Water^	1.00	91.42	1.47	0.17	2.72	91.42	1.47
Total Water Added for Aggregate Absorptior	1.00	22.61	0.36	0.04	0.67	22.61	0.36
Total Water from All Admixtures§	1.00	128.39	2.06	0.24	3.82	128.39	2.06
Total Water		242.41	3.88	0.45	7.21	242.41	3.88
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. Superplasticizer; Density, 9.20 lb/gal	32.00	6.69	2.42	0.09	0.00	6.69	2.42
2. Shrinkage Reducer; Density, 8.11 lb/gal	6.00	12.64	5.58	0.17	0.01	12.64	5.58
3. Latex; Density, 10.84 lb/gal	40.00	410.20	120.39	5.66	0.22	410.20	120.39
4. Iron Oxide Pigment; Density, 42.56 lb/gal	100.00	2.40	0.00	0.03	0.00	2.40	0.00
Cement-Cementitious Materials Ratio		0.60		0.60		0.60	
Water-Cementitious Materials Ratio		0.30		0.30		0.30	
Flow (flow table), Slump, Slump Flow, in.		4		4		4	
Air Content, %		21.0		21.0		21.0	
Density (Unit Weight), lb/ft^3		54.0		54.0		54.0	
Gravimetric Air Content, %				21.0			
Yield, ft^3		27.0		0.050		27.0	

* *For aggregates provide ASTM C 127 oven-dry bulk specific gravity.*

^ *Excluding water added for aggregate absorption.*

‡ *Water content of admixture.*

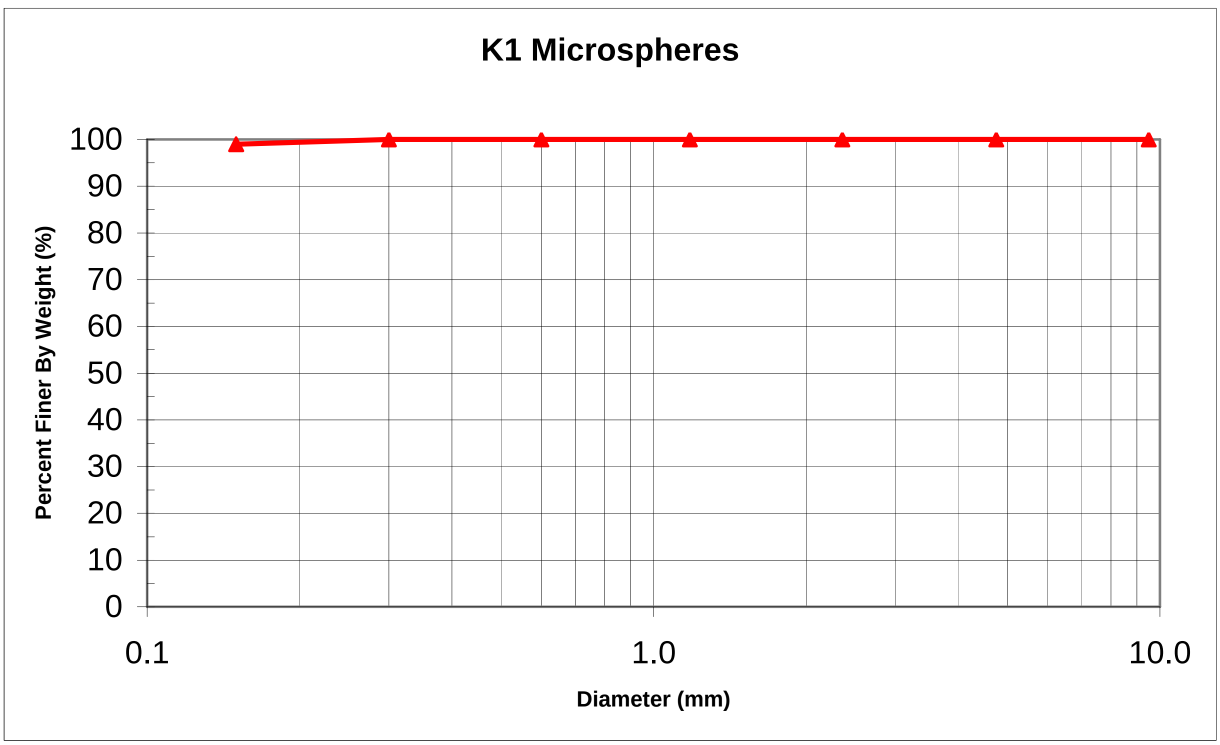
§ *If impact on water-cementitious materials ratio is less than 0.01 enter zero.*

*** Reported volumes are equal to actual volumes multiplied by 10^3*

Appendix C — Gradation Curves and Tables

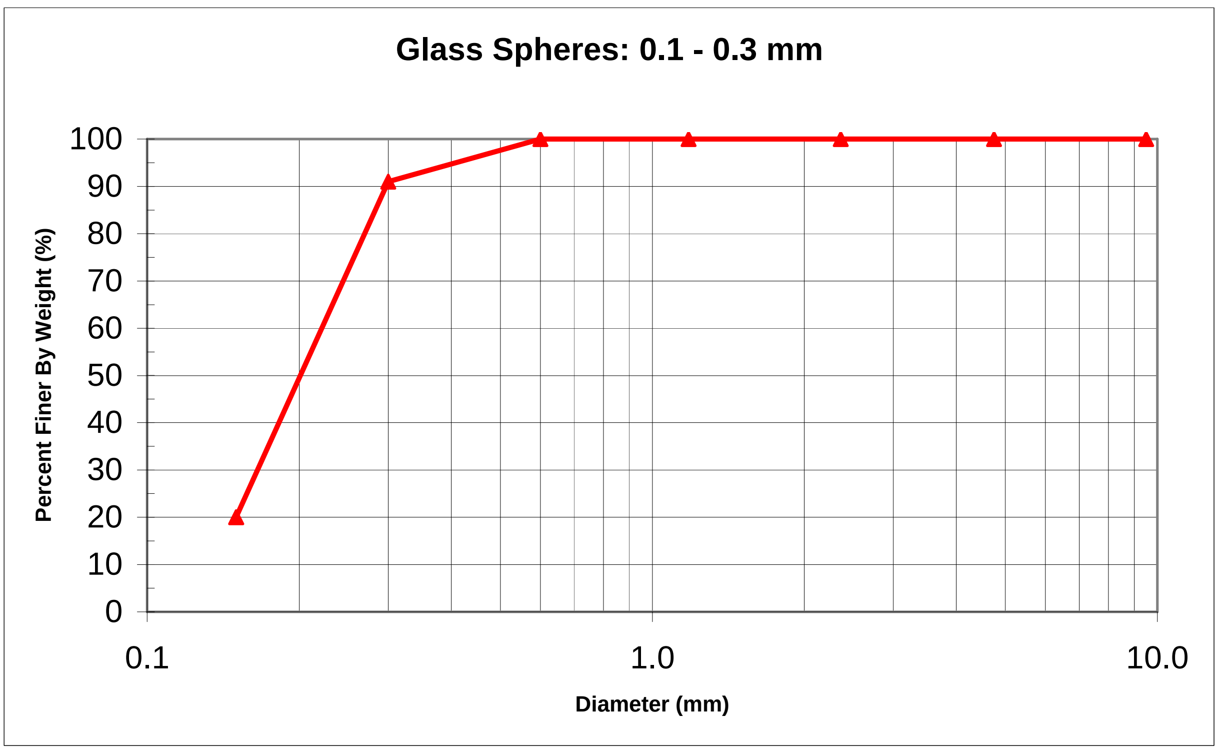
Concrete Aggregate:	**K1 Microspheres**
Sample Weight (g):	**500**
Specific Gravity (G_s):	**0.13**
Fineness Modulus:	**N/A**

Sieve	Diameter (mm)	Weight Retained (g)	Cumulative Weight Retained (g)	Percent Finer (%)
3/8 inch	9.50	0	0	100
No. 4	4.75	0	0	100
No. 8	2.36	0	0	100
No. 16	1.18	0	0	100
No. 30	0.60	0	0	100
No. 50	0.30	0	0	100
No. 100	0.15	5	5	99
Pan	0	495	500	0



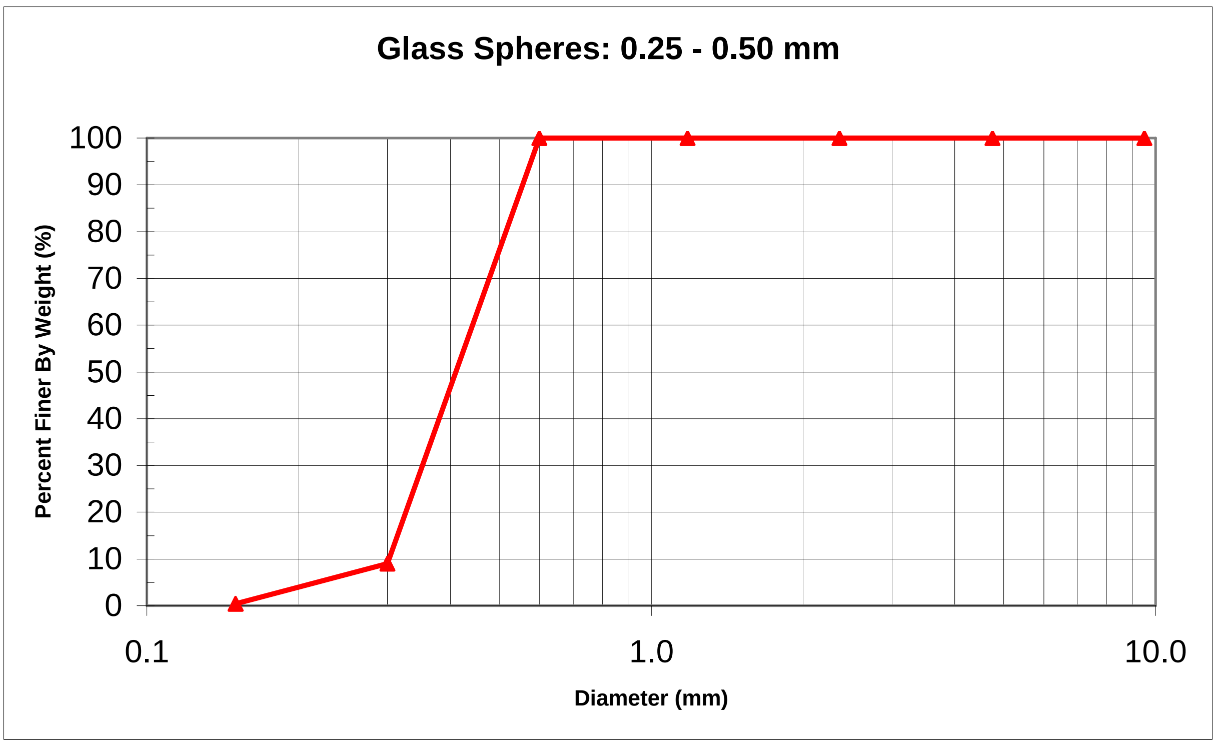
Concrete Aggregate:	**Glass Spheres 0.1-0.3 mm**
Sample Weight (g):	**500**
Specific Gravity (G_s):	**0.90**
Fineness Modulus:	**0.89**

Sieve	Diameter (mm)	Weight Retained (g)	Cumulative Weight Retained (g)	Percent Finer (%)
3/8 inch	9.50	0	0	100
No. 4	4.75	0	0	100
No. 8	2.36	0	0	100
No. 16	1.18	0	0	100
No. 30	0.60	0	0	100
No. 50	0.30	45	45	91
No. 100	0.15	355	400	20
Pan	0.00	100	500	0



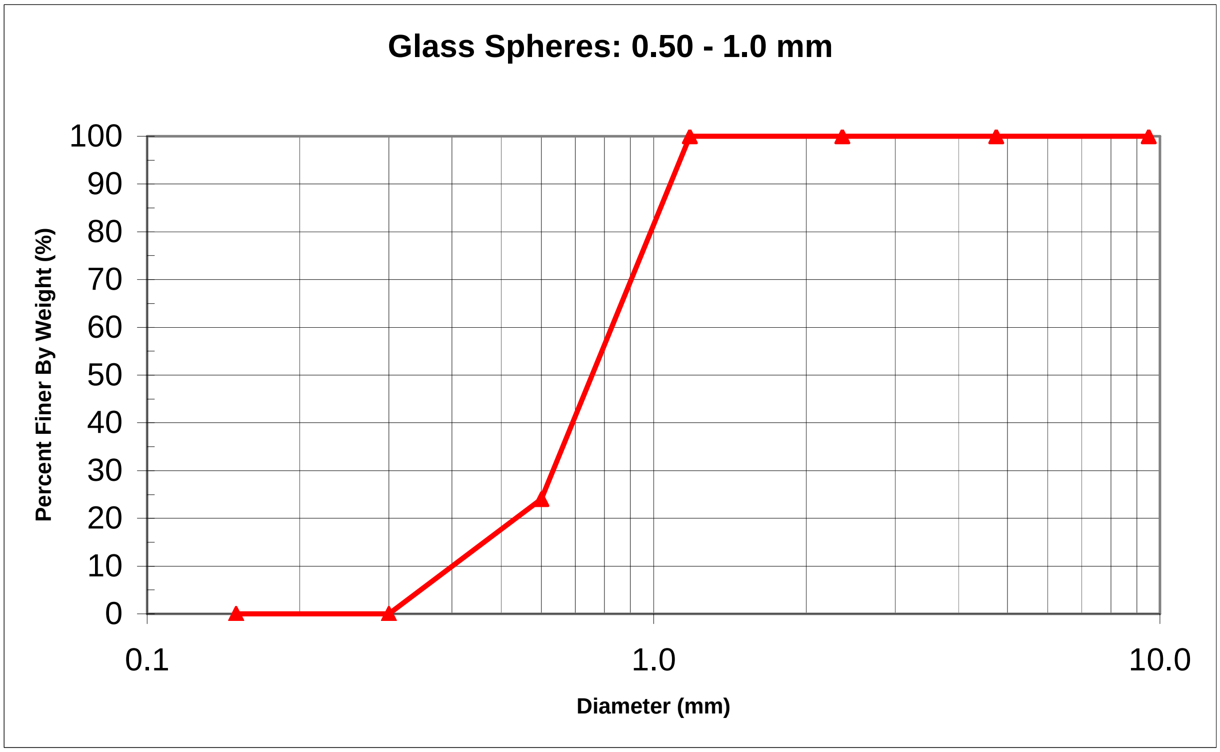
Concrete Aggregate:	**Glass Spheres 0.25-0.50 mm**
Sample Weight (g):	**500**
Specific Gravity (G_s):	**0.59**
Fineness Modulus:	**1.91**

Sieve	Diameter (mm)	Weight Retained (g)	Cumulative Weight Retained (g)	Percent Finer (%)
3/8 inch	9.50	0	0	100
No. 4	4.75	0	0	100
No. 8	2.36	0	0	100
No. 16	1.18	0	0	100
No. 30	0.60	0	0	100
No. 50	0.30	455	455	9
No. 100	0.15	43	498	0
Pan	0.00	2	500	0



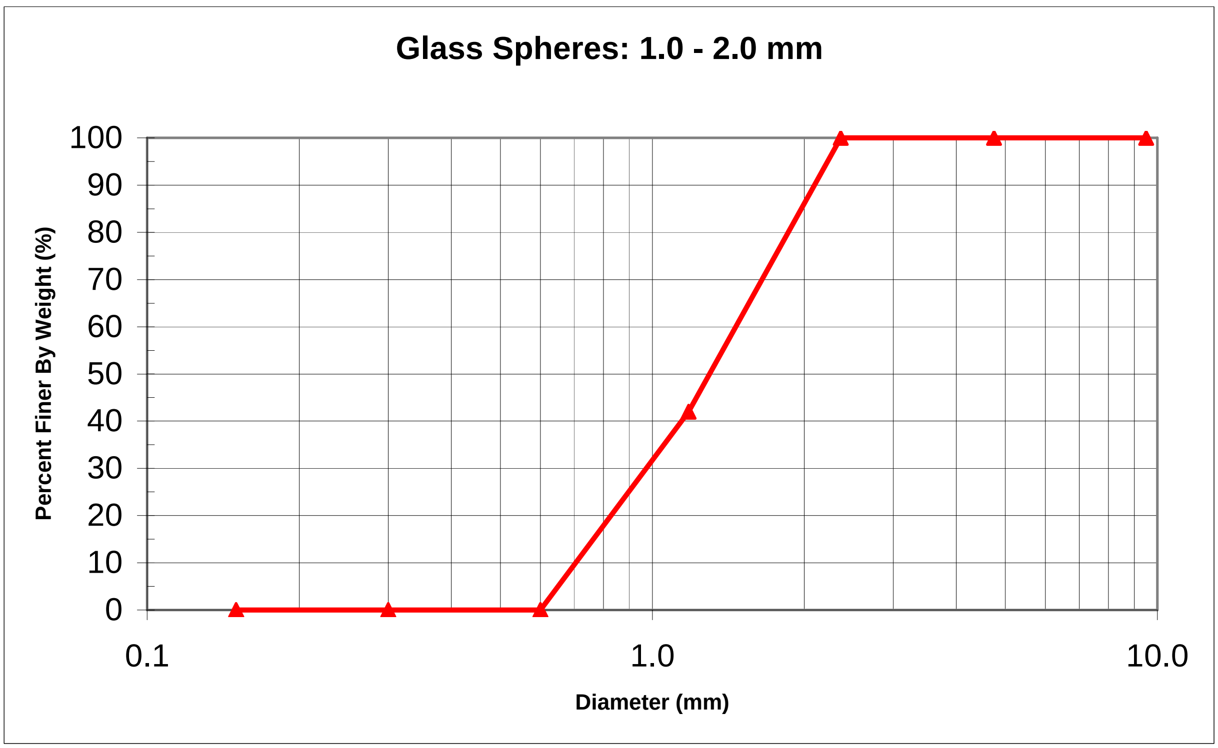
Concrete Aggregate:	**Glass Spheres 0.50-1.0 mm**
Sample Weight (g):	**500**
Specific Gravity (G_s):	**0.47**
Fineness Modulus:	**2.76**

Sieve	Diameter (mm)	Weight Retained (g)	Cumulative Weight Retained (g)	Percent Finer (%)
3/8 inch	9.50	0	0	100
No. 4	4.75	0	0	100
No. 8	2.36	0	0	100
No. 16	1.18	0	0	100
No. 30	0.60	380	380	24
No. 50	0.30	120	500	0
No. 100	0.15	0	500	0
Pan	0	0	500	0



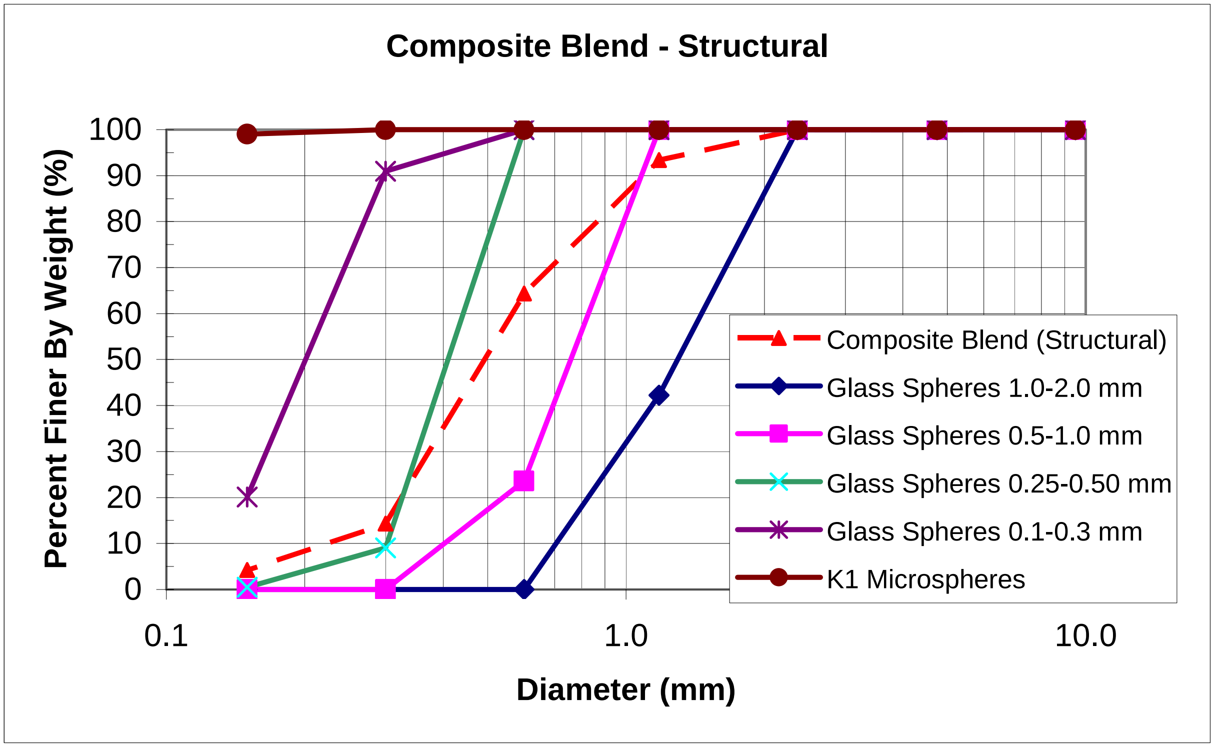
Concrete Aggregate: Glass Spheres 1.0-2.0 mm
Sample Weight (g): 500
Specific Gravity (G_s): 0.39
Fineness Modulus: 3.58

Sieve	Diameter (mm)	Weight Retained (g)	Cumulative Weight Retained (g)	Percent Finer (%)
3/8 inch	9.50	0	0	100
No. 4	4.75	0	0	100
No. 8	2.36	0	0	100
No. 16	1.18	290	290	42
No. 30	0.60	210	500	0
No. 50	0.30	0	500	0
No. 100	0.15	0	500	0
Pan	0	0	500	0



Concrete Aggregate:	**Composite Blend - Structural**
Sample Weight (g):	**500**
Specific Gravity (G_s):	**0.55**
Fineness Modulus:	**2.24**

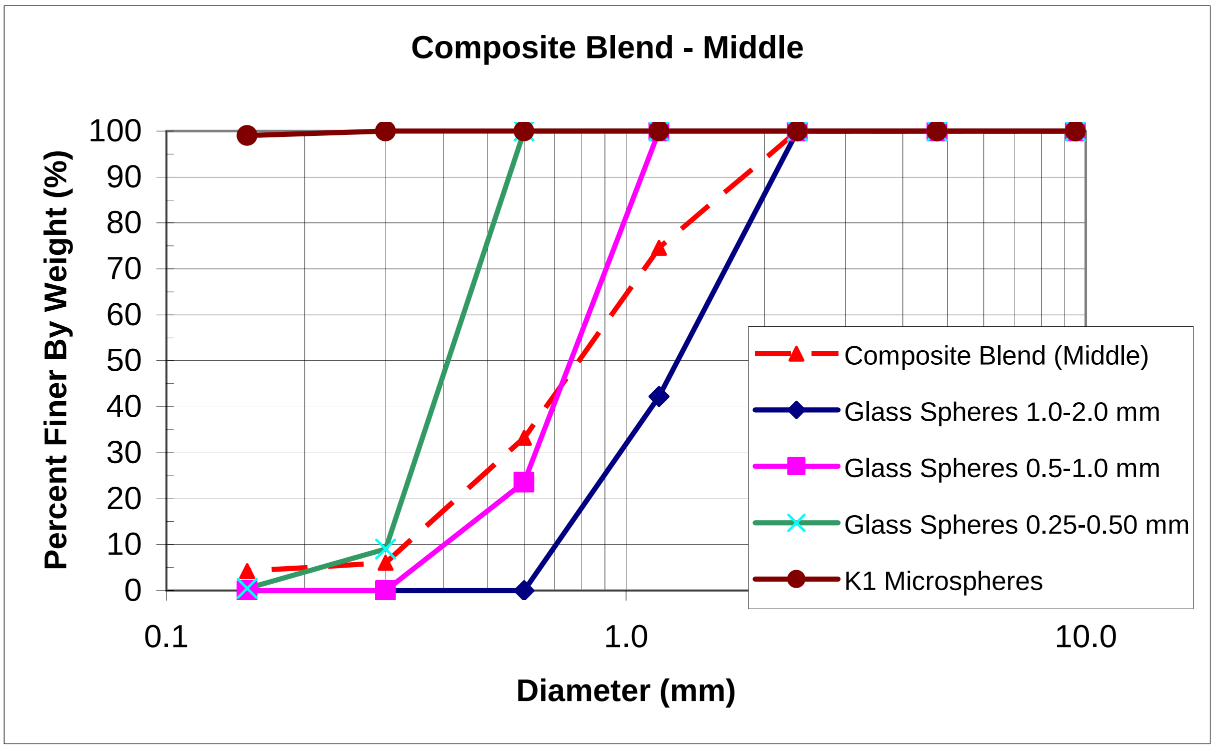
Sieve	Diameter (mm)	Weight Retained (g)	Cumulative Weight Retained (g)	Percent Finer (%)
3/8 inch	9.50	0	0	100
No. 4	4.75	0	0	100
No. 8	2.36	0	0	100
No. 16	1.18	33	33	93
No. 30	0.60	145	178	64
No. 50	0.30	250	428	14
No. 100	0.15	51	479	4
Pan	0	21.3	500	0



Note: Composite blend is 12% 1.0-2.0 mm spheres, 31% 0.5-1.0 mm spheres, 46% 0.25-0.5 mm spheres, 9% 0.1-0.3 mm spheres, 2% K1 microspheres (based on dry weight percentage)

Concrete Aggregate:	**Composite Blend - Middle**
Sample Weight (g):	**500**
Specific Gravity (G_s):	**0.45**
Fineness Modulus:	**2.82**

Sieve	Diameter (mm)	Weight Retained (g)	Cumulative Weight Retained (g)	Percent Finer (%)
3/8 inch	9.50	0	0	100
No. 4	4.75	0	0	100
No. 8	2.36	0	0	100
No. 16	1.18	127	127	75
No. 30	0.60	207	334	33
No. 50	0.30	136	470	6
No. 100	0.15	9	479	4
Pan	0	21.1	500	0



Note: Composite blend is 45% 1.0-2.0 mm spheres, 29% 0.5-1.0 mm spheres, 22% 0.25-0.5 mm spheres, 4% K1 microspheres (based on dry weight percentage)