UNIVERSITY OF WISCONSIN-MADISON

Concrete Canoe Team

TALIESIN

2004-2005

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TALIESIN Profile

Dimensions and Properties	
Weight	175 lb
Length	21.5 ft
Maximum Width	2.5 ft
Maximum Depth	12.25 in.
Average Thickness	0.5 in.
Fiberglass Mesh Reinforcement	4.5 oz/yd^2
Steel Pre-Stress Wire	20 gage
Composite Concrete Mixture	
Unit Weight	57.6 lb/ft^3
Flexural Strength	1,250 lb/in^2
Structural Concrete Mixture	
Unit Weight	56.9 lb/ft^3
Compressive Strength	850 lb/in^2
Flexural Strength	680 lb/in^2
Finishing Mixture	
Unit Weight	62.4 lb/ft^3
Compressive Strength	1,330 lb/in^2
Flexural Strength	350 lb/in^2
Inlay Mixture	
Unit Weight	57.3 lb/ft^3
Compressive Strength	810 lb/in^2
Flexural Strength	640 lb/in^2
Inlay Finishing Mixture	
Unit Weight	62.7 lb/ft^3
Compressive Strength	1,280 lb/in^2
Flexural Strength	320 lb/in^2

Executive Summary

The University of Wisconsin-Madison is located on a 933-acre campus between Lake Mendota and Lake Monona. UW-Madison has 41,000 students enrolled, with 350 studying Civil Engineering. The UW-Madison Concrete Canoe Team has competed at the Great Lakes Regional Competition since 1991 and has qualified for the National Competition eleven consecutive times. In 2002, the team achieved its first top-five finish at the National Competition, followed by national championships in 2003 and 2004.

The 2005 team gained inspiration from the architectural principles of Wisconsin native Frank Lloyd Wright. ***Taliesin*** [tălēes'in], named after Wright's famous Wisconsin estate, incorporates ingenuity with aspects of art and architectural detail.

Engineering science and architectural principles challenged the team to think creatively in developing ***Taliesin***. The hull design team incorporated the key hull attributes of maneuverability, stability, and straight-line speed from the most recent UW-Madison canoes. A finite element analysis provided a basis to vary the wall thickness and to taper the ribs. Engineering knowledge enabled the development of these innovative features to complement the architectural theme. ***Taliesin's*** white hue provided a canvas to display the artistic inlay design on the canoe's interior.

Four concrete mixtures were used in the construction of ***Taliesin***: a structural mixture, an inlay mixture and two finishing mixtures. Standardized tests measured strength, and a unique punching shear test simulated the force of the paddlers during race competitions. These tests provided technical data and allowed for a visual inspection of the structural concrete mixture's performance.

Construction engineers used a humidity tent within a temperature controlled room to create ideal curing conditions. Linoleum tiles attached to the mold created depressions for the variable wall thickness and the artistic inlay design.

A hierarchical project committee led the team in all phases of design. ***Taliesin*** team leaders organized an arterial communication network for processing ideas among the entire team. This system created a motivated and unified team to continue UW-Madison's strong tradition of ingenuity, innovation, and project excellence.

Hull Design

The goal of the hull design team was to expand on prior knowledge to design a canoe that balanced stability, maneuverability, and straight-line speed. The development of ***Taliesin*** began with research of hull geometry including longitudinal curvature, water plane area, rocker, chine transitions, and freeboard. The stability and high maneuverability of *Chequamegon*, and the straight-line speed of *Rock Solid* were balanced to create the hybrid design of ***Taliesin*** (Table 1).

Taliesin hull design engineers strived to produce a sufficiently stable canoe that maintained straight-line speed. A reduction of longitudinal curvature (the change in width of the canoe hull from the bow and stern to the amidship) in *Rock Solid* allowed for increased straight-line speed from that of *Chequamegon*. However, the streamlined hull of *Rock Solid* reduced the water plane area (the horizontal cross-sectional area at the waterline), which resulted in a loss of stability. Therefore, ***Taliesin's*** design incorporated a streamlined hull along with a wider longitudinal curvature from that of *Rock Solid*. As a result, an increase in stability was achieved without sacrificing significant straight-line speed.

A greater longitudinal curvature also influences the maneuverability by allowing paddlers to sit closer to the bow and stern of the canoe. This arrangement produces a longer moment arm from the pivot point at the bow paddler's rudder to the stern paddler, resulting in a faster turn.

Table 1: Hull Geometry

Hull Geometry	**Dimensions & Parameters**		
	Chequamegon 2003	***Taliesin*** ***2005***	*Rock Solid* 2004
Depth at center	11.5 in.	**12.25 in.**	13.0 in.
Total Hull Area	67.8 ft^2	**65.9 ft^2**	69.5 ft^2
Water Plane Area*	32.2 ft^2	**31.2 ft^2**	28.8 ft^2
Bow Rocker	2.5 in.	**2.6 in.**	3.5 in.
Stern Rocker	1.6 in.	**1.8 in.**	1.6 in.

*Based on the four person loading condition

Maneuverability and stability are also affected by altering the rocker (Johns@ 2004). An increase in bow rocker from *Chequamegon* to *Rock Solid* added to the instability of *Rock Solid*. However, an increase in rocker also increases maneuverability, so it is not beneficial to considerably reduce the rocker. Therefore, ***Taliesin's*** rocker values were modified to provide a balance between stability and maneuverability.

Taliesin incorporates the hard-chine transition found in both *Chequamegon's* and *Rock Solid's* designs. The hard chine functions like a curved keel as the paddlers lean the canoe (Figure 1), allowing the canoe to maintain velocity throughout the turns (Pygmy@ 2003). This increased turning ability is advantageous to paddlers during the race competitions.

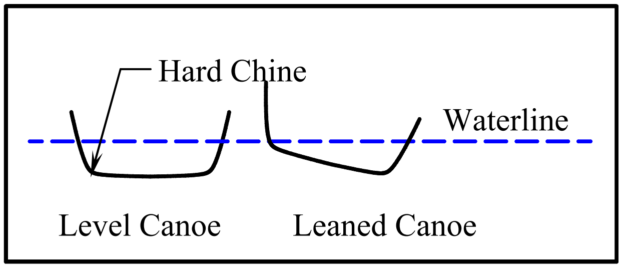


Figure 1: Function of a hard chine transition

The curved freeboard design of *Chequamegon* proved to be inadequate when water entered the stern of the canoe during the co-ed race. *Rock Solid's* team recognized this problem and created a constant freeboard along the length of the canoe, which proved to be over-designed. Since the lack of *Chequamegon's* freeboard was concentrated in the stern, ***Taliesin's*** design utilized freeboard values of *Chequamegon* at the bow and amidship, and increased the freeboard equal to *Rock Solid's* values in the stern.

Design knowledge and paddling experience from previous years were integral components in the hull design of ***Taliesin***. By combining key elements from the past two canoes, the hull design team successfully created a hybrid design.

Analysis

The goal of the analysis team was to develop a structural system that provided ***Taliesin*** with the strength needed to withstand the rigors of the competition that also incorporated architectural features. A pre-stress system and ribs were developed to provide additional support and to negate cracking in ***Taliesin***. Two-dimensional and three-dimensional analyses were used to achieve the goals of designing ***Taliesin's*** structural system.

The analysis team looked at load cases from the male, female, and co-ed loading conditions to develop this structural system. ***Taliesin*** was assumed to be 180lbs equally distributed along its length with male paddlers weighing 180lbs and female paddlers weighing 140lbs. For the male and female loading scenarios, loads were applied at 3.5ft and 18ft from the bow. For the co-ed loading scenarios, loads were positioned at 3.5ft, 7ft, 14.5ft, and 18ft from the bow, with the male paddlers nearest to the bow and stern. The uniformly distributed buoyancy force was equivalent to the weights of paddlers and the canoe.

A two-dimensional analysis used these loading conditions and assumed ***Taliesin*** as a simply supported beam of uniform cross-sectional area. The co-ed loading scenario governed both the shear and moment envelopes that were used to design the pre-stress system. The incorporation of a pre-stress system reduces the bending of the canoe, and as a result, minimizes the cracking that would otherwise occur. Steel wire was chosen for its superior bonding capabilities with concrete when compared to carbon fiber tow, which had been used in previous canoes. The moments obtained from two-dimensional analysis were used to determine that ten longitudinal pre-stress wires, tensioned to 150lbs each, would allow ***Taliesin*** to remain in compression for all loading conditions.

A three-dimensional analysis was performed using SAP$^{\circledR}$2000 finite element analysis (FEA) to determine the required composite strength and the rib locations. Principle stresses revealed that ***Taliesin*** required minimum composite strengths of 800psi in compression and 1,000psi in tension. The analysis team assumed concrete would contribute the necessary compressive strength, while the reinforcement would provide the required tensile strength. In addition, FEA showed that high stress concentrations were located near the paddlers' knees and at the adjacent chine. An iterative process modeled the ribs at various locations until a maximum stress reduction of 36% was achieved.

Ribs provided ***Taliesin*** with the support needed to further reduce tensile cracking in the canoe. The cross-sectional shapes of last year's ribs were structurally redundant and added excess weight. ***Taliesin*** engineers aimed to be more efficient and used FEA to match the modeled stresses to cross-sectional shapes that would provide sufficient, but not excessive, support. As a result, 1 1/4in. tall by 1/2in. wide ribs were situated across the bottom of the canoe and through the chine to effectively reduce cracking in these locations.

Architectural features were created to enhance the appearance and to reduce the weight of ***Taliesin***. It was revealed from FEA that stresses decreased considerably from the chine toward the gunwales. Rib designs were modified to complement the stresses induced onto the hull. As a result, the ribs were tapered from the chine to the gunwales. This innovative design provided structural support, reduced weight, and added a sophisticated architectural feature to ***Taliesin***.

Another architectural component that also reduced weight was the newly implemented variable wall thickness (VWT). Low stresses in the walls allowed engineers to reduce hull thickness to 3/8in. in specified locations without compromising structural integrity. The VWT was strategically placed to utilize the pre-stress wires for support and was designed to follow linear principles of Frank Lloyd Wright. In doing so, ***Taliesin*** innovatively combines advanced structural analysis with principles of architectural design.

Development & Testing

Taliesin development engineers researched new mixture components and performed standard and custom tests to create a sound composite concrete material. The development team's primary goal was to create a lightweight concrete mixture that, when combined with reinforcement, reached strengths of 800psi in compression and 1,000psi in flexure. Standard test methods were used to determine if test specimens met these strength requirements, while a newly incorporated punching shear test assessed the durability of the final composite concrete mixture. Though strength requirements governed mixture design, a secondary goal was to minimize the density of the concrete mixture to produce a canoe weighing less than 180lbs. A final goal was to enhance the appearance of ***Taliesin*** with the implementation of finishing mixtures and an inlay design.

Aggregate research was critical to the development of the final ***Taliesin*** mixtures. Engineers aimed to find strong, lightweight aggregates that complied with the gradation requirement of ASTM C33-04. Ceramic beads, alumino-silicate microspheres, and glass microspheres were selected based on their strength properties and low unit weights. A sieve analysis (ASTM C136-01-04) revealed that some of the selected aggregates needed to be separated to obtain particles that, when combined with the other aggregates, would produce a composite aggregate source that complied with ASTM C33.

These aggregates, along with binders, fibers, and admixtures, were tested in different proportions to develop the final ***Taliesin*** mixtures. Binders were chosen based on strength and workability properties. Type I white cement was used to give ***Taliesin*** its white hue, and was also used to create uniformly colored inlay mixtures. Latex, slag, epoxy, and fly ash were considered as secondary binders to achieve a strong, workable, and lightweight mixture. Latex was used in all test mixtures due to its ability to increase flexural strength and workability. Mixtures containing slag exhibited low unit weights but unacceptable strength and workability, while epoxy-modified mixtures were denser than desired. Mixtures with fly ash were slightly denser than mixtures with slag, but attained sufficient workability and strength, leading to its selection as a binder (Table 2).

Table 2: Secondary Binder Selection

Binder	Sufficient Density	Sufficient Strength	Workable
Latex	**Yes**	**Yes**	**Yes**
Slag	Yes	No	No
Epoxy	No	Yes	Yes
Fly Ash	**Yes**	**Yes**	**Yes**

Fibers were incorporated into mixture development to improve the ductility and impact resistance of the canoe. Fiber quantity was varied throughout mixture development to find a balance between flexural strength and workability. Carbon, polypropylene, and plastic fibers were chosen for testing in trial mixtures. Plastic fibers did not bond to the concrete well and were removed from consideration. Mixtures with carbon fibers resisted failure at larger loads, but failed more suddenly when compared to mixtures using polypropylene fibers. These properties led to a combination of carbon and polypropylene fibers in the final structural concrete mixture.

Forty-two test mixtures were cast into cylinders and formed into composite plates and subjected to compressive and flexural tests at 7 and 28 days (ASTM C39-04, ASTM C1018-04). Different reinforcing materials were considered, as were different hull thicknesses.

Mixture development proceeded through two stages. Initial trials were used to establish a baseline from which modified trials could be created and tested to refine the mixture design. Initial trials yielded compressive strengths up to three times the required strength and were also denser than desired. This prompted a reduction in cement and an increase in lightweight aggregate to reduce the unit weight of the concrete. Modified trials were used to fine tune the water-to-cement ratio and cement-to-aggregate ratio, and develop a reinforcement scheme that improved the composite flexural strength.

Development engineers considered two different types of fiberglass mesh to use as reinforcement. A stronger, thicker mesh was tested in 1/2in. thick plates, but delamination occurred at the concrete-mesh interface, causing an early failure of the composite section. A thinner, more flexible mesh was also tested, which bonded more effectively to the concrete layers, providing greater strength values. Half-inch plates using three layers of this mesh exceeded flexural strength requirements, so 3/8in. plates were considered to minimize the weight of the canoe. These plates displayed insufficient strength values to warrant an entire 3/8in. thick hull, but allowed for thinner sections in the wall, enabling the implementation of ***Taliesin's*** architectural variable wall thicknesses.

The final structural concrete mixture displayed a strength of 850psi in compression, while the final composite concrete mixture reached a strength of 1,250psi in flexure. Both of these values exceeded requirements established by structural analysis. The composite mixture's unit weight of 57.6pcf resulted in a 175lb canoe, which was less than the desired canoe weight of 180lbs (Table 3).

Throughout development, engineers also tested the durability of composite mixtures with a punching shear test. The test was performed on 12in. by 12in. by 1/2in. plates that represented the bottom of the canoe. Plates rested on four corner supports during the test and a crosshead was used to simulate the force exerted by a paddler's knee during the race competitions (Figure 2). A cyclical load ranging from 80lbf to 120lbf was applied on a test plate for 1,000 cycles, which is the estimated number of strokes throughout the races. The test plate proved to be durable when subjected to this loading, so the test was repeated with an increased cyclical loading from 160lbf to 240lbf. Data from these tests and a visual examination of the plates led engineers to conclude that the composite section would not fail under these loading conditions. Thus, the development team reached its first two goals, and could now focus on the aesthetic appeal of ***Taliesin***.

Table 3: Composite Mixture Design Progression

Mixture	Unit Weight	Compressive Strength	Flexural Strength*
	lb/ft^3	lb/in^2	lb/in^2
Initial Trials	65-72	1,300-2,500	500-850
Modified Trials	48-60	600-1,000	650-1,100
Final Mixture	**57.6**	**850**	**1,250**

*For composite test plates

Figure 2: Punching Shear Test

Sanding was performed on test plates to assess the finished surface of the structural concrete mixture. The hollow ceramic beads left concavities on the canoe's surface, prompting engineers to develop a finishing mixture with an increased water-to-cement ratio and a minimized aggregate content. This mixture was highly workable and easily filled the concavities. Slag replaced fly ash as a binder for this mixture because test mixtures with slag produced a desirable white color, improving the appearance of the canoe. Finally, inlay mixtures were developed using the structural mixture and the finishing mixture as baselines to complete the aesthetic elements of ***Taliesin***.

With the development team's successful completion of a composite concrete section that met the goals of structural analysis and architectural demands, engineers could now create ***Taliesin***.

Construction & Project Management

Construction

The goal of the construction team was to develop construction methods to accommodate for new design features, while maintaining organization throughout the entire process. Construction was divided into three phases: mold construction, placement, and finishing.

Completion of the hull design initiated mold construction. Sixty AutoCAD ™ cross sections were exported and stationed using 2in., 3in., and 6in. intervals to accurately represent the shape of ***Taliesin***. The sections were imported into a milling machine, creating templates of 1/2in. medium density fiberboard (MDF). Inexpensive and easily formed expanded polystyrene sections of interval thicknesses were selected and secured between the MDF templates and shaped with a hot wire. Sections were aligned onto a board affixed to a table constructed of MDF and sheet steel. The tapered ribs and the tips were cut and shaped by hand. Drywall joint compound was applied and sanded to smooth the surface. Custom shaped linoleum tiles were adhered to the surface to form well-defined depressions for the inlay design and variable wall thickness, and a plastic release agent was applied to aide in removal of ***Taliesin*** from the mold.

Placement was a critical component for ***Taliesin*'s** construction. Preparation involved dividing 30 engineers into teams based on specific tasks. Members of each team attended informational sessions to learn their assigned tasks to reduce error during the placement process. Proportioning of dry materials was done in advance to ensure efficiency throughout placing. Laboratory preparation involved the assembly of a humidity tent within a temperature controlled room to create ideal curing conditions.

Placement began with construction of the four tapered ribs (Rib Detail - Page 9). Then the first concrete layer of 1/8in. was placed on the entire mold followed by reinforcement and a 1/4in. layer of concrete. Ten longitudinal pre-stress wires were then tensioned and the two final layers of reinforcement were placed, along with the external concrete layer, forming an overall thickness of 1/2in.

Finishing was the final stage of construction. Approximately 400 person-hours were spent sanding with 60 to 2,000 grit sandpaper. Inlay depressions were filled with dyed concrete, and finishing mixtures provided a smooth surface. After sanding was complete, a clear sealant was used according to manufacturer's recommendations and decals were applied.

Project Management

An innovative five person committee was formed consisting of the project manager, project engineer, and three lead engineers (Page 6). This committee, which was formed based upon experience, built the framework that led the ***Taliesin*** team. The project manager and project engineer established an arterial structure that allowed information and ideas to flow among all members. A web-based network was used by all members to share information and maintain organization throughout the project.

The project schedule included a critical path that was developed from ambitious milestones. Timelines formed for each task established a detailed project schedule (Page 7). Milestones, which were chosen based on previous years' experiences, prompted the critical path (Table 4). A total of 3,000 person-hours, divided among all team members, were devoted to the project to continue UW-Madison's strong tradition of success.

Table 4: Project Milestones

Milestone	Difference	Explanation
Hull Design	On Schedule	Modified design caused no delay
Mixture Design	2 Week Delay	New testing methods
Placement Day	1 Week Delay	Assembly of humidity tent
Design Paper	On Schedule	Strict schedule and productive reviews

Organizational Chart

The *TALIESIN* Team

Project Manager

Jaime Kurten

Set project schedule, managed finances, coordinated all engineers. Involved in all aspects of the project.

Project Engineer

Sean Schutten

Organized and prepared meetings, coordinated lead engineers. Involved in all aspects of the project.

Administrative Engineer

Amy Roth

Managed presentation, paper, recruitment, and fundraising

Mix Design Engineer

Dave Chmielewski

Hull Design Engineer

Linda Vanevenhoven

Construction Engineer

Megan Martiny

Oral Presentation
Robbie Sivak
Conducted writing sessions, allocated presentation props

Design Paper
Jay Hille
Gathered information from team members, led writing sessions

Engineer's Notebook
Brad Groh
Coordinated materials & compiled information

Fundraising
Dana Dentice
Contacted business & alumni for donations

Administrative Team

Structural Engineer
Samantha Thompson
Performed 2D & 3D analyses, established structural system

Material Research
Kevin Forrest
Studied aggregates, binders, & reinforcement

Quality Control
Kelly Greuel
Formulated concrete mixing and testing processes

Structural Team

Paddling Engineer
Arick Groth
Organized paddling outings & inventoried paddling equipment

Practice Canoe
Amy Roth
Ordered fiberglass and epoxy, led practice canoe construction

Paddling Team
Amy Roth
Linda Vanevenhoven
Arick Groth
Dave Chmielewski

Paddling Team

Architectural Engineer
Ann Thielmann
Established theme & developed aesthetic requirements

Display Stand Construction
Joe Monahan
Developed design & led construction of stands

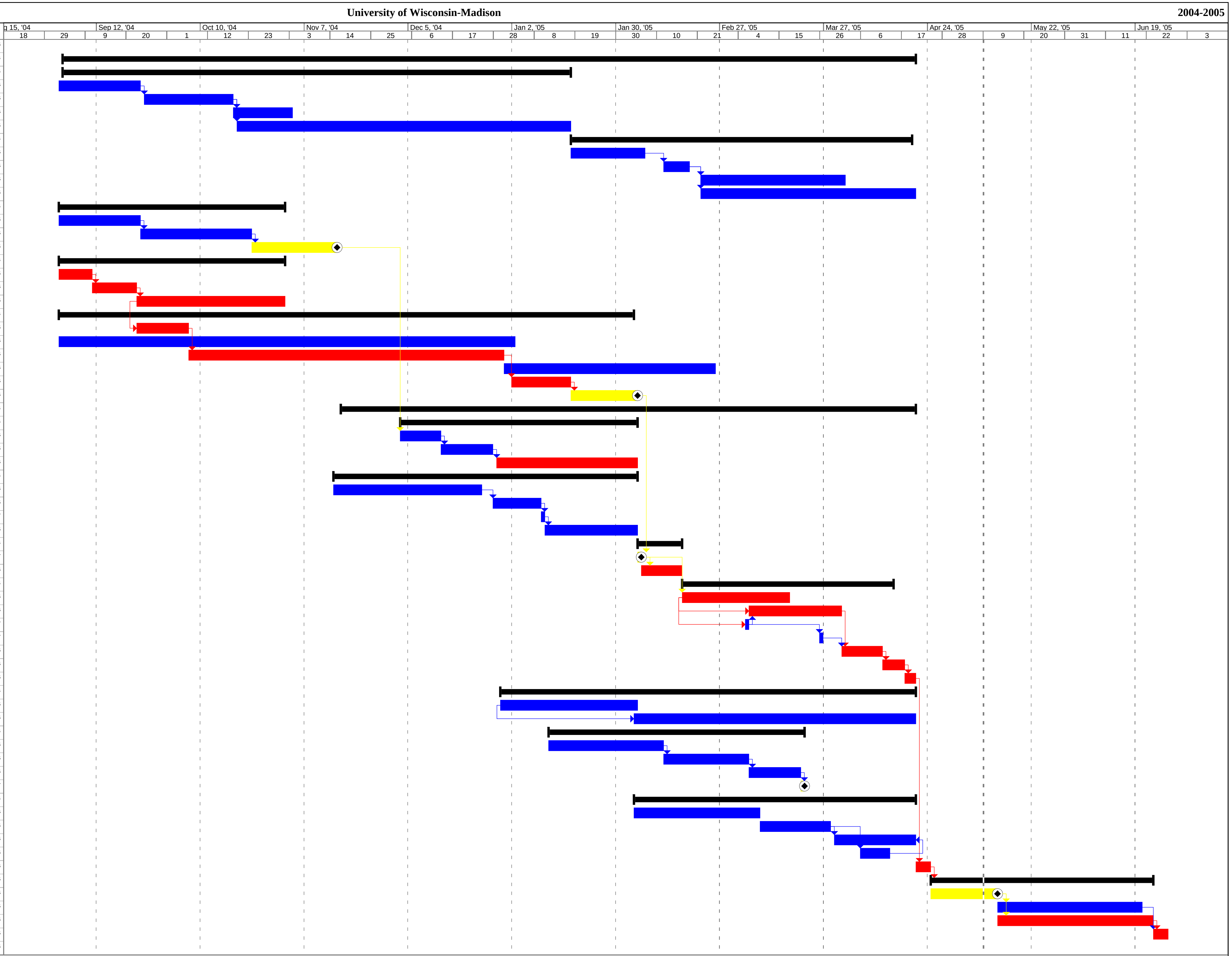
Cross Section
Alex Rexrode
Placed concrete and reinforcement for cross section cutaway

Graphic/Inlay Design
Ivy Harmon
Developed graphics & inlay design

Architectural Team

PROJECT SCHEDULE **University of Wisconsin-Madison** **2004-2005**

ID	Task Name	Start	Finish	Duration
1	Beginning of Taliesin	Thu 9/2/04	Thu 9/2/04	0 days
2	**Fundraising**	**Fri 9/3/04**	**Wed 4/20/05**	**188 days**
3	**Fall Semester**	**Fri 9/3/04**	**Mon 1/17/05**	**107 days**
4	1st Polygon Funding Committee Proposal	Thu 9/2/04	Thu 9/23/04	17 days
5	Prepare and Send Donation Letters	Sat 9/25/04	Mon 10/18/04	19 days
6	2nd Polygon Funding Committee Proposal	Tue 10/19/04	Wed 11/3/04	14 days
7	Collect Donations & Send Thank You Letters	Wed 10/20/04	Mon 1/17/05	70 days
8	**Spring Semester**	**Tue 1/18/05**	**Tue 4/19/05**	**80 days**
9	1st Polygon Funding Committee Proposal	Tue 1/18/05	Sun 2/6/05	19 days
10	Prepare and Send Donation Letters	Sat 2/12/05	Fri 2/18/05	6 days
11	2nd Polygon Funding Committee Proposal	Tue 2/22/05	Fri 4/1/05	31 days
12	Collect Donations & Send Thank You Letters	Tue 2/22/05	Wed 4/20/05	49 days
13	**Hull Design**	**Thu 9/2/04**	**Mon 11/1/04**	**49 days**
14	Preliminary Hull Design	Thu 9/2/04	Thu 9/23/04	17 days
15	Prolines Hull Design	Fri 9/24/04	Sat 10/23/04	25 days
16	Finalize Hull Design	Sun 10/24/04	Mon 11/15/04	18 days
17	**Analysis**	**Thu 9/2/04**	**Mon 11/1/04**	**49 days**
18	Concepts & Goals of Analysis	Thu 9/2/04	Fri 9/10/04	7 days
19	2-D Analysis	Sat 9/11/04	Wed 9/22/04	9 days
20	3-D Finite Element Analysis	Thu 9/23/04	Mon 11/1/04	33 days
21	**Mixture & Reinforcement Design**	**Thu 9/2/04**	**Thu 2/3/05**	**124 days**
22	Concepts & Goals of Mixture Design	Thu 9/23/04	Wed 10/6/04	12 days
23	Material Acquisition	Thu 9/2/04	Sun 1/2/05	95 days
24	Structural Mixture Design	Thu 10/7/04	Thu 12/30/04	65 days
25	Finishing Mixture Design	Fri 12/31/04	Fri 2/25/05	51 days
26	Reinforcement Scheme Design	Sun 1/2/05	Mon 1/17/05	14 days
27	Finalize Structural Mixture & Reinforcement	Tue 1/18/05	Fri 2/4/05	17 days
28	**Construction**	**Wed 11/17/04**	**Wed 4/20/05**	**128 days**
29	**Mold Construction**	**Fri 12/3/04**	**Fri 2/4/05**	**52 days**
30	Mill Cross Sections	Fri 12/3/04	Mon 12/13/04	7 days
31	Construct Expanded Polystyrene Mold	Tue 12/14/04	Mon 12/27/04	10 days
32	Finalize Mold Construction	Wed 12/29/04	Fri 2/4/05	34 days
33	**Prototype Practice Canoe**	**Mon 11/15/04**	**Fri 2/4/05**	**66 days**
34	Material Acquisition	Mon 11/15/04	Fri 12/24/04	30 days
35	Finalize Mold Construction-Prototype	Tue 12/28/04	Sun 1/9/05	11 days
36	Placement-Prototype	Mon 1/10/05	Mon 1/10/05	1 day
37	Finishing-Prototype	Tue 1/11/05	Fri 2/4/05	23 days
38	**Placement**	**Sat 2/5/05**	**Wed 2/16/05**	**11 days**
39	Taliesin's Placement Day	Sat 2/5/05	Sat 2/5/05	1 day
40	Cure Concrete	Sun 2/6/05	Wed 2/16/05	10 days
41	**Finishing**	**Thu 2/17/05**	**Thu 4/14/05**	**47 days**
42	Sand-Rough Finish	Thu 2/17/05	Thu 3/17/05	23 days
43	Patch-Imperfections	Mon 3/7/05	Thu 3/31/05	20 days
44	Remove Taliesin from the Mold	Sun 3/6/05	Sun 3/6/05	1 day
45	Inlay Placement	Sat 3/26/05	Sat 3/26/05	1 day
46	Sand-Intermediate Finish	Fri 4/1/05	Mon 4/11/05	10 days
47	Sand-Final Finish	Tue 4/12/05	Sun 4/17/05	6 days
48	Finalize with Clear Coat & Decals	Mon 4/18/05	Wed 4/20/05	3 days
49	**Paddling**	**Thu 12/30/04**	**Wed 4/20/05**	**97 days**
50	Workout Sessions	Thu 12/30/04	Fri 2/4/05	33 days
51	Paddling Training Sessions	Fri 2/4/05	Wed 4/20/05	65 days
52	**Design Paper**	**Wed 1/12/05**	**Mon 3/21/05**	**58 days**
53	Writing Sessions-Rough Draft	Wed 1/12/05	Fri 2/11/05	29 days
54	Critical Review & Revisions	Sat 2/12/05	Sun 3/6/05	18 days
55	Final Draft, Review, & Details	Mon 3/7/05	Sun 3/20/05	10 days
56	Submit Regional Paper	Mon 3/21/05	Mon 3/21/05	1 day
57	**Presentation**	**Fri 2/4/05**	**Wed 4/20/05**	**65 days**
58	Concept & Theme Generation	Fri 2/4/05	Wed 3/9/05	29 days
59	Writing Sessions	Thu 3/10/05	Mon 3/28/05	14 days
60	Rehearsal & Visuals Development	Wed 3/30/05	Wed 4/20/05	21 days
61	Critical Review & Revisions	Wed 4/6/05	Wed 4/13/05	8 days
62	**Regionals in Chicago, IL**	**Thu 4/21/05**	**Sun 4/24/05**	**3 days**
63	**Nationals Preparation**	Mon 4/25/05	Thu 6/23/05	45 days
64	Design Paper Revisions & Submittal	Mon 4/25/05	Thu 5/12/05	14 days
65	Presentation Improvements & Practice	Fri 5/13/05	Mon 6/20/05	28 days
66	Finishing Details	Fri 5/13/05	Thu 6/23/05	31 days
67	**Nationals in Clemson, SC**	Fri 6/24/05	Mon 6/27/05	4 days
68	Completetion of Taliesin	Mon 6/27/05	Mon 6/27/05	0 days



Project: ***Taliesin***

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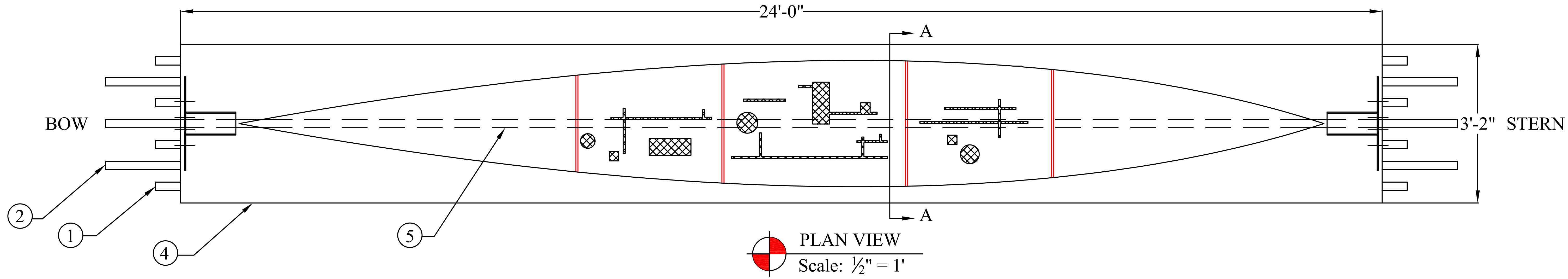
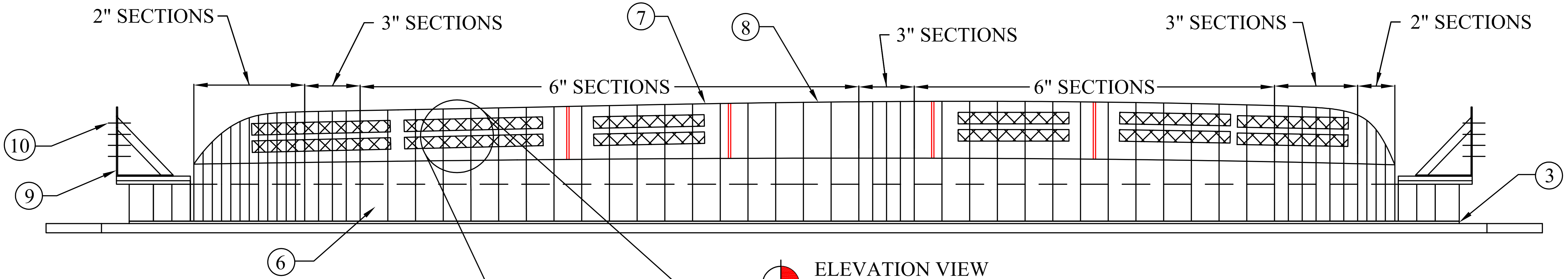


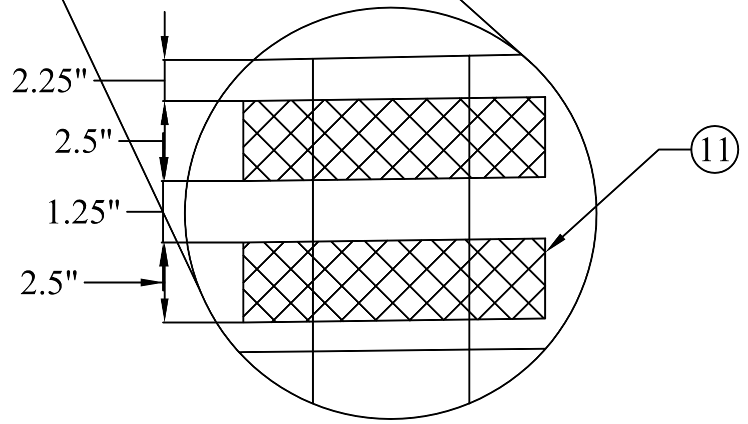
PLAN VIEW
Scale: ½" = 1'



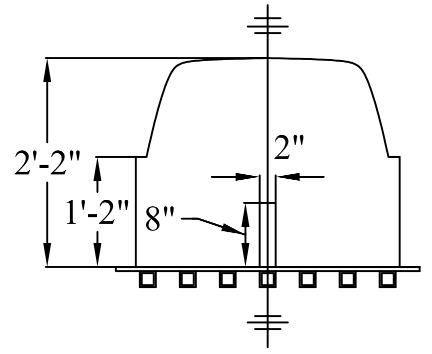
ELEVATION VIEW
Scale: ½" = 1'

BILL OF MATERIALS

NO.	QTY.	DESCRIPTION
1	4	2" X 2" X 25' STEEL TUBE
2	3	2" X 2" X 27' STEEL TUBE
3	1	½" MEDIUM DENSITY FIBERBOARD
4	1	20 GAGE SHEET STEEL
5	1	2" X 8" WOOD TRACK
6	60	EXPANDED POLYSTYRENE
7	N/A	ALL PURPOSE JOINT COMPOUND
8	1	PLASTIC RELEASE AGENT
9	2	STANCHION
10	10	TURNBUCKLE
11	40	⅛" LINOLEUM TILES



VARIABLE WALL THICKNESS DETAIL
Not to scale

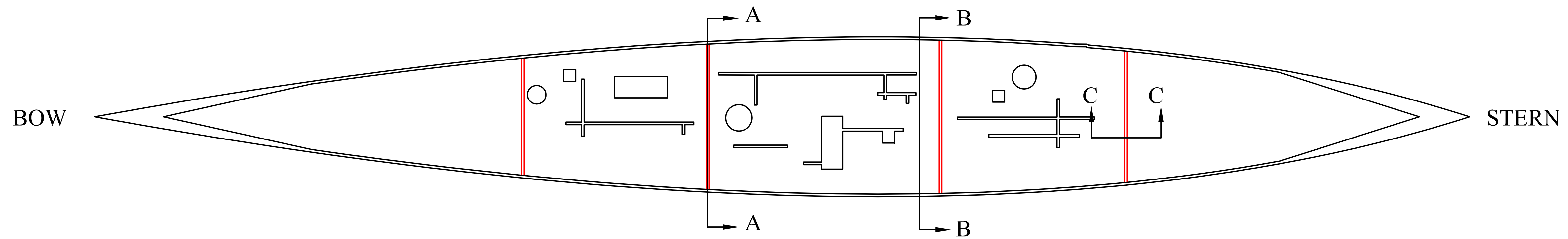


SECTION A-A

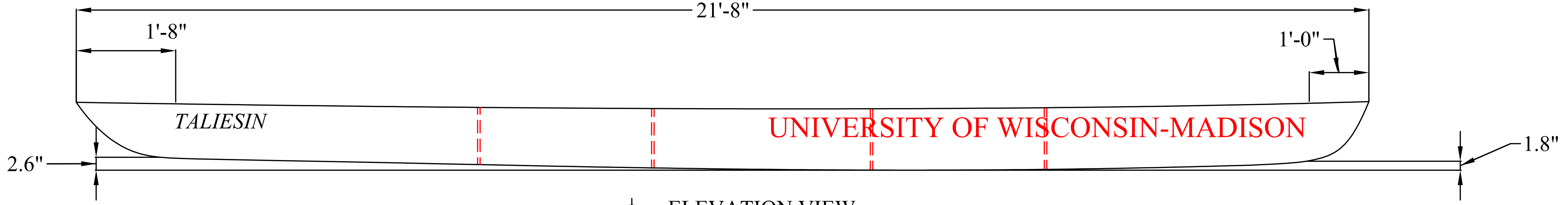
TYPICAL CROSS SECTION
Scale: ½" = 1'

GENERAL NOTES:
1. SECTION A-A IS AT THE WIDEST SECTION OF THE MOLD

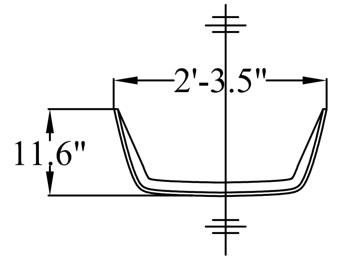
PROJECT NAME: **TALIESIN**
DRAWING NAME: FORM DESIGN
DATE: May 13, 2005
SHEET NUMBER: 8
UNIVERSITY OF WISCONSIN MADISON



PLAN VIEW
Scale: ½" = 1'

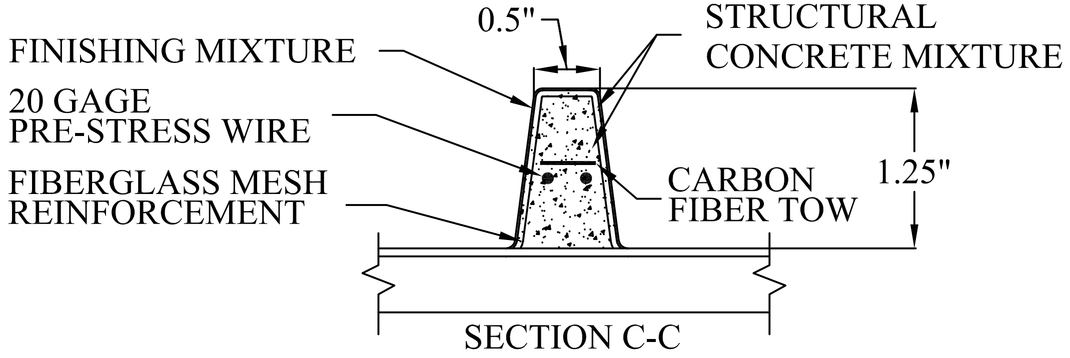


ELEVATION VIEW
Scale: ½" = 1'



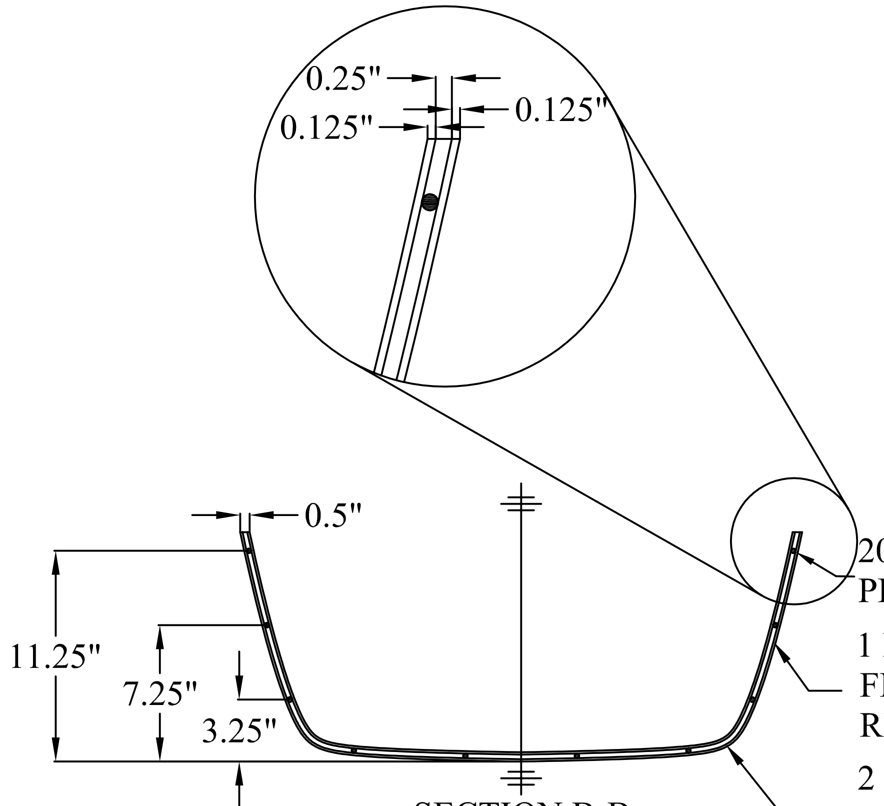
SECTION A-A

TYPICAL RIB CROSS SECTION
Scale: ½" = 1'



SECTION C-C

RIB DETAIL
Not to scale



SECTION B-B

PRESTRESS DETAIL
Not to scale

GENERAL NOTES:

1. THE FOUR RIBS ARE LOCATED AT 6.75 FT, 9.67 FT, 13.33 FT, AND 16.25 FT AFT BOW.
2. SECTION B-B IS AT THE WIDEST SECTION OF THE CANOE.

BILL OF MATERIALS

NO.	QTY.	DESCRIPTION
1	10	20 GAGE STEEL WIRES
2	3	4.5 OZ/SQ YD FIBERGLASS MESH REINFORCEMENT (69.5 SQ FT)
3	4	CARBON FIBER TOW (~4'-0")
4	2.77 cf	SRUCTURAL CONCRETE MIXTURE
5	0.36 cf	FINISHING MIXTURE
6	0.01 cf	INLAY MIXTURE
7	N/A	INLAY FINISHING MIXTURE

PROJECT NAME: **TALIESIN**
DRAWING NAME: HULL DESIGN
DATE: May 13, 2005
SHEET NUMBER: 9

UNIVERSITY OF WISCONSIN MADISON

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Table 3.1.1 - Summary Of Mixture Proportions
Mixture Designation: Structural Concrete Mixture

Air and Cementitious Materials

Air Content of Concrete	Amount: 7.80%	Volume:	0.47×10^{-3} (m^3)	
Cementitious Material	**Specific Gravity**	**Amount (kg/m^3)**	**Volume (m^3)**	
ASTM C 150 Cement Type: I	3.15	246.65	0.08	
2*: Class C Fly Ash	2.60	52.81	0.02	
3*: Acrylic Latex (28% Solids)	1.10	51.55	0.05	
∑(all cementitious materials)		*cm:* 351.01	Vol$_{cm}$: 0.15	(1)
Cement-to-cementitious materials ratio		*c/cm:* 0.82		

Aggregates

Aggregate #	Amount (kg/m^3)	ASTM C 127/128 BSG (*SSD*)	Volume (m^3)	Batch Weight (kg/m^3)	
1. Glass Microspheres	$W_{SSD,1}$: 36.41	0.20	0.18	$W_{stk,1}$: 36.39	
2. Alumino-Silicate Spheres	$W_{SSD,2}$: 80.35	0.70	0.11	$W_{stk,2}$: 80.25	
3. ML 714 Ceramic Beads	$W_{SSD,3}$: 85.92	0.77	0.11	$W_{stk,3}$: 85.56	
4. ML 1430 Ceramic Beads	$W_{SSD,4}$: 198.76	0.85	0.23	$W_{stk,4}$: 197.97	
5. ML 3050 Ceramic Beads	$W_{SSD,5}$: 15.81	1.05	0.02	$W_{stk,5}$: 15.74	
Combined	$W_{SSD,agg}$: 417.25	0.62	0.67	$W_{stk,agg}$: 415.91	(2)

Fibers

Fiber #	Volume Fraction (%)	Specific Gravity	Volume (m^3)	Batch Weight (kg/m^3)	
1. Polypropylene Fibers	0.14%	0.90	1.32×10^{-3}	1.18	
2. Carbon Fibers	0.21%	1.80	1.98×10^{-3}	3.54	
∑(all fibers)	0.35%		3.30×10^{-3}	4.72	(3)

Dye

Dye #	Volume Fraction (%)	Specific Gravity	Volume (m^3)	Batch Weight (kg/m^3)	
∑(all dyes)	0.00%		0	0.00	(4)

Water

Water †	*W*: 140.45	w_{batch}: 11.08	kg/m^3	
Vol. of Acrylic Latex	x_1: 136978.68		mL/m^3	
Water from Acrylic Latex		$w_{admx,1}$: 130.71	kg/m^3	
Total of free water from all aggregates		$\sum w_{free}$: -1.34	kg/m^3	
Total Water	*w*: 140.45	*w*: ‡ 140.45	kg/m^3	(5)

Concrete density §	912.09	kg/m^3
Water-to-cement ratio	*w/c*: 0.57	
Water-to-cementitious materials ratio	*w/cm*: 0.47	

* If the binder comes from the manufacturer mixed with water, include only the weight of the binder here.

† 1st column is used for the desired total water, the 2nd column is for water added directly to the batch.

‡ *w* in this column = $w_{batch} + w_{admx,1}$. This value should match the value for *w* in the previous column.

§ The sum of items in rows (1), (2), (3), (4) and (5).

Table 3.1.2 - Summary Of Mixture Proportions
Mixture Designation: Finishing Mixture

Air and Cementitious Materials

Air Content of Concrete	Amount: 5.50%	Volume:	0.33×10^{-3} (m^3)	
Cementitious Material	Specific Gravity	Amount (kg/m^3)	Volume (m^3)	
ASTM C 150 Cement Type: I	3.15	339.18	0.11	
2*: Grade 120 Slag	2.30	121.48	0.05	
3*: Acrylic Latex (28% Solids)	1.10	23.46	0.02	
∑(all cementitious materials)		*cm:* 484.13	Vol_{cm}: 0.18	(1)
Cement-to-cementitious materials ratio		*c/cm:* 0.74		

Aggregates

Aggregate #	Amount (kg/m^3)	ASTM C 127/128 BSG (*SSD*)	Volume (m^3)	Batch Weight (kg/m^3)	
1. Glass Microspheres	$W_{SSD,1}$: 26.62	0.20	0.13	$W_{stk,1}$: 26.60	
2. Alumino-Silicate Spheres	$W_{SSD,2}$: 54.60	0.70	0.08	$W_{stk,2}$: 54.53	
3. ML 714 Ceramic Beads	$W_{SSD,3}$: 151.38	0.77	0.20	$W_{stk,3}$: 150.75	
4. ML 1430 Ceramic Beads	$W_{SSD,4}$: 78.35	0.85	0.09	$W_{stk,4}$: 78.03	
Combined	$W_{SSD,agg}$: 310.94	0.62	0.50	$W_{stk,agg}$: 309.92	(2)

Fibers

Fiber #	Volume Fraction (%)	Specific Gravity	Volume (m^3)	Batch Weight (kg/m^3)	
∑(all fibers)	0.00%		0	0.00	(3)

Dye

Dye #	Volume Fraction (%)	Specific Gravity	Volume (m^3)	Batch Weight (kg/m^3)	
∑(all dyes)	0.00%		0	0.00	(4)

Water

Water †	*W*: 205.81	w_{batch}: 147.33	kg/m^3	
Vol. of Acrylic Latex	x_1: 11484.38		mL/m^3	
Water from Acrylic Latex		$w_{admx,1}$: 59.50	kg/m^3	
Total of free water from all aggregates		$\sum w_{free}$: -1.02	kg/m^3	
Total Water	*w*: 205.81	*w*: ‡ 205.81	kg/m^3	(5)
Concrete density §	999.85		kg/m^3	
Water-to-cement ratio	*w/c*: 0.61			
Water-to-cementitious materials ratio	*w/cm*: 0.45			

* If the binder comes from the manufacturer mixed with water, include only the weight of the binder here.

† 1st column is used for the desired total water, the 2nd column is for water added directly to the batch.

‡ *w* in this column = $w_{batch} + w_{admx,1}$. This value should match the value for *w* in the previous column.

§ The sum of items in rows (1), (2), (3), (4) and (5).

TABLE 3.1.3 - SUMMARY OF MIXTURE PROPORTIONS
MIXTURE DESIGNATION: INLAY MIXTURE

AIR AND CEMENTITIOUS MATERIALS

Air Content of Concrete	Amount: 7.30%	Volume:	0.44×10^{-3} (m^3)

Cementitious Material	Specific Gravity	Amount (kg/m^3)	Volume (m^3)	
ASTM C 150 Cement Type: I	3.15	245.35	0.08	
2*: Class C Fly Ash	2.60	52.53	0.02	
3*: Acrylic Latex (28% Solids)	1.10	51.28	0.05	
∑(all cementitious materials)		*cm:* 349.15	Vol_{cm}: 0.14	(1)
Cement-to-cementitious materials ratio		*c/cm:* 0.82		

AGGREGATES

Aggregate #	Amount (kg/m^3)	ASTM C 127/128 BSG (*SSD*)	Volume (m^3)	Batch Weight (kg/m^3)	
1. Glass Microspheres	$W_{SSD,1}$: 36.22	0.20	0.18	$W_{stk,1}$: 36.20	
2. Alumino-Silicate Spheres	$W_{SSD,2}$: 79.92	0.70	0.11	$W_{stk,2}$: 79.83	
3. ML 714 Ceramic Beads	$W_{SSD,3}$: 85.47	0.77	0.11	$W_{stk,3}$: 85.11	
4. ML 1430 Ceramic Beads	$W_{SSD,4}$: 197.73	0.85	0.23	$W_{stk,4}$: 196.94	
5. ML 3050 Ceramic Beads	$W_{SSD,5}$: 15.73	1.05	0.01	$W_{stk,5}$: 15.65	
Combined	$W_{SSD,agg}$: 415.06	0.62	0.67	$W_{stk,agg}$: 413.72	(2)

FIBERS

Fiber #	Volume Fraction (%)	Specific Gravity	Volume (m^3)	Batch Weight (kg/m^3)	
1. Polypropylene Fibers	0.34%	0.90	3.28×10^{-3}	2.93	
∑(all fibers)	0.34%		3.28×10^{-3}	2.93	(3)

DYE

Dye #	Volume Fraction (%)	Specific Gravity	Volume (m^3)	Batch Weight (kg/m^3)	
1. Powdered Dye	0.12%	5.00	1.18×10^{-3}	5.87	
∑(all dyes)	0.12%		1.18×10^{-3}	5.87	(4)

WATER

Water †	*W*: 146.46	w_{batch}: 17.77	kg/m^3	
Vol. of Acrylic Latex	x_1: 67677.87		mL/m^3	
Water from Acrylic Latex		$w_{admx,1}$: 130.02	kg/m^3	
Total of free water from all aggregates		$\sum w_{free}$: -1.34	kg/m^3	
Total Water	*w*: 146.46	*w*: ‡ 146.46	kg/m^3	(5)

Concrete density §	918.14	kg/m^3
Water-to-cement ratio	*w/c*: 0.60	
Water-to-cementitious materials ratio	*w/cm*: 0.49	

* If the binder comes from the manufacturer mixed with water, include only the weight of the binder here.

† 1st column is used for the desired total water, the 2nd column is for water added directly to the batch.

‡ w in this column = $w_{batch} + w_{admx,1}$. This value should match the value for w in the previous column.

§ The sum of items in rows (1), (2), (3), (4), and (5).

TABLE 3.1.4 - SUMMARY OF MIXTURE PROPORTIONS
MIXTURE DESIGNATION: INLAY FINISHING MIXTURE

AIR AND CEMENTITIOUS MATERIALS

Air Content of Concrete	Amount: 5.50%	Volume:	0.33 x 10^{-3} (m^3)	
Cementitious Material	**Specific Gravity**	**Amount (kg/m^3)**	**Volume (m^3)**	
ASTM C 150 Cement Type: I	3.15	317.30	0.10	
2*: Grade 120 Slag	2.30	113.65	0.05	
3*: Acrylic Latex (28% Solids)	1.10	21.95	0.02	
∑(all cementitious materials)		*cm:* 452.89	Vol$_{cm}$: 0.17	(1)
Cement-to-cementitious materials ratio		*c/cm:* 0.74		

AGGREGATES

Aggregate #	Amount (kg/m^3)	ASTM C 127/128 BSG (*SSD*)	Volume (m^3)	Batch Weight (kg/m^3)	
1. Glass Microspheres	$W_{SSD,1}$: 28.22	0.20	0.14	$W_{stk,1}$: 28.20	
2. Alumino-Silicate Spheres	$W_{SSD,2}$: 57.72	0.70	0.08	$W_{stk,2}$: 57.65	
3. ML 714 Ceramic Beads	$W_{SSD,3}$: 159.94	0.77	0.21	$W_{stk,3}$: 159.27	
4. ML 1430 Ceramic Beads	$W_{SSD,4}$: 82.87	0.85	0.10	$W_{stk,4}$: 82.54	
Combined	$W_{SSD,agg}$: 328.75	0.62	0.53	$W_{stk,agg}$: 327.67	(2)

FIBERS

Fiber #	Volume Fraction (%)	Specific Gravity	Volume (m^3)	Batch Weight (kg/m^3)	
∑(all fibers)	0.00%		0	0.00	(3)

DYE

Dye #	Volume Fraction (%)	Specific Gravity	Volume (m^3)	Batch Weight (kg/m^3)	
1. Powdered Dye	0.28%	5.00	2.43 x 10^{-3}	11.20	
∑(all dyes)	0.28%		1.18 x 10^{-3}	11.20	(4)

WATER

Water †	*W*: 213.27	w_{batch} : 158.69	kg/m^3	
Vol. of Acrylic Latex	x_1: 10688.14		mL/m^3	
Water from Acrylic Latex		$w_{admx,1}$: 55.66	kg/m^3	
Total of free water from all aggregates		$\sum w_{free}$: -1.08	kg/m^3	
Total Water	*w* : 213.27	*w* : ‡ 213.27	kg/m^3	(5)

Concrete density §	1005.03	kg/m^3
Water-to-cement ratio	*w/c* : 0.67	
Water-to-cementitious materials ratio	*w/cm* : 0.49	

* If the binder comes from the manufacturer mixed with water, include only the weight of the binder here.

† 1st column is used for the desired total water, the 2nd column is for water added directly to the batch.

‡ *w* in this column = $w_{batch} + w_{admx,1}$. This value should match the value for *w* in the previous column.

§ The sum of items in rows (1), (2), (3), (4), and (5).

Gradation Curves & Tables

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: Alumino Silicate Spheres

Sample Weight: 323.5 g

Specific Gravity (G_s): 0.70

Fineness Modulus: 0.95

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	3.2	3.2	99%
No. 100	0.15	300.2	303.4	6%
P 100	0.00	19.5	322.9	0%

Gradation Curves & Tables

Concrete Aggregate: ML 714 Ceramic Beads

Sample Weight: 500.1 g

Specific Gravity (G_s): 0.77

Fineness Modulus: 4.00

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	498.7	498.7	0%
No. 30	0.60	1.1	499.8	0%
No. 50	0.30	0.0	499.8	0%
No. 100	0.15	0.0	499.8	0%
P 100	0.00	0.0	499.8	0%

Concrete Aggregate: ML 1430 Ceramic Beads

Sample Weight: 500.0 g

Specific Gravity (G_s): 0.85

Fineness Modulus: 2.99

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	495.6	495.6	1%
No. 50	0.30	3.7	499.3	0%
No. 100	0.15	0.0	499.3	0%
P 100	0.00	0.0	499.3	0%

Gradation Curves & Tables

Concrete Aggregate: ML 3050 Ceramic Beads

Sample Weight: 500.1 g

Specific Gravity (G_s): 1.05

Fineness Modulus: 2.00

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	0.1	0.1	100%
No. 50	0.30	497.0	497.1	0%
No. 100	0.15	2.2	499.3	0%
P 100	0.00	0.0	499.3	0%

Structural Concrete Mixture

Concrete Aggregate: Structural Concrete Mixture Aggregate

Sample Weight: 415.46 kg/m^3

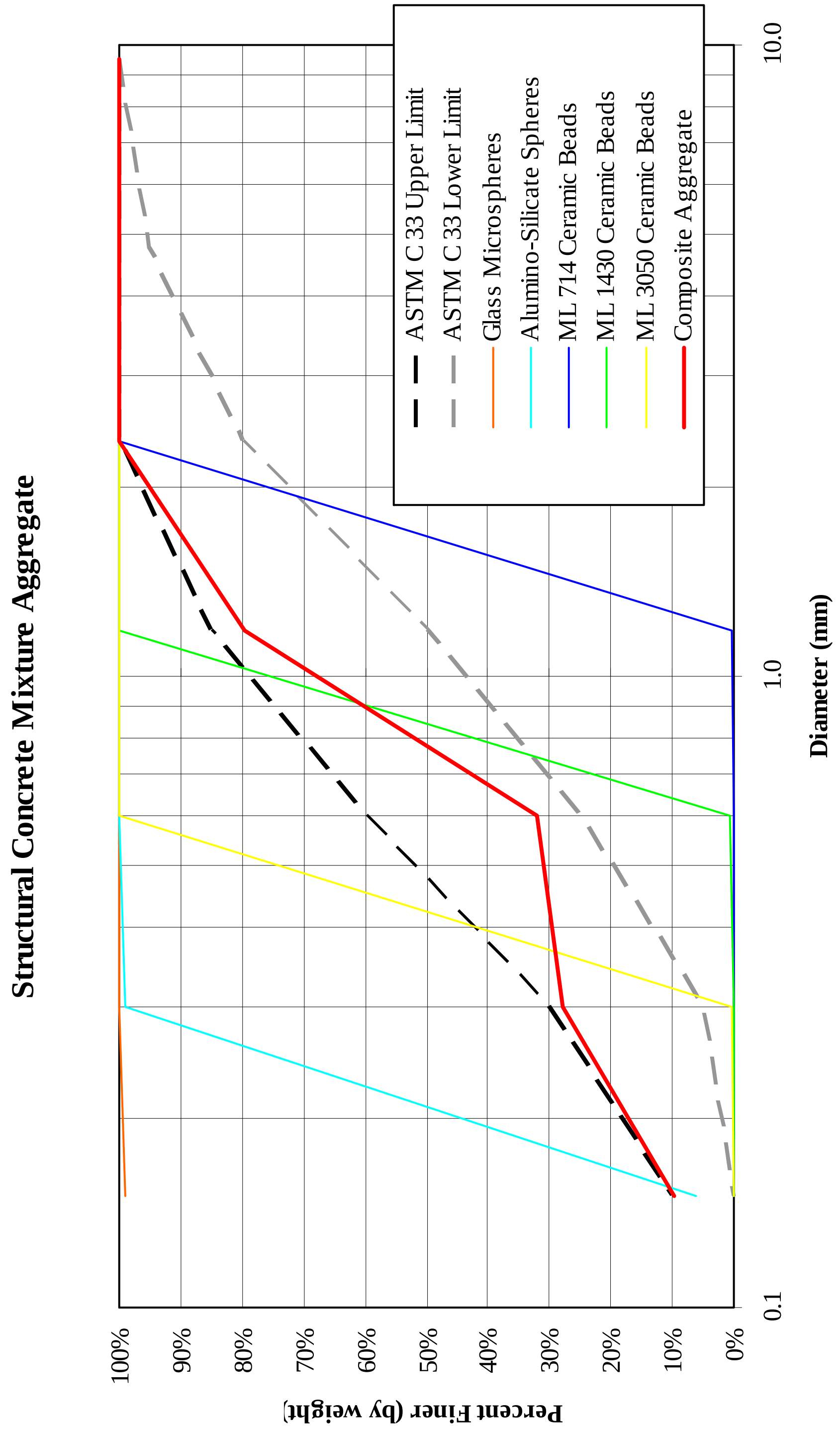
Specific Gravity (G_s): 0.62

Fineness Modulus: 2.51

Aggregate	Oven Dry Weight (kg/m^3)
1. Glass Bubbles	36.35
2. Trelleborg Fillite 500	80.11
3. ML 714 Ceramic Beads	85.49
4. ML 1430 Ceramic Beads	197.77
5. ML 3050 Ceramic Beads	15.74

Percent Finer (%)

Sieve	Glass Microspheres	Alumino-Silicate Spheres	ML 714 Ceramic Beads	ML 1430 Ceramic Beads	ML 3050 Ceramic Beads	Composite
3/8 inch	100%	100%	100%	100%	100%	100.0%
No. 4	100%	100%	100%	100%	100%	100.0%
No. 8	100%	100%	100%	100%	100%	100.0%
No. 16	100%	100%	0%	100%	100%	79.5%
No. 30	100%	100%	0%	1%	100%	32.2%
No. 50	100%	99%	0%	0%	0%	27.9%
No. 100	99%	6%	0%	0%	0%	9.8%
P 100	0%	0%	0%	0%	0%	0.0%


Structural Concrete Mixture Aggregate
Percent Finer (by weight)
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0.1
1.0
10.0
Diameter (mm)
ASTM C 33 Upper Limit
ASTM C 33 Lower Limit
Glass Microspheres
Alumino-Silicate Spheres
ML 714 Ceramic Beads
ML 1430 Ceramic Beads
ML 3050 Ceramic Beads
Composite Aggregate

Finishing Mixture

Concrete Aggregate: Finishing Mixture Aggregate

Sample Weight: 309.59 kg/m^3

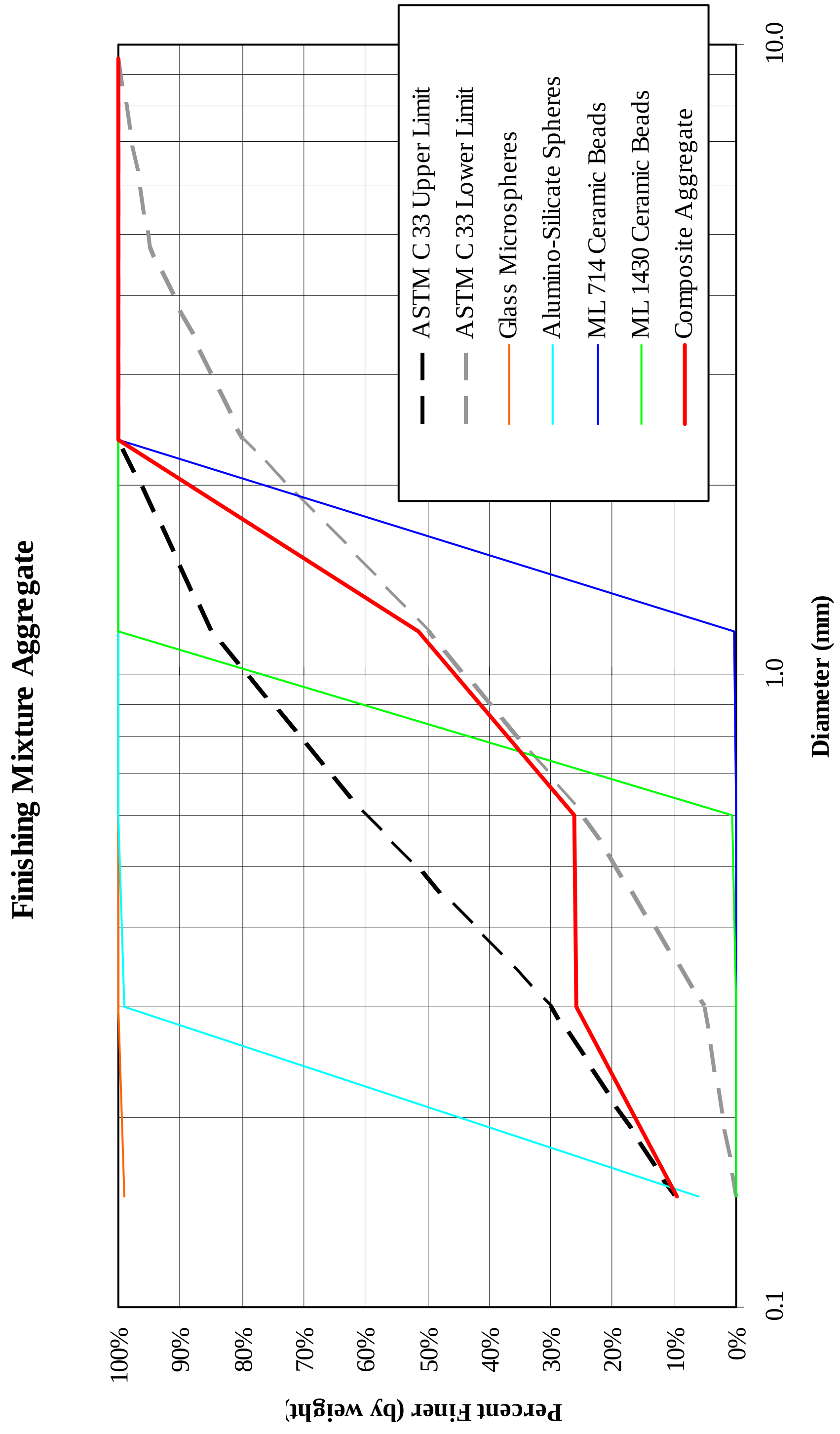
Specific Gravity (G_s): 0.62

Fineness Modulus: 2.87

Aggregate	Oven Dry Weight (kg/m^3)
1. Glass Bubbles	26.58
2. Trelleborg Fillite 500	54.44
3. ML 714 Ceramic Beads	150.63
4. ML 1430 Ceramic Beads	77.96

Percent Finer (%)

Sieve	Glass Microspheres	Alumino-Silicate Spheres	ML 714 Ceramic Beads	ML 1430 Ceramic 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%	100%	0%	100%	51.5%
No. 30	100%	100%	0%	1%	26.4%
No. 50	100%	99%	0%	0%	26.0%
No. 100	99%	6%	0%	0%	9.6%
P 100	0%	0%	0%	0%	0.0%


Finishing Mixture Aggregate
Percent Finer (by weight)
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0.1
1.0
10.0
Diameter (mm)
ASTM C 33 Upper Limit
ASTM C 33 Lower Limit
Glass Microspheres
Alumino-Silicate Spheres
ML 714 Ceramic Beads
ML 1430 Ceramic Beads
Composite Aggregate

Inlay Mixture

Concrete Aggregate: Inlay Mixture Aggregate

Sample Weight: 413.72 kg/m^3

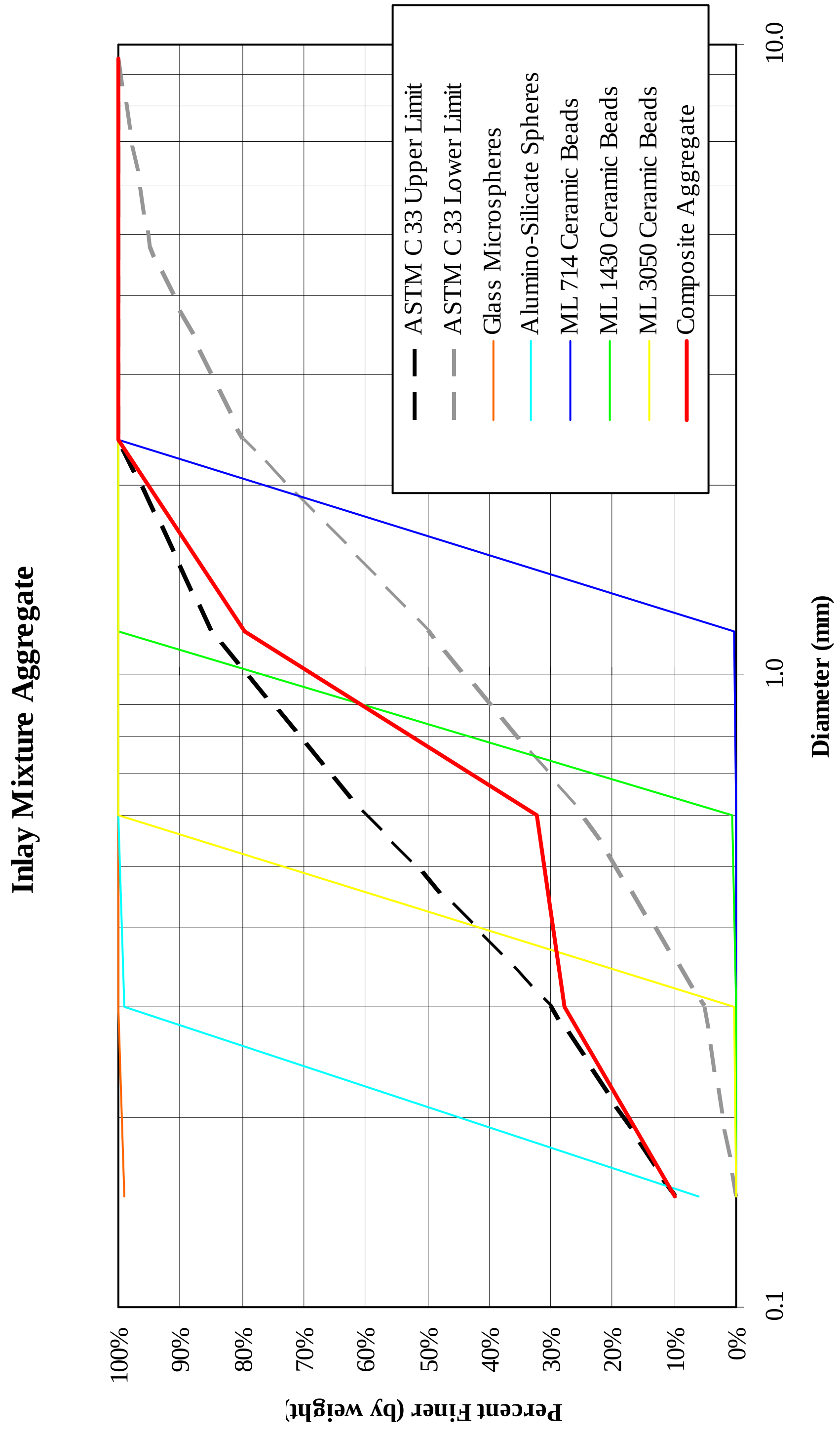
Specific Gravity (G_s): 0.62

Fineness Modulus: 2.51

Aggregate	Oven Dry Weight (kg/m^3)
1. Glass Bubbles	36.20
2. Trelleborg Fillite 500	79.83
3. ML 714 Ceramic Beads	85.11
4. ML 1430 Ceramic Beads	196.94
5. ML 3050 Ceramic Beads	15.65

Percent Finer (%)

Sieve	Glass Microspheres	Alumino-Silicate Spheres	ML 714 Ceramic Beads	ML 1430 Ceramic Beads	ML 3050 Ceramic Beads	Composite
3/8 inch	100%	100%	100%	100%	100%	100.0%
No. 4	100%	100%	100%	100%	100%	100.0%
No. 8	100%	100%	100%	100%	100%	100.0%
No. 16	100%	100%	0%	100%	100%	79.5%
No. 30	100%	100%	0%	1%	100%	32.2%
No. 50	100%	99%	0%	0%	0%	27.9%
No. 100	99%	6%	0%	0%	0%	9.8%
P 100	0%	0%	0%	0%	0%	0.0%


Inlay Mixture Aggregate
Percent Finer (by weight)
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Diameter (mm)
0.1
1.0
10.0
ASTM C 33 Upper Limit
ASTM C 33 Lower Limit
Glass Microspheres
Alumino-Silicate Spheres
ML 714 Ceramic Beads
ML 1430 Ceramic Beads
ML 3050 Ceramic Beads
Composite Aggregate

Inlay Finishing Mixture

Concrete Aggregate: Inlay Finishing Mixture Aggregate

Sample Weight: 327.67 kg/m^3

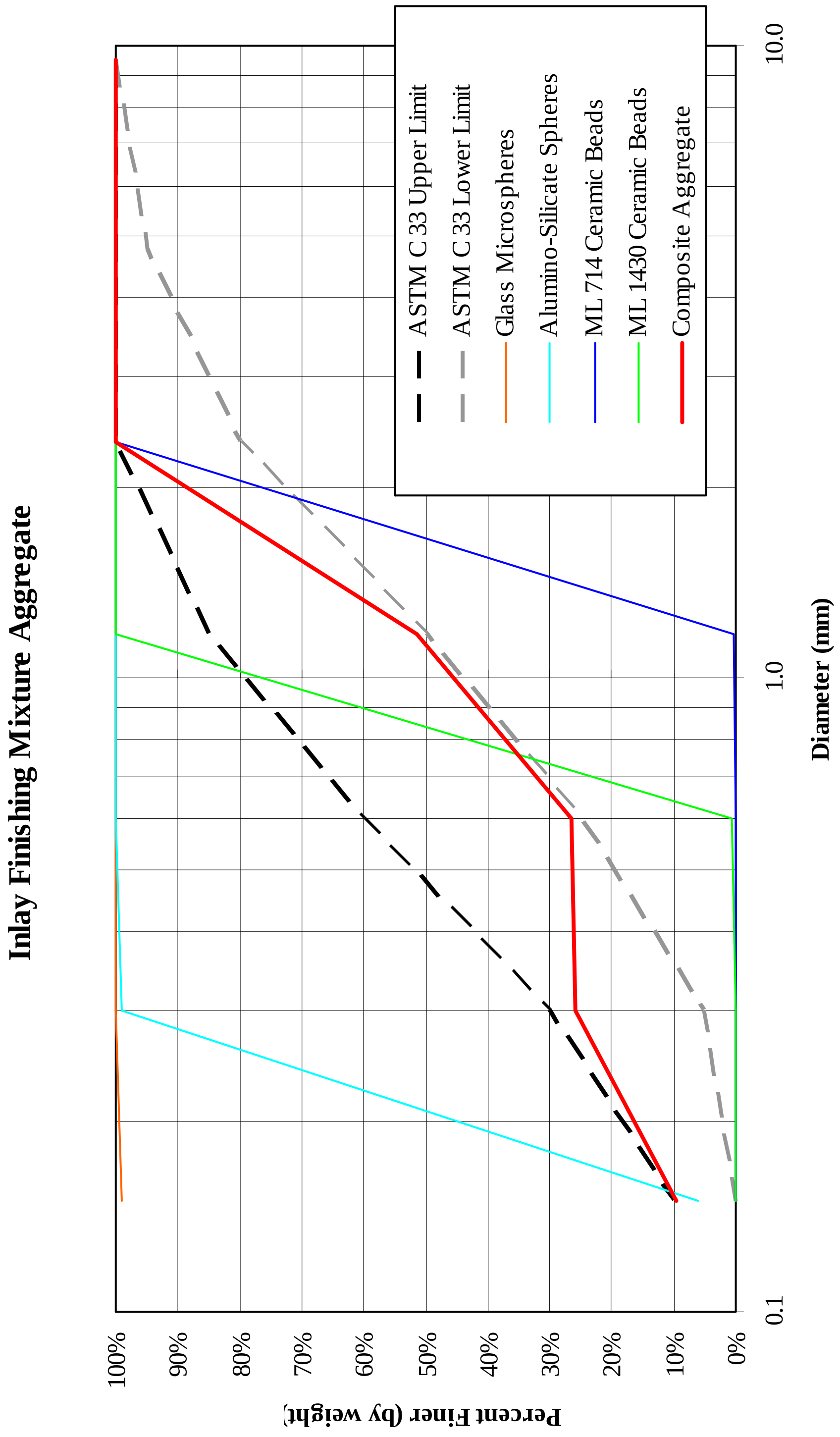
Specific Gravity (G_s): 0.62

Fineness Modulus: 2.86

Aggregate	Oven Dry Weight (kg/m^3)
1. Glass Bubbles	28.20
2. Trelleborg Fillite 500	57.65
3. ML 714 Ceramic Beads	159.27
4. ML 1430 Ceramic Beads	82.54

Percent Finer (%)

Sieve	Glass Microspheres	Alumino-Silicate Spheres	ML 714 Ceramic Beads	ML 1430 Ceramic 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%	100%	0%	100%	51.5%
No. 30	100%	100%	0%	1%	26.4%
No. 50	100%	99%	0%	0%	26.0%
No. 100	99%	6%	0%	0%	9.6%
P 100	0%	0%	0%	0%	0.0%


Inlay Finishing Mixture Aggregate
Percent Finer (by weight)
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Diameter (mm)
0.1
1.0
10.0
ASTM C 33 Upper Limit
ASTM C 33 Lower Limit
Glass Microspheres
Alumino-Silicate Spheres
ML 714 Ceramic Beads
ML 1430 Ceramic Beads
Composite Aggregate