Michigan Tech

Concrete Canoe
Design Paper 2009-2010

Yooper

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Figure 1: Michigan Technological University

Executive Summary

Michigan Technological University (Michigan Tech), located in Houghton, Michigan, is home to more than 6,500 students with over 1,000 enrolled in its graduate school (see Figure 1). Academics aside, the University is known for its remote location in Michigan's Upper Peninsula, better known as the U.P. Making up nearly one-third of Michigan's land area, the U.P. contains only about three percent of Michigan's population. Local communities combat the long, cold, snowy winters that are fueled by the never-ending snowfall, as demonstrated by a record snowfall of over 390 inches in the winter of 1979. The U.P. is home to a vast array of wildlife and is recognized for its logging and mining industries. The climate and isolation of the communities unite locals, instilling a strong sense of pride. As students having the privilege to be a part of this strong bond, the team decided to share the experience and natural beauty of the U.P. by making it this year's theme.

The Michigan Tech Concrete Canoe Team has been participating in the North Central Conference since the mid-1970s, representing the conference ten times at the national level and achieving a team best of third place in 2005. In an effort to continue the growth of the team, several innovative features were introduced this year, especially within project management and construction. An accelerated schedule was employed to optimize semester break as a curing period which allowed additional time for a higher quality, aesthetically-appealing finish. The additional time allocated for finishes enabled more colors to be used and broadened aesthetics to encompass outlay designs. In terms of design, the team successfully complied with the 2010 ASCE National Concrete Canoe Competition™ Rules to achieve 100% recycled aggregate for the concrete mixes. Derived from "U.P.-er," the Michigan Tech Concrete Canoe Team is proud to present their 2009-2010 canoe YOOPER (see Tables 1 and 2 below for canoe specifics).

Table 1: Canoe Characteristics

Name	YOOPER
Weight	162 lbs
Length	19' 11.375 "
Width	31.625"
Depth	16.0"
Nominal Thickness	0.375"
Main Color	White
Complimentary Colors	Dark and Sky Blue, Brick Red, Gray, Forest Green, Crème, Black, Brown

Table 2: Canoe Engineering Properties

Unit Weight	53.0 pcf
14 day Compressive Strength	2255 psi
14 day Tensile Strength	385 psi
Continuous Reinforcement	Chromarat C-Grid® CT300 and CT275 Carbon Fiber Grid
Fiber Reinforcement	Nycon Kuralon™ RF4000 and RECS15 Polyvinyl Alcohol Fibers

Analysis

The team's software experience and availability permitted the use of Abaqus/CAE to perform a Finite Element Analysis (FEA) on YOOPER to identify high stress areas. The canoe hull was modeled as a 3-D object using symmetry about a vertical plane through the keel (Abaqus's 3-D Axisymmetric technique). The 3-D model was meshed by connecting distributed nodes to create 2-D planar elements where assumed material properties were applied.

The canoe was modeled exclusively as concrete in order to determine the stress levels within the hull. Since the final concrete mix and composite reinforcement design were not known at the time of analysis, modeling as concrete-only was deemed appropriate. In order to utilize Abaqus, assumptions were established and basic material properties of the concrete were required. The canoe was assumed to be modeled statically. Ideally, dynamic analysis would be preferred but was not possible within the constraints of the schedule. Even so, the correlations of previous years' analyses and the canoes' structural performances have proven static analysis to be adequate. The concrete hull was assumed to be isotropic with an elastic modulus of 3180 ksi and a Poisson's ratio of 0.36. These material properties were determined from 2007-2008 testing.

Due to the range of forces exerted on the boat during the five different races, a loading scenario for each was originally considered. It was recognized that the female's races would exhibit lower loads than the male's races and thus these loading cases were discarded. As a result, only three loading scenarios were considered: the male sprint, the male endurance, and the co-ed sprint. Based on historical analyses, the male sprint loading scenario has typical induced the largest stresses on the hull. Because of this, as well as a desire to expedite the analysis process, one finite element model was created based on this loading scenario.

For the male sprint loading scenario, three forces were considered acting on the canoe: two forces due to the male paddlers and the weight of the canoe itself. The force attributed to a male paddler was determined considering both the weight of the male and the exertion force from paddling. To obtain the combined weight and exertion force of a male paddler, an average-size male paddler performed the motions of paddling on a household scale and the maximum weight reading was taken as 240 lbs. The two 240lb-loads were distributed over a 36 square-inch area, one located 40 inches from the bow and one located 40 inches from the stern. The distributed area of 36 square-inches was used to apply the force exerted on the canoe by the paddler in a kneeling position. Abaqus determined the self-weight of the canoe to be 125 lbs based on an assumed unit weight of 60.5 pcf (corresponding to the 2007-2008 material testing), the desired final thickness of 3/8-in, and the surface area of the canoe shell. The discrepancy of calculated self-weight and actual self-weight (from Table 1) comes from the necessity of assumptions during analysis, as the final design is not known. The self-weight was uniformly applied to the interior canoe shell such that the individual forces acted downward on each element.

To counteract the paddlers' forces and the self-weight of the canoe, a hydrostatic load equal to the summation of the applied forces was linearly applied with depth to the elements below the waterline (beginning with zero at the waterline). The waterline of YOOPER was estimated at 10.2 inches below the uppermost tip of the bow. This value was determined using the modeling software Vacanti Prolines98 where the software estimated the water displacement based on input values of hull dimensions and applied loads.

The analysis was conducted using inertia relief as a support condition. This modeling technique was deemed appropriate as it allowed for the canoe to be simulated as an unconstrained structure in a static analysis. Inertia relief means that the mass of the canoe is used to resist the applied loadings and consequently is in a state of static equilibrium even though it is not constrained.

The maximum tensile stress was identified as 206.1 psi located in the upper portion of the gunwales (see Figure 2). Abaqus also presented a maximum compressive stress of 210.9 psi located on either side of the applied paddler loading areas (see Figure 3).

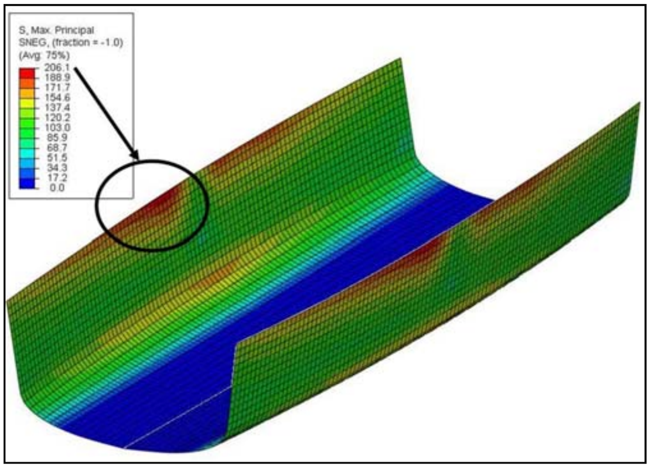


Figure 2: Abaqus FEA results illustrating the tensile stress distribution.

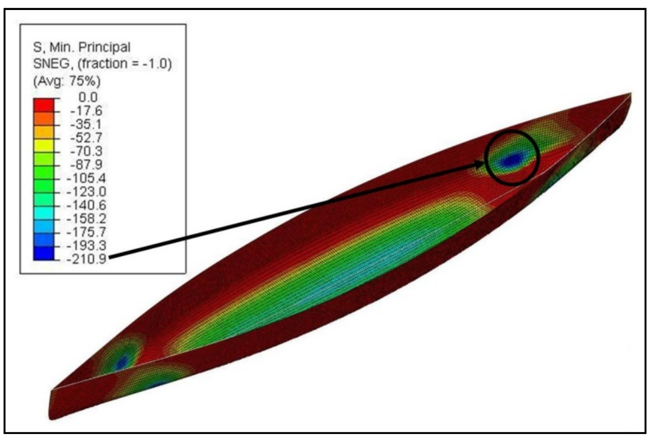


Figure 3: Abaqus FEA results illustrating the compressive stress distribution.

Development and Testing

The benefit of this year's hull matching last year's allowed for development and testing to begin with receipt of rules using last year's FEA results as a guideline. The 2008-2009 structural mix, Accretion, was selected as a baseline mix for its low unit weight and adequate strength. Test results of Accretion proved conservative in relation to last year's analysis suggesting the team could focus on reducing unit weight and still meet strength requirements. A five tier system was employed to transform the baseline mix to current design specifications. Tiers I, II, III, IV, and V were associated respectively with binders, aggregates, fibers, water-cementitious (w/c) ratio, and admixtures (see Figure 4).

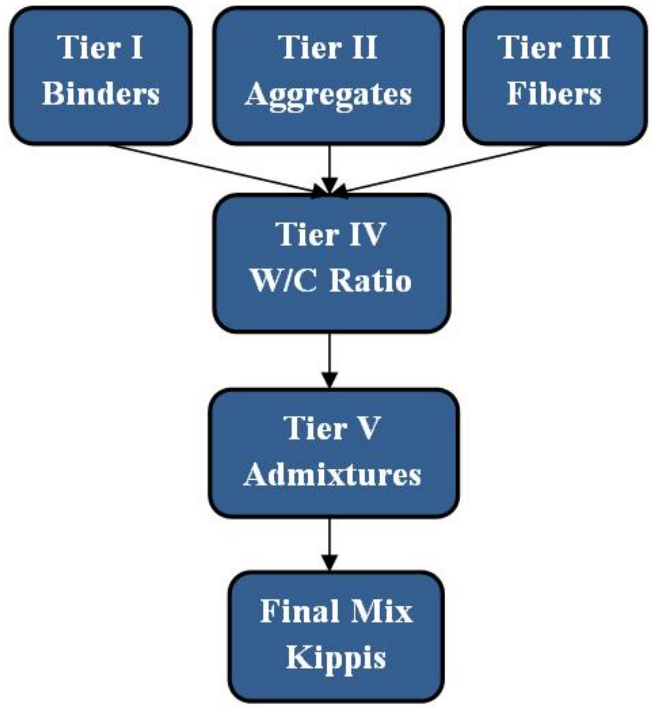


Figure 4: Flowchart of the tiers used for the development and testing of the structural concrete mix.

Considerations for material selections were recycled content, availability, and cost while still achieving the strength requirements determined from the FEA. The goal to create a white structural concrete mix added an aesthetic component to material selection, resulting in the elimination of several materials based on their dark color.

During binder testing, all other constituents were held constant in order to observe the affects of varying cementitious materials in relation to one another. The binders investigated were Type I White Portland Cement, grades 140 and 160 vitreous calcium aluminosilicate (VCAS™) white pozzolans, grade 120 ground granulated blast-furnace slag (GGBFS), Class C fly ash, and rice husk ash (RHA). The latter two binders were dismissed based on their dark color. Also, the expense to obtain RHA was not justified when the selected binders proved adequate. Grade 160 VCAS™ was selected over grade 140 because its smaller particle size provided a more workable mix.

Aggregates were evaluated concurrent to binder testing using the same principle of holding all other materials constant. The 2009-2010 rules require a minimum of two different recycled materials for aggregate. Research was conducted to obtain a recycled aggregate to supplement the Poraver® glass spheres (a post-consumer recycled glass) the team had from previous years. The team explored recycled rubber, glass, concrete, foam, and ceramics. A primary elimination factor was specific gravity, where recycled rubber, glass, and concrete were considered too dense. Foam was disqualified based on its low strength characteristic. SG and HA 350 grades of Extendospheres™ ceramic spheres, a co-product of coal burning power plants, were obtained for initial testing purposes. Proportions and sizes of glass spheres, ceramic spheres, and 3M® Glass Bubbles were varied. To meet the gradation requirements, the glass bubbles were eliminated from consideration. Extendospheres™ SG was chosen over HA 350 because of its lower density and finer particle size. As a result, the aggregates selected were Poraver® glass spheres and Extendospheres™ SG ceramic spheres, resulting in a 100% recycled aggregate mix.

Simultaneously to tiers I and II, fiber testing was conducted. In this tier, a standard mix was utilized that held all materials constant with the exception of the fibers. Fiber reinforcement was added to the mix to obtain a sufficient tensile strength. Previous years' mixes have had poor workability when the fibers were in overabundance and too long. Nycon Kuralon™ RF4000 (30mm) and RECS15 (8mm) polyvinyl alcohol (PVA) fibers were chosen to be incorporated in the final mix. A 2:1 blend, respectively, of these two sizes was chosen as the most workable fiber combination.

In tier IV the amount of water in the mix was varied to test the affects of the w/c ratio. During these iterations, the goal was to improve strength while providing enough water to maintain workability. A final w/c ratio of 0.27 was used to provide the desired combination of strength and workability characteristics.

The top two mixes from tiers I and II, in regards to tensile strength and unit weight, were combined with the selected fiber blend and w/c ratio to create four mixes for admixture testing. Two different admixture combinations were tested, yielding eight mixes for the final tier. The final selection process was dependent on admixture compatibility with the given proportions of the other concrete components. A high-range water-reducer (HRWR), BASF Glenium 3030® NS, was utilized to increase workability of the mix without compromising the w/c ratio and subsequently the strength of the mix. BASF MB-AE™ 90 air-entraining admixture was added to meet minimum air requirements specified in the rules. Xypex Xycrylic-Admix was added not only for its waterproofing characteristic, but also to further increase air content, reduce shrinkage, and eliminate the need for wet curing. The manufacturer recommended 3-8 fl oz/cwt for the HRWR while the air-entrainer and Xycrylic had no manufacturer dosage specifications. The proportion of HRWR used in the structural concrete mix was in compliance with the manufacturer's recommended dosage.

In each tier, six 2"x4" cylinders from each batch were cast for testing purposes. A compressive test was performed in accordance with ASTM C39 on one cylinder and split-tensile tests were conducted in compliance with ASTM C496 on two cylinders at both 14 and 28 days. Through diligent testing and based on strength and unit weight properties, the team selected the final mix, Kippis (see Table 3, page 4). Kippis is the Finnish word for Cheers, selected as an appropriate final mix name to celebrate the completion of a major milestone and to give recognition to the Finnish culture that encompasses Michigan Tech's local community.

Table 3: Material and Engineering Properties

	Unit Weight (pcf)	14 day Tensile Strength (psi)	14 day Compressive Strength (psi)
FEA Specifications	60.5	206.1	210.9
Kippis	53.0	385	2255

Table 4: Final Structural Concrete Mix Components

Binders	Aggregates	Reinforcing Fibers	Admixtures
Type I White Portland Cement	Poraver® 1.0-2.0mm Glass Spheres	Nycon Kuralon™ RF4000 (30mm) PVA	BASF Glenium 3030®NS (HR Water Reducer)
Vitro Minerals VCAS™ Grade 160	Poraver® 0.5-1.0mm Glass Spheres	Nycon Kuralon™ RECS15 (8mm) PVA	BASF MB-AE™ 90 (Air-Entrainer)
GGBFS Grade 120	Extendospheres™ SG Ceramic Spheres	-	Xypex Xycrylic-Admix

Components of Kippis are shown in Table 4 (above) while specific proportions are presented in Appendix B.

It is noted that Kippis yielded a 1.87 factor of safety beyond the required tensile specifications of the FEA. Continuous reinforcement was used to increase the durability of the canoe during the rigors of competition. Qualitative results from previous years' studies were analyzed when considering reinforcement type. Due to an abundance of material left over from previous years and past success with Chromarat C-Grid® CT300, it was selected to reinforce YOOPER. However, the amount of remaining material was found to be insufficient to complete the proposed two layers of reinforcement. The material supplier was contacted to obtain the additional amount of C-Grid® CT300 required, but the team was informed that the reinforcement was no longer produced. Instead, C-Grid® CT275 was recommended as an alternative to complete the second layer of reinforcement. The percent open area of C-Grid® CT300 was measured as 77.25% and CT275 was determined as 84.75%, surpassing specifications.

In addition to Kippis, a finishing concrete mix was developed with goals of attaining a high ratio of available paste for pigmenting, while minimizing losses in strength and gains in unit weight. For binders, white or gray Type I Portland cement, depending on the color intensity, was used in combination with grade 160 VCAS™, and grade 120 GGBFS. Testing concluded that the elimination of Poraver®1.0-2.0mm glass spheres resulted in a more aesthetically pleasing mix. The aggregates used were Poraver® 0.5-1.0mm glass spheres and Extendospheres™ HA 350 ceramic spheres to meet the recycled aggregate specification. Fiber reinforcement was excluded for increased workability and a more uniform finish. The admixtures used were BASF MB-AE™ 90 air-entrainer, Xypex Xycrylic-Admix, and BASF Glenium 3030®NS HRWR. The HRWR manufacturer recommended dosage was exceeded to increase the workability of the mix. Once the binders, aggregates, and admixtures were finalized, pigments were tested in various quantities and combinations.

Project Management and Construction

As in previous years, the team was led by senior and junior co-captains. A safety program, chaired by a team safety officer, was implemented throughout all aspects of the project. The team utilized a departmental management system by dividing the team into four specific departments: administration, construction, design and engineering, and competition. The compliance committee was involved in each department to guarantee adherence to specifications (refer to the Organizational Chart on page 8 for details). Each department was managed by an experienced team member who trained new members in an effort to maintain the team's knowledge base. The use of this system ensured an on-time and on-budget project completion while allowing knowledge to be passed on to younger team members.

To start off the academic year, Michigan Tech's Civil and Environmental Engineering Department safety director briefed all members of the team in a safety orientation. Members were introduced to the safety equipment, material safety data sheets, fire extinguishers, exit routes, and proper emergency contact information. In addition, students involved in the construction department were trained by a competent person in power equipment use and maintenance. The team appointed a student safety officer to monitor and enforce compliance with all team safety regulations. Proper personal protective equipment was worn for the various tasks in testing and construction. In addition to the use of safe work practices, the team's facility and methods were inspected for safety by the University Health and Safety Department to be proactive safety advocates.

The team is fortunate to receive a majority of supplies and materials as donations from affiliated sponsors, reducing the necessary costs for the canoe design and construction. Excluding the cost of donated materials and services, estimated at $10,000, it was anticipated that remaining construction supplies and materials would cost $1,200. A large portion of the budget is required for competition and travel expenses, estimated at $2,500. Two major attributes to this cost are the size of the team and Michigan Tech's location relative to the North Central Conference. The team this year is comprised of 28 members and believes that each active member should be rewarded by attending the competition. For the 2010 North Central Competition, the transportation of the team requires a one-way travel distance of over 550 miles and a time investment of nearly 11 hours. From a time perspective, the majority of costs occur near the end of the project life, while early costs were attenuated by material and service donations. As a result of this expense imbalance, fundraising efforts were distributed evenly throughout the academic year. In addition to fundraising, a membership fee was administered to assist with registration fees for competition (see Figure 5 for a representation of fund divisions).

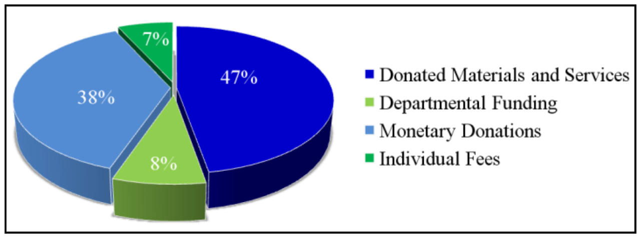


Figure 5: Illustration of 2009-2010 Funding Breakdown.

A major improvement for the team this year was the use of an accelerated schedule. The main objective of the accelerated schedule was to utilize the semester break for concrete curing. Significant time had been lost in the past for aesthetics and finishes while waiting for concrete to cure during the spring semester. The accelerated schedule placed stiff time constraints on analysis and design during the beginning of the academic year. In order to meet these deadlines, material selection and procurement had to occur much earlier, making material availability a crucial factor. Procurement of materials began shortly after the release of rules using remaining funds from the previous year. These new materials were incorporated with surplus materials from previous years and donated materials from sponsors. The same hull design as last year reduced the risk associated with the accelerated schedule because the previous year's analysis and design could be used as guidelines for this year. The similarities of this year's and last year's hull design and subsequent FEA improved quality of construction.

Activities were considered milestones if they completed a major segment of the project. Major activities are detailed in Table 5 (page 6) and are indicated with a star on the project schedule (page 9). The team was able to achieve major milestones through hard work and commitment, guided by the time management of the project managers.

Table 5: Milestone Activities

Theme Final Decision
Final FEA Results
Mold Delivery
Structural Concrete Mix Selection
Reinforcement Selection
Concrete Placement
Design Paper Submittal
Finishes Complete
Display Components Complete
North Central Conference
National Competition

The critical path was determined based on activities that, if delayed, would delay the entire project. Activities comprising the critical path may be seen in Table 6 below and are represented on the project schedule (page 9). To tackle the accelerated schedule, the team worked 328 man-hours for development and testing, 96 man-hours to cast, and expects to complete YOOPER with 475 man-hours applying finishes.

Table 6: Critical Path Activities

Research and Material Procurement
Release Hull Dimensions
Foam Sized and CNC Milled
Mold Pick-up and Delivery
Binder, Aggregate, and Fiber Testing
Proposed Final Structural Concrete Mix Testing
Mold Assembly and Release Application
Pre-batch Final Structural Concrete Mix

The established relationship the team has with a mold production company allowed a female-style mold of the canoe to be CNC milled out of 10% pre-consumer recycled high density polystyrene foam. Prompt release of the hull dimensions to the subcontractor was especially necessary to allow adequate time for milling, pick-up, and delivery of the mold at an earlier date than in the past. The mold was milled in six sections; each section was determined by cutting the hull in half about its keel and in thirds along its length. Delivery of the mold permitted form assembly which was coupled with quality control measures. Two layers of epoxy were applied to each of the six mold sections with Poraver® 1.0-2.0mm glass spheres broadcast on the first coating while still wet. This epoxy was not used structurally but rather to prevent water loss into the foam and to create a rigid surface for concrete placement. The aggregate was concentrated along the gunwales of the canoe to prevent the concrete from sloughing while troweling up the vertical surface.

Once the six pieces were prepared with the epoxy-aggregate finish, the sections were assembled and secured by aligning the edges and screwing wood blocks to the form table around the perimeter of the mold. Holes were drilled at six-inch increments through the mold and form table along the keel, the chines, and gunwales to anchor the continuous reinforcement during casting. Prior to casting day, Huron Technologies Release Coating 7572 release agent was applied to the mold. Per manufacturer specifications, the release agent is formulated for release of concrete from epoxy finishes to provide an aesthetically-pleasing surface appearance. On casting day, three 1/8-inch layers of concrete were placed, alternating with two layers of C-Grid® CT300 and CT275 continuous reinforcement. The first layer of reinforcement consisted of C-Grid® CT300 placed with a two-inch lap between adjacent pieces; the second layer of reinforcement, C-Grid® CT275, was placed with a three-inch lap. Casting of YOOPER was completed within three hours. After 14 days of dry curing, the combination of the new release agent and the sectioning of the mold provided for easy form removal in a team record time of ten minutes and in a manner that will allow the mold to be completely reused. YOOPER was left to cure an additional 14 days before finishes began.

Quality control measures were implemented throughout the project life to ensure quality assurance. During development and testing, the same individuals oversaw procedures to promote consistency and enforcement of standards. Due to the time lapse during placement, the initial set was delayed by keeping the concrete below 50°F while casting (see Figure 6). This was obtained by cooling the individual components prior to mixing. The slump, unit weight, and air-entrainment of the concrete were monitored throughout placement to ensure compliance with ASTM Standards as specified in the rules. Uniform hull thickness was regulated with depth gauges set to measure 1/8, 1/4, and 3/8-inch to correlate with the three layers of concrete.

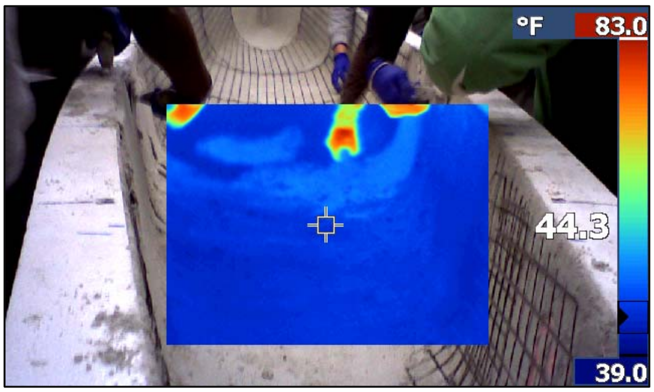


Figure 6: Use of an infrared imaging gun allowed the temperature of the concrete to be monitored during casting.

Innovation and Sustainability

YOOPER was developed using innovative techniques with a focus on sustainability. One example of the team's interest to become more sustainable was the team's investment in reusable rubber gloves. This allows the team to reduce the amount of waste produced and to be more cost efficient.

Traditionally, the team would cast its canoe after semester break. However, this year the team implemented an accelerated schedule allowing the canoe to be cast after Thanksgiving break. The new schedule provided the team with an extended period of time devoted to canoe finishes. In this period, the team was able to explore the use of outlays as aesthetics designs, expanding on the team's exclusive use of inlay designs. Outlays and inlays both employ colored concrete where the outlays are attached to the surface of the canoe to form a raised image, while the inlays are placed flush (see Figure 7).

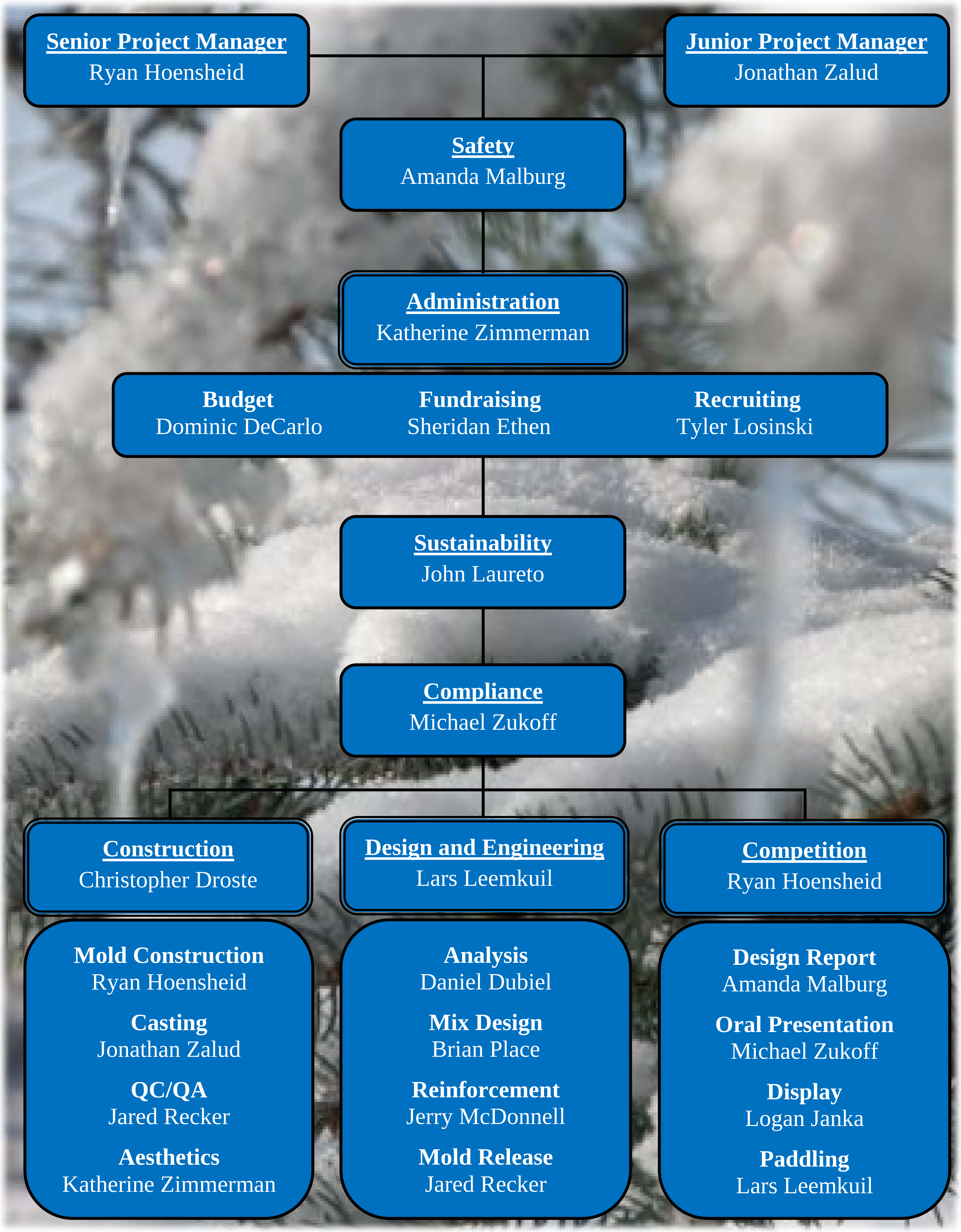
Figure 7: Illustration of colored concrete use for outlays (left) and inlays (right).

YOOPER's composition consists of 57% by mass and nearly 69% by volume of recycled materials. Specifically, the GGBFS, VCAS™, Poraver® glass spheres, and Extendospheres™ ceramic spheres are recycled materials. Considering the aggregate, the team was required to use a minimum of 50% recycled aggregate in the concrete mixes this year. Not only were applicable aggregates discovered, but they were deemed comparable to previously used non-recycled aggregates. Through this, the structural and finishing mixes were comprised of 100% recycled aggregates. The team plans to use these recycled aggregates in the future to further promote sustainability, regardless of whether recycled content is required.

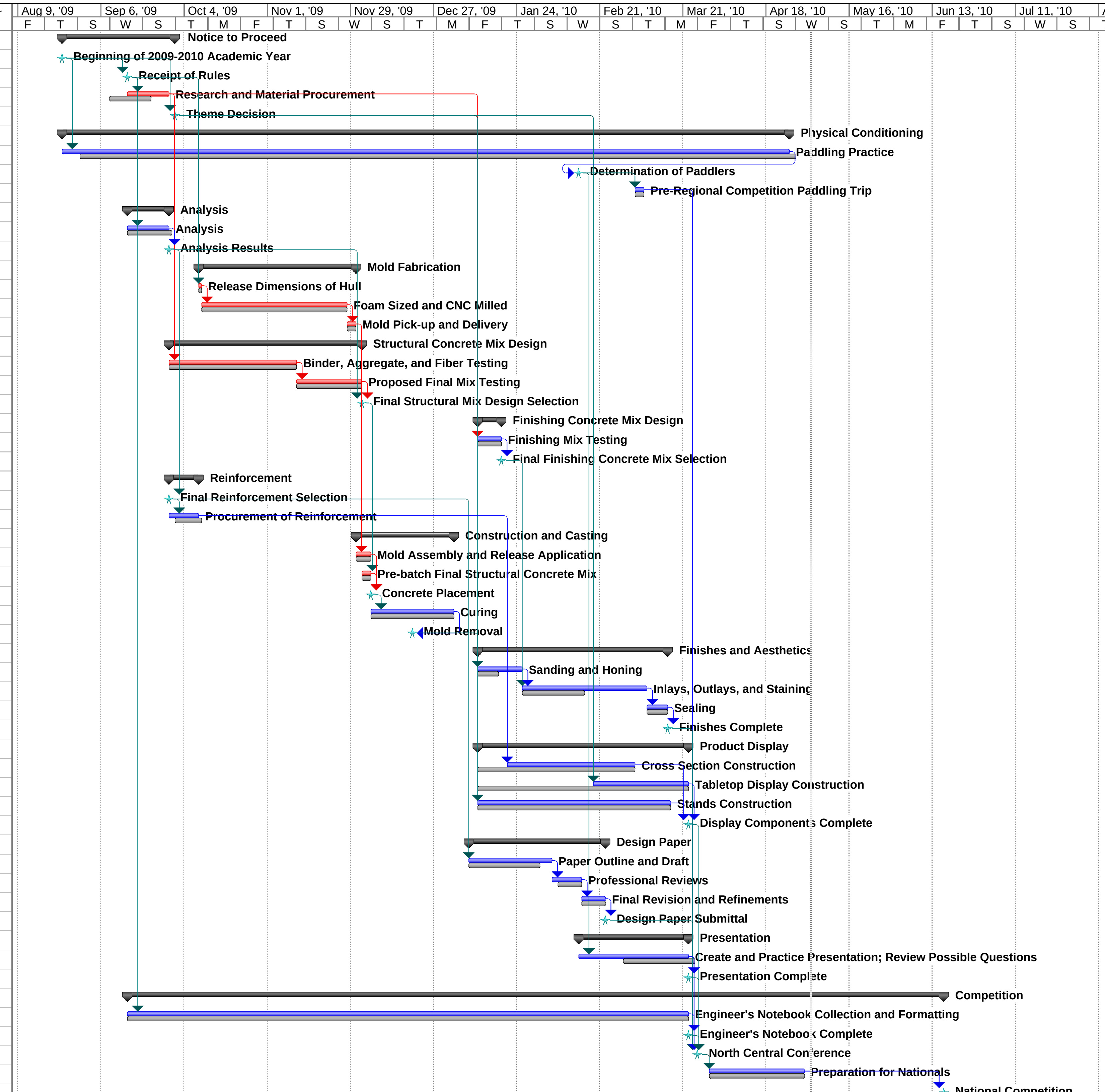
During casting day the team used an infrared imaging gun to insure that placed concrete was cold enough to postpone initial set. Curing of the concrete creates bonds between the layers and the act of troweling weakens the concrete as these bonds are broken and reformed. The casting room and concrete were kept at a lower temperature retarding the formation of bonds until casting was complete and heat was returned to the room.

In past years, the team has struggled with releasing the canoe from its mold. This year, the team did extensive research and found a release aid specifically designed for separating concrete from an epoxy surface. With this advancement, de-molding of the canoe was completed within minutes compared to the many hours it has taken in the past. This release aid innovation also allowed the team to de-mold the canoe without causing severe damage to the mold. The ease of mold removal sustainably diverts the material from the waste stream by allowing for its reuse.

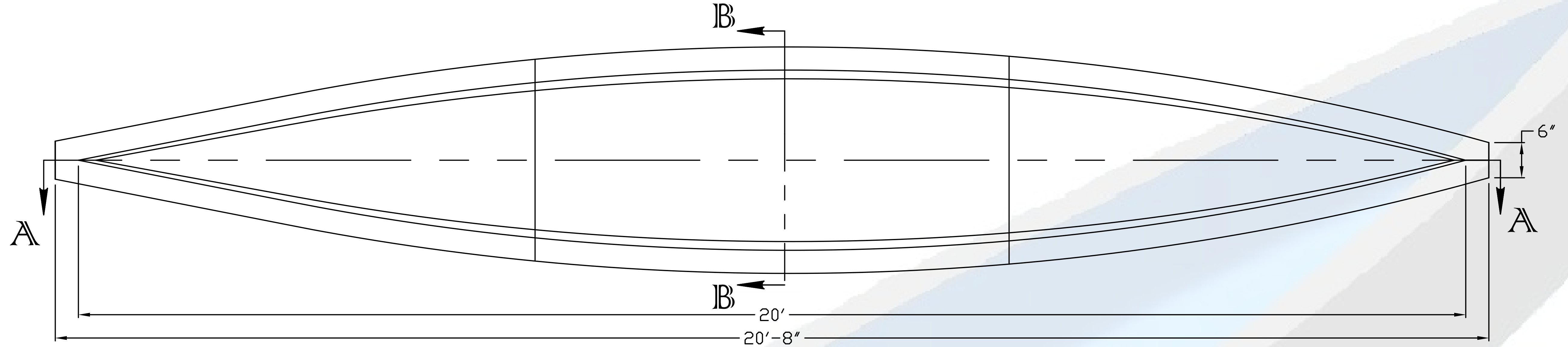
Organization Chart

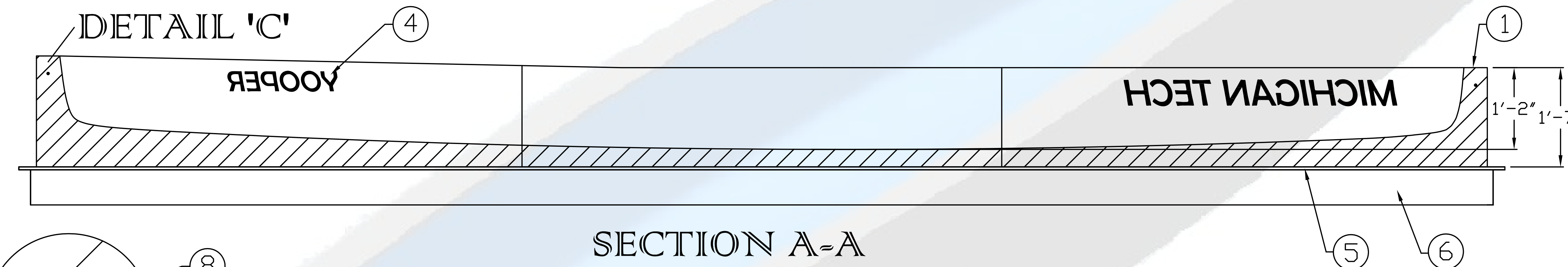


ID	Task Name	Baseline Start	Baseline Finish	~Actual Start~	~Actual Finish~
1	**Notice to Proceed**	**8/24/09**	**10/1/09**	**8/24/09**	**10/1/09**
2	Beginning of 2009-2010 Academic Year	8/24/09	8/24/09	8/24/09	8/24/09
3	Receipt of Rules	9/8/09	9/8/09	9/15/09	9/15/09
4	Research and Material Procurement	9/9/09	9/22/09	9/15/09	9/28/09
5	Theme Decision	10/1/09	10/1/09	10/1/09	10/1/09
6	**Physical Conditioning**	**8/30/09**	**3/25/10**	**8/30/09**	**4/29/10**
7	Paddling Practice	8/30/09	4/30/10	8/30/09	4/29/10
8	Determination of Paddlers	2/14/10	2/14/10	2/14/10	2/14/10
9	Pre-Regional Competition Paddling Trip	3/5/10	3/7/10	3/5/10	3/7/10
10	**Analysis**	**9/15/09**	**9/28/09**	**9/15/09**	**9/28/09**
11	Analysis	9/15/09	9/29/09	9/15/09	9/28/09
12	Analysis Results	9/28/09	9/28/09	9/28/09	9/28/09
13	**Mold Fabrication**	**10/9/09**	**11/28/09**	**10/9/09**	**11/30/09**
14	Release Dimensions of Hull	10/9/09	10/9/09	10/9/09	10/9/09
15	Foam Sized and CNC Milled	10/10/09	11/27/09	10/10/09	11/27/09
16	Mold Pick-up and Delivery	11/28/09	11/30/09	11/28/09	11/30/09
17	**Structural Concrete Mix Design**	**9/15/09**	**11/30/09**	**9/29/09**	**12/2/09**
18	Binder, Aggregate, and Fiber Testing	9/29/09	11/10/09	9/29/09	11/10/09
19	Proposed Final Mix Testing	11/11/09	12/2/09	11/11/09	12/2/09
20	Final Structural Mix Design Selection	11/30/09	11/30/09	12/2/09	12/2/09
21	**Finishing Concrete Mix Design**	**9/15/09**	**1/25/10**	**1/11/09**	**1/18/10**
22	Finishing Mix Testing	1/11/10	1/18/10	1/11/10	1/18/10
23	Final Finishing Concrete Mix Selection	1/25/10	1/25/10	1/18/10	1/18/10
24	**Reinforcement**	**9/15/09**	**10/8/09**	**9/28/09**	**10/8/09**
25	Final Reinforcement Selection	9/28/09	9/28/09	9/28/09	9/28/09
26	Procurement of Reinforcement	10/1/09	10/9/09	9/29/09	10/8/09
27	**Construction and Casting**	**9/2/09**	**1/2/10**	**9/29/09**	**1/2/10**
28	Mold Assembly and Release Application	12/1/09	12/5/09	12/1/09	12/5/09
29	Pre-batch Final Structural Concrete Mix	12/3/09	12/5/09	12/3/09	12/5/09
30	Concrete Placement	12/5/09	12/5/09	12/5/09	12/5/09
31	Curing	12/6/09	1/2/10	12/6/09	1/2/10
32	Mold Removal	12/19/09	12/19/09	12/19/09	12/19/09
33	**Finishes and Aesthetics**	**1/11/10**	**3/15/10**	**1/11/10**	**3/15/10**
34	Sanding and Honing	1/11/10	1/17/10	1/11/10	1/25/10
35	Inlays, Outlays, and Staining	1/26/10	2/15/10	1/26/10	3/8/10
36	Sealing	3/9/10	3/15/10	3/9/10	3/15/10
37	Finishes Complete	3/15/10	3/15/10	3/15/10	3/15/10
38	**Product Display**	**1/11/10**	**3/22/10**	**1/11/10**	**3/22/10**
39	Cross Section Construction	1/11/10	3/4/10	1/21/10	3/4/10
40	Tabletop Display Construction	1/11/10	3/22/10	2/19/10	3/22/10
41	Stands Construction	1/11/10	3/16/10	1/11/10	3/16/10
42	Display Components Complete	3/22/10	3/22/10	3/22/10	3/22/10
43	**Design Paper**	**1/8/10**	**2/22/10**	**1/8/10**	**2/22/10**
44	Paper Outline and Draft	1/8/10	1/31/10	1/8/10	2/4/10
45	Professional Reviews	2/7/10	2/14/10	2/5/10	2/14/10
46	Final Revision and Refinements	2/15/10	2/22/10	2/15/10	2/22/10
47	Design Paper Submittal	2/22/10	2/22/10	2/22/10	2/22/10
48	**Presentation**	**2/14/10**	**3/26/10**	**2/14/10**	**3/26/10**
49	Create and Practice Presentation; Review Possible Questions	3/1/10	3/26/10	2/26/10	3/12/10
50	Presentation Complete	3/8/10	3/8/10	3/26/10	3/26/10
51	**Competition**	**9/15/09**	**3/26/10**	**9/15/09**	**On Track**
52	Engineer's Notebook Collection and Formatting	9/15/09	3/22/10	9/15/09	3/22/10
53	Engineer's Notebook Complete	3/22/10	3/22/10	3/22/10	3/22/10
54	North Central Conference	3/26/10	3/28/10	3/26/10	3/28/10
55	Preparation for Nationals	3/30/10	4/30/10	4/19/10	5/7/10
56	National Competition	6/17/10	6/19/10	On Track	On Track

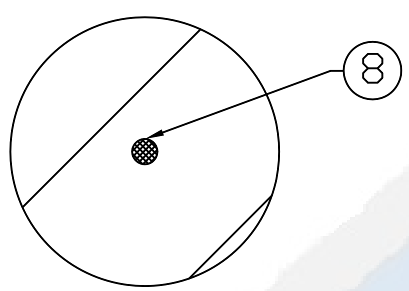


Task | Critical Task | Milestone | Summary | Baseline

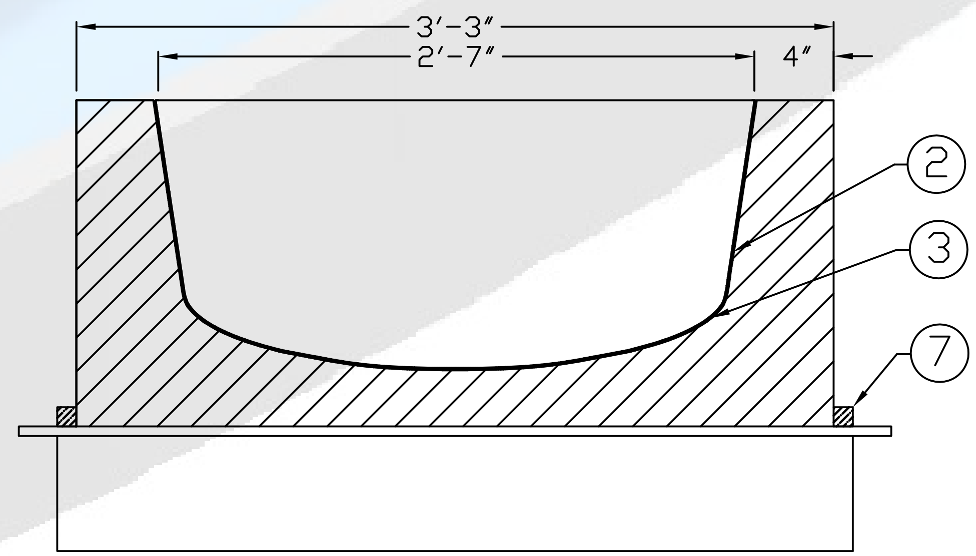




SECTION A-A



DETAIL 'C'
SCALE 4:1



SECTION B-B
SCALE 2:1

BILL OF MATERIALS		
NO.	DESCRIPTION	QTY.
1	POLYSTYRENE FOAM MOLD	6
2	EPOXY	x
3	PORAVER 1.0-2.0mm	x
4	VINYL INLAY	83 SQ IN
5	1/2″ OSB	24 SQ FT
6	2″X6″ LUMBER	56 LN FT
7	2″X4″ LUMBER	4 LN FT
8	3/8″ X 8″ BOLT ASSEMBLY	2 EA.

MichiganTech

MICHIGAN TECHNOLOGICAL
UNIVERSITY
CONCRETE CANOE
1400 TOWNSEND DRIVE
HOUGHTON, MI 49931

DRAWING NAME: MOLD DESIGN	DATE:
BOAT NAME: YOOPER	2/21/2010
DRAWN BY: BRIAN PLACE, BRADLEY JOHNSON	SCALE: 1:20
CHECKED BY: RYAN HOENSHEID	SHEET: 10

Appendix A – References

ABAQUS/CAE. (2006). "Using a composite layup to model a yacht hull," http://127.0.0.1:2080/texis/search/hilight2.html/+/exa/ch01s01aex24.html?CDB=v6.8

ASTM. (2007). "Standard Test Method for Bulk Density ("Unit Weight") and Voids in Aggregate." *C29/C29M-07,* West Conshohocken, Pennsylvania.

ASTM. (2006). "Standard Test Method for Determining Density of Structural Lightweight Concrete."*C567-05a,* West Conshohocken, Pennsylvania.

ASTM. (2009). "Standard Practice for Making and Curing Concrete Test Specimens in the Field."*C31/C31M-09A,* West Conshohocken, Pennsylvania.

ASTM. (2006). "Standard Test Method for Compressive Strength of Cylindrical Concrete Specimens."*C39/C39M-05,*West Conshohocken, Pennsylvania.

ASTM. (2007). "Standard Terminology Relating to Concrete and Concrete Aggregates." *C125-07,*West Conshohocken, Pennsylvania.

ASTM. (2007). "Standard Test Method for Density, Relative Density (Specific Gravity), and Absorption of Coarse Aggregate." *C127-07,* West Conshohocken, Pennsylvania.

ASTM. (2007). "Standard Test Method for Density, Relative Density (Specific Gravity), and Absorption of Fine Aggregate." *C128-07,* West Conshohocken, Pennsylvania.

ASTM. (2006). "Standard Test Method for Sieve Analysis of Fine and Course Aggregates." *C136-06,* West Conshohocken, Pennsylvania.

ASTM. (2009). "Standard Test Method for Density (Unit Weight), Yield, and Air Content (Gravimetric) of Concrete." C138 / C138M - 09, West Conshohocken, Pennsylvania.

ASTM. (2009). "Standard Test Method for Slump of Hydraulic-Cement Concrete." *C143 / C143M - 09,* West Conshohocken, Pennsylvania.

ASTM. (2006). "Standard Specification for Portland Cement." *C150-05,* West Conshohocken, Pennsylvania.

ASTM. (2008). "Standard Practice for Sampling Freshly Mixed Concrete." *C172-08,* West Conshohocken, Pennsylvania.

ASTM. (2009). "Standard Test Method for Air Content of Freshly Mixed Concrete by the Volumetric Method." *C173 / C173M - 09,* West Conshohocken, Pennsylvania.

ASTM. (2006). "Standard Test Method for Air Content of Freshly Mixed Concrete by the Pressure Method." *C231 / C231M -09b,* West Conshohocken, Pennsylvania.

ASTM. (2006). “Standard Specifications for Air-Entraining Admixtures for Concrete.” *C260-01,* West Conshohocken, Pennsylvania.

ASTM. (2006). “Standard Test Method for Static Modulus of Elasticity and Poisson's Ratio of Concrete in Compression.” *C469-02,* West Conshohocken, Pennsylvania.

ASTM. (2008). “Standard Specification for Chemical Admixtures for Concrete.” *C494/C494M-08a,* West Conshohocken, Pennsylvania.

ASTM. (2006). “Standard Test Method for Splitting Tensile Strength of Cylindrical Concrete Specimens.” *C496/C496M-04,* West Conshohocken, Pennsylvania.

ASTM. (2006). “Standard Specification for Pigments for Integrally Colored Concrete.” *C979-05,* West Conshohocken, Pennsylvania.

ASTM. (2009). “Standard Specification for Ground Granulated Blast-Furnace Slag for use in Concrete and Mortars.” *C989-09,* Conshohocken, Pennsylvania.

ASTM. (2009). “Standard Specification for Fiber-Reinforced Concrete and Shotcrete.” *C1116-09,*West Conshohocken, Pennsylvania.

ASTM. (2006). “Standard Specification for Latex and Powder Polymer Modifiers for Hydraulic Cement Concrete and Mortar.” *C1438-99e1,* West Conshohocken, Pennsylvania.

ASTM. (2006). “Standard Test Method for Poisson’s Ratio at Room Temperature.” *E132-04,* West Conshohocken, Pennsylvania.

Michigan Tech Concrete Canoe. (2007). “Gitchee Gumee.” NCCC Design Paper, Michigan Technological University, Houghton, Michigan.

Michigan Tech Concrete Canoe. (2008). “Gambler.” NCCC Design Paper, Michigan Technological University, Houghton, Michigan.

Michigan Tech Concrete Canoe. (2009). “Polaris.” NCCC Design Paper, Michigan Technological University, Houghton, Michigan.

NCCC FAQ. (2010). “ASCE National Concrete Canoe Competition Frequently Asked Questions,”online at: http://concretecanoe.org/2010Trivia/2010FAQ110509.pdf

NCCC Rules. (2010). “2010 American Society of Civil Engineers National Concrete Canoe Competition Rules and Regulations,” online at: http://content.asce.org/conferences/nccc2010/rules.html

SIMULIA. (2006). “Abaqus,” Providence, RI.

Appendix B – Mixture Proportions

Mixture: KIPPIS Structural

Batch Size (ft3): 0.0570

		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 Type I White Portland Cement	3.15	339.38	1.727	0.75	0.004	335.26	1.706
2. Ground Granulated Blast Furnace Slag	2.99	214.71	1.151	0.47	0.003	212.11	1.137
3. VCAS-160	2.60	138.52	0.854	0.31	0.002	136.84	0.843
Total of All Cementitious Materials:		692.60	3.731	1.53	0.008	684.21	3.686
Fibers							
1. 30 mm PVA	1.30	10.01	0.123	0.02	0.000	9.89	0.122
2. 8 mm PVA	1.30	5.01	0.062	0.01	0.000	4.95	0.061
Total of All Fibers:		15.02	0.185	0.03	0.000	14.84	0.183
Aggregates							
1. Poraver 1.0-2.0mm Abs.: 12.1% ; MC: 0.1%	0.51	193.32	6.135	0.43	0.014	190.98	6.060
2. Poraver 0.5-1.0mm Abs.: 8.0% ; MC: 0.1%	0.65	140.16	3.440	0.31	0.008	138.46	3.398
3. Extendospheres SG Abs.: 13.2% ; MC: 0.1%	0.72	149.82	3.335	0.33	0.007	148.01	3.294
Total of All Aggregates:		483.30	12.909	1.06	0.028	477.44	12.753
Water							
1. Total Batched Water^	1.00	177.77	2.849	0.39	0.006	175.61	2.814
2. Water Added for Agg. Absorption▼∞	1.00	53.90	0.864	0.12	0.002	53.24	0.853
3. Total Water from All Admixtures§	1.00	66.47	1.065	0.15	0.002	65.67	1.052
Total Water:		244.24	3.914	0.54	0.009	241.28	3.867
Solids Content of Latex Modifiers							
1. Xycrylic; Lb/gal: 9.18	1.10	92.35	1.347	0.20	0.003	91.23	1.330
Total Latex Solids:		92.35	1.347	0.20	0.003	91.23	1.330
Admixtures	% Solids	Amount (fl oz/cwt)	Water‡ in Admixture (lb/yd^3)	Amount (fl oz)	Water‡ in Admixture (lb)	Amount (fl oz/cwt)	Water‡ in Admixture (lb/yd^3)
1. Air Entrainer; Lb/gal: 8.48	6.7	0.67		0.010		0.66	
2. High-Range Water-Reducer; Lb/gal: 8.76	20.27	12.19		0.186		12.05	
Cement-Cementitious Materials Ratio		0.49		0.49		0.49	
Water-Cementitious Materials Ratio (w/cm)		0.27		0.27		0.27	
Slump, Slump Flow, in. (Flow Table, %)		7 ± 1		7.50		7.50	
Design Air Content, %		25.00					
Density (Unit Weight), lb/ft^3		54.34		53.48		53.68	
Gravimetric Air Content, %				26.19		25.91	
Yield, ft^3		27.00		0.057		27.00	

Abs. = Absorption; MC = Batched moisture content;
^ Including water added for aggregate absorption;
** For aggregates, provide ASTM C 128 oven-dry bulk specific gravity.*
▼Volumes in this row are not used in the density calculation.
‡ Water content of admixture.
§ If impact on w/cm is less than 0.01 enter zero.
∞ Masses in this row are not included in w/cm calculation.

Mixture: KIPPIS Endcap

Batch Size (ft3): 0.0570

		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 Type I White Portland Cement	3.15	341.87	1.739	0.75	0.004	333.89	1.699
2. Ground Granulated Blast Furnace Slag	2.99	216.28	1.159	0.47	0.003	211.23	1.132
3. VCAS-160	2.60	139.54	0.860	0.31	0.002	136.28	0.840
Total of All Cementitious Materials:		697.69	3.759	1.53	0.008	681.40	3.671
Fibers							
1. 8 mm PVA	1.30	5.04	0.062	0.01	0.000	4.92	0.061
Total of All Fibers:		5.04	0.062	0.01	0.000	4.92	0.061
Aggregates							
1. Poraver 1.0-2.0mm Abs.: 12.1% ; MC: 0.1%	0.51	194.74	6.180	0.43	0.014	190.19	6.036
2. Poraver 0.5-1.0mm Abs.: 8.0% ; MC: 0.1%	0.65	141.19	3.465	0.31	0.008	137.89	3.384
3. Extendospheres SG Abs.: 13.2% ; MC: 0.1%	0.72	150.92	3.359	0.33	0.007	147.40	3.281
Total of All Aggregates:		486.85	13.004	1.06	0.028	475.48	12.700
Water							
1. Total Batched Water^	1.00	179.07	2.870	0.39	0.006	174.89	2.803
2. Water Added for Agg. Absorption▼ ∞	1.00	54.29	0.870	0.12	0.002	53.03	0.850
3. Total Water from All Admixtures§	1.00	66.96	1.073	0.15	0.002	65.40	1.048
Total Water:		246.03	3.943	0.54	0.009	240.29	3.851
Solids Content of Latex Modifiers							
1. Xycrylic; Lb/gal: 9.18	1.10	93.02	1.356	0.20	0.003	90.85	1.325
Total Latex Solids:		93.02	1.356	0.20	0.003	90.85	1.325
Admixtures	% Solids	Amount (fl oz/cwt)	Water‡ in Admixture (lb/yd^3)	Amount (fl oz)	Water‡ in Admixture (lb)	Amount (fl oz/cwt)	Water‡ in Admixture (lb/yd^3)
1. Air Entrainer; Lb/gal: 8.48	6.7	0.67		0.010		0.65	
2. High-Range Water-Reducer; Lb/gal: 8.76	20.27	8.87		0.135		8.66	
Cement-Cementitious Materials Ratio		0.49		0.49		0.49	
Water-Cementitious Materials Ratio (w/cm)		0.27		0.27		0.27	
Slump, Slump Flow, in. (Flow Table, %)		6 ± 1		6.25		6.25	
Design Air Content, %		25.00					
Density (Unit Weight), lb/ft^3		54.30		53.04		53.04	
Gravimetric Air Content, %				26.75		26.75	
Yield, ft^3		27.00		0.057		27.00	

Abs. = Absorption; MC = Batched moisture content;
^ Including water added for aggregate absorption;
** For aggregates, provide ASTM C 128 oven-dry bulk specific gravity.*
▼Volumes in this row are not used in the density calculation.
‡ Water content of admixture.
§ If impact on w/cm is less than 0.01 enter zero.
∞ Masses in this row are not included in w/cm calculation.

Mixture: KIPPIS Dark Blue Finishing

Batch Size (ft3): 0.0580

		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 Type I Gray Portland Cement	3.15	373.97	1.903	0.79	0.004	358.01	1.821
2. Ground Granulated Blast Furnace Slag	2.99	160.27	0.859	0.34	0.002	153.43	0.822
3. VCAS-160	2.60	228.96	1.411	0.48	0.003	219.19	1.351
Total of All Cementitious Materials:		763.21	4.173	1.62	0.009	730.64	3.995
Fibers							
1. 30 mm PVA	1.30	0.00	0.000	0.00	0.000	0.00	0.000
2. 8 mm PVA	1.30	0.00	0.000	0.00	0.000	0.00	0.000
Total of All Fibers:		0.00	0.000	0.00	0.000	0.00	0.000
Aggregates							
1. Poraver 0.5-1.0mm Abs.: 8.0% ; MC: 0.1%	0.65	274.19	6.729	0.58	0.014	262.49	6.442
2. Extendospheres HA 350 Abs.: 13.2% ; MC: 0.1%	0.75	297.04	6.347	0.63	0.013	284.37	6.076
Total of All Aggregates:		571.24	13.076	1.21	0.028	546.86	12.518
Water							
1. Total Batched Water^	1.00	262.04	4.199	0.55	0.009	250.85	4.020
2. Water Added for Agg. Absorption▼ ∞	1.00	60.57	0.971	0.13	0.002	57.99	0.929
3. Total Water from All Admixtures§	1.00	54.06	0.866	0.11	0.002	51.75	0.829
Total Water:		316.09	5.066	0.67	0.011	302.60	4.849
Solids Content of Latex Modifiers							
1. Xycrylic; Lb/gal: 9.18	1.10	50.88	0.742	0.11	0.002	48.71	0.710
Total Latex Solids:		50.88	0.742	0.11	0.002	48.71	0.710
Admixtures	% Solids	Amount (fl oz/cwt)	Water‡ in Admixture (lb/yd^3)	Amount (fl oz)	Water‡ in Admixture (lb)	Amount (fl oz/cwt)	Water‡ in Admixture (lb/yd^3)
1. Air Entrainer; Lb/gal: 8.48	6.7	2.51		0.041		2.40	
2. High-Range Water-Reducer; Lb/gal: 8.76	20.27	41.86	17.43	0.676	0.037	40.08	16.69
3. Blue Pigment■; Lb/gal: 37.91	100.00	2.30	0.00	0.037	0.000	2.21	0.00
4. Black Pigment■; Lb/gal: 48.56	100.00	1.08	0.00	0.017	0.000	1.03	0.00
Cement-Cementitious Materials Ratio		0.49		0.49		0.49	
Water-Cementitious Materials Ratio (w/cm)		0.33		0.33		0.33	
Slump, Slump Flow, in. (Flow Table, %)		8 ± 1		8.25		8.25	
Design Air Content, %		20.00					
Density (Unit Weight), lb/ft^3		62.18		59.52		59.52	
Gravimetric Air Content, %				23.41		23.41	
Yield, ft^3		27.00		0.058		27.00	

Abs. = Absorption; MC = Batched moisture content;
^ Including water added for aggregate absorption;
** For aggregates, provide ASTM C 128 oven-dry bulk specific gravity.*
▼ Volumes in this row are not used in the density calculation.
■ Denotes solid admixture; units shown are lb/gal (US Dry), oz/cwt or oz, where appropriate.
‡ Water content of admixture.
§ If impact on w/cm is less than 0.01 enter zero.
∞ Masses in this row are not included in w/cm calculation.

Mixture: KIPPIS Sky Blue Finishing

Batch Size (ft3): 0.0580

		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 Type I White Portland Cement	3.15	374.38	1.905	0.79	0.004	359.57	1.829
2. Ground Granulated Blast Furnace Slag	2.99	160.45	0.860	0.34	0.002	154.10	0.826
3. VCAS-160	2.60	229.21	1.413	0.48	0.003	220.15	1.357
Total of All Cementitious Materials:		764.04	4.177	1.62	0.009	733.83	4.012
Fibers							
1. 30 mm PVA	1.30	0.00	0.000	0.00	0.000	0.00	0.000
2. 8 mm PVA	1.30	0.00	0.000	0.00	0.000	0.00	0.000
Total of All Fibers:		0.00	0.000	0.00	0.000	0.00	0.000
Aggregates							
1. Poraver 0.5-1.0mm Abs.: 8.0% ; MC: 0.1%	0.65	274.49	6.736	0.58	0.014	263.64	6.470
2. Extendospheres HA 350 Abs.: 13.2% ; MC: 0.1%	0.75	297.37	6.354	0.63	0.013	285.61	6.103
Total of All Aggregates:		571.86	13.090	1.21	0.028	549.25	12.573
Water							
1. Total Batched Water^	1.00	262.32	4.204	0.55	0.009	251.95	4.038
2. Water Added for Agg. Absorption▼ ∞	1.00	60.64	0.972	0.13	0.002	58.24	0.933
3. Total Water from All Admixtures§	1.00	54.12	0.867	0.11	0.002	51.98	0.833
Total Water:		316.44	5.071	0.67	0.011	303.92	4.871
Solids Content of Latex Modifiers							
1. Xycrylic; Lb/gal: 9.18	1.10	50.94	0.743	0.11	0.002	48.92	0.713
Total Latex Solids:		50.94	0.743	0.11	0.002	48.92	0.713
Admixtures	% Solids	Amount (fl oz/cwt)	Water‡ in Admixture (lb/yd^3)	Amount (fl oz)	Water‡ in Admixture (lb)	Amount (fl oz/cwt)	Water‡ in Admixture (lb/yd^3)
1. Air Entrainer; Lb/gal: 8.48	6.7	2.51		0.041		2.41	
2. High-Range Water-Reducer; Lb/gal: 8.76	20.27	41.86	17.45	0.676	0.037	40.21	16.76
3. Blue Pigment■; Lb/gal: 37.91	100.00	0.46	0.00	0.007	0.000	0.44	0.00
Cement-Cementitious Materials Ratio		0.49		0.49		0.49	
Water-Cementitious Materials Ratio (w/cm)		0.33		0.33		0.33	
Slump, Slump Flow, in. (Flow Table, %)		8 ± 1		8.25		8.25	
Design Air Content, %		20.00					
Density (Unit Weight), lb/ft^3		61.97		59.52		59.52	
Gravimetric Air Content, %				23.16		23.16	
Yield, ft^3		27.00		0.058		27.00	

Abs. = Absorption; MC = Batched moisture content;
^ Including water added for aggregate absorption;
** For aggregates, provide ASTM C 128 oven-dry bulk specific gravity.*
▼ Volumes in this row are not used in the density calculation.
■ Denotes solid admixture; units shown are lb/gal (US Dry), oz/cwt or oz, where appropriate.
‡ Water content of admixture.
§ If impact on w/cm is less than 0.01 enter zero.
∞ Masses in this row are not included in w/cm calculation.

Mixture: KIPPIS Brick Red Finishing

Batch Size (ft3): 0.0580

		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 Type I Gray Portland Cement	3.15	373.87	1.902	0.79	0.004	357.57	1.819
2. Ground Granulated Blast Furnace Slag	2.99	160.23	0.859	0.34	0.002	153.24	0.821
3. VCAS-160	2.60	228.90	1.411	0.48	0.003	218.92	1.349
Total of All Cementitious Materials:		763.00	4.172	1.62	0.009	729.74	3.990
Fibers							
1. 30 mm PVA	1.30	0.00	0.000	0.00	0.000	0.00	0.000
2. 8 mm PVA	1.30	0.00	0.000	0.00	0.000	0.00	0.000
Total of All Fibers:		0.00	0.000	0.00	0.000	0.00	0.000
Aggregates							
1. Poraver 0.5-1.0mm Abs.: 8.0% ; MC: 0.1%	0.65	274.12	6.727	0.58	0.014	262.17	6.434
2. Extendospheres HA 350 Abs.: 13.2%; MC: 0.1%	0.75	296.96	6.345	0.63	0.013	284.02	6.069
Total of All Aggregates:		571.08	13.073	1.21	0.028	546.19	12.503
Water							
1. Total Batched Water^	1.00	261.96	4.198	0.55	0.009	250.54	4.015
2. Water Added for Agg. Absorption▼ ∞	1.00	60.56	0.970	0.13	0.002	57.92	0.928
3. Total Water from All Admixtures§	1.00	54.04	0.866	0.11	0.002	51.69	0.828
Total Water:		316.01	5.064	0.67	0.011	302.23	4.843
Solids Content of Latex Modifiers							
1. Xycrylic; Lb/gal: 9.18	1.10	50.87	0.742	0.11	0.002	48.65	0.709
Total Latex Solids:		50.87	0.742	0.11	0.002	48.65	0.709
Admixtures	% Solids	Amount (fl oz/cwt)	Water‡ in Admixture (lb/yd^3)	Amount (fl oz)	Water‡ in Admixture (lb)	Amount (fl oz/cwt)	Water‡ in Admixture (lb/yd^3)
1. Air Entrainer; Lb/gal: 8.48	6.7	2.51		0.041		2.40	
2. High-Range Water-Reducer; Lb/gal: 8.76	20.27	41.86	17.43	0.676	0.037	40.04	16.67
3. Red Pigment■; Lb/gal: 42.44	100.00	4.12	0.00	0.066	0.000	3.94	0.00
Cement-Cementitious Materials Ratio		0.49		0.49		0.49	
Water-Cementitious Materials Ratio (w/cm)		0.33		0.33		0.33	
Slump, Slump Flow, in. (Flow Table, %)		8 ± 1		8.25		8.25	
Design Air Content, %		20.00					
Density (Unit Weight), lb/ft^3		62.24		59.52		59.52	
Gravimetric Air Content, %				23.49		23.49	
Yield, ft^3		27.00		0.058		27.00	

Abs. = Absorption; MC = Batched moisture content;
^ Including water added for aggregate absorption;
** For aggregates, provide ASTM C 128 oven-dry bulk specific gravity.*
▼ Volumes in this row are not used in the density calculation.
■ Denotes solid admixture; units shown are lb/gal (US Dry), oz/cwt or oz, where appropriate.
‡ Water content of admixture.
§ If impact on w/cm is less than 0.01 enter zero.
∞ Masses in this row are not included in w/cm calculation.

Mixture: KIPPIS Gray Finishing

Batch Size (ft3): 0.0580

		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 Type I Gray Portland Cement	3.15	374.44	1.905	0.79	0.004	359.80	1.830
2. Ground Granulated Blast Furnace Slag	2.99	160.47	0.860	0.34	0.002	154.20	0.826
3. VCAS-160	2.60	229.25	1.413	0.48	0.003	220.28	1.358
Total of All Cementitious Materials:		764.16	4.178	1.62	0.009	734.28	4.015
Fibers							
1. 30 mm PVA	1.30	0.00	0.000	0.00	0.000	0.00	0.000
2. 8 mm PVA	1.30	0.00	0.000	0.00	0.000	0.00	0.000
Total of All Fibers:		0.00	0.000	0.00	0.000	0.00	0.000
Aggregates							
1. Poraver 0.5-1.0mm Abs.: 8.0% ; MC: 0.1%	0.65	274.53	6.737	0.58	0.014	263.80	6.474
2. Extendospheres HA 350 Abs.: 13.2% ; MC: 0.1%	0.75	297.41	6.355	0.63	0.013	285.78	6.106
Total of All Aggregates:		571.95	13.092	1.21	0.028	549.58	12.581
Water							
1. Total Batched Water^	1.00	262.36	4.204	0.55	0.009	252.10	4.040
2. Water Added for Agg. Absorption▼ ∞	1.00	60.65	0.972	0.13	0.002	58.28	0.934
3. Total Water from All Admixtures§	1.00	54.12	0.867	0.11	0.002	52.01	0.833
Total Water:		316.48	5.072	0.67	0.011	304.11	4.874
Solids Content of Latex Modifiers							
1. Xycrylic; Lb/gal: 9.18	1.10	50.94	0.743	0.11	0.002	48.95	0.714
Total Latex Solids:		50.94	0.743	0.11	0.002	48.95	0.714
Admixtures	% Solids	Amount (fl oz/cwt)	Water‡ in Admixture (lb/yd^3)	Amount (fl oz)	Water‡ in Admixture (lb)	Amount (fl oz/cwt)	Water‡ in Admixture (lb/yd^3)
1. Air Entrainer; Lb/gal: 8.48	6.7	2.51		0.041		2.41	
2. High-Range Water-Reducer; Lb/gal: 8.76	20.27	41.86	17.46	0.676	0.037	40.23	16.77
Cement-Cementitious Materials Ratio		0.49		0.49		0.49	
Water-Cementitious Materials Ratio (w/cm)		0.33		0.33		0.33	
Slump, Slump Flow, in. (Flow Table, %)		8 ± 1		8.25		8.25	
Design Air Content, %		20.00					
Density (Unit Weight), lb/ft^3		61.95		59.52		59.52	
Gravimetric Air Content, %				23.13		23.13	
Yield, ft^3		27.00		0.058		27.00	

Abs. = Absorption; MC = Batched moisture content;
^ Including water added for aggregate absorption;
** For aggregates, provide ASTM C 128 oven-dry bulk specific gravity.*
▼ Volumes in this row are not used in the density calculation.
‡ Water content of admixture.
§ If impact on w/cm is less than 0.01 enter zero.
∞ Masses in this row are not included in w/cm calculation.

Mixture: KIPPIS Forest Green Finishing

Batch Size (ft3): 0.0580

		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 Type I Gray Portland Cement	3.15	373.88	1.902	0.79	0.004	357.12	1.817
2. Ground Granulated Blast Furnace Slag	2.99	160.23	0.859	0.34	0.002	153.05	0.820
3. VCAS-160	2.60	228.91	1.411	0.48	0.003	218.65	1.348
Total of All Cementitious Materials:		763.02	4.172	1.62	0.009	728.82	3.985
Fibers							
1. 30 mm PVA	1.30	0.00	0.000	0.00	0.000	0.00	0.000
2. 8 mm PVA	1.30	0.00	0.000	0.00	0.000	0.00	0.000
Total of All Fibers:		0.00	0.000	0.00	0.000	0.00	0.000
Aggregates							
1. Poraver 0.5-1.0mm Abs.: 8.0% ; MC: 0.1%	0.65	274.13	6.728	0.58	0.014	261.84	6.426
2. Extendospheres HA 350 Abs.: 13.2% ; MC: 0.1%	0.75	296.97	6.346	0.63	0.013	283.66	6.061
Total of All Aggregates:		571.10	13.073	1.21	0.028	545.50	12.487
Water							
1. Total Batched Water^	1.00	261.97	4.198	0.55	0.009	250.23	4.010
2. Water Added for Agg. Absorption▼ ∞	1.00	60.56	0.971	0.13	0.002	57.85	0.927
3. Total Water from All Admixtures§	1.00	54.04	0.866	0.11	0.002	51.62	0.827
Total Water:		316.02	5.064	0.67	0.011	301.85	4.837
Solids Content of Latex Modifiers							
1. Xycrylic; Lb/gal: 9.18	1.10	50.87	0.742	0.11	0.002	48.59	0.709
Total Latex Solids:		50.87	0.742	0.11	0.002	48.59	0.709
Admixtures	% Solids	Amount (fl oz/cwt)	Water‡ in Admixture (lb/yd^3)	Amount (fl oz)	Water‡ in Admixture (lb)	Amount (fl oz/cwt)	Water‡ in Admixture (lb/yd^3)
1. Air Entrainer; Lb/gal: 8.48	6.7	2.51		0.041		2.40	
2. High-Range Water-Reducer; Lb/gal: 8.76	20.27	41.86	17.43	0.676	0.037	39.99	16.65
3. Green Pigment■; Lb/gal: 52.07	100.00	3.35	0.00	0.054	0.000	3.20	0.00
4. Black Pigment■; Lb/gal: 48.56	100.00	0.72	0.00	0.012	0.000	0.69	0.00
Cement-Cementitious Materials Ratio		0.49		0.49		0.49	
Water-Cementitious Materials Ratio (w/cm)		0.33		0.33		0.33	
Slump, Slump Flow, in. (Flow Table, %)		8 ± 1		8.25		8.25	
Design Air Content, %		20.00					
Density (Unit Weight), lb/ft^3		62.32		59.52		59.52	
Gravimetric Air Content, %				23.58		23.58	
Yield, ft^3		27.00		0.058		27.00	

Abs. = Absorption; MC = Batched moisture content;
^ Including water added for aggregate absorption;
** For aggregates, provide ASTM C 128 oven-dry bulk specific gravity.*
▼ Volumes in this row are not used in the density calculation.
■ Denotes solid admixture; units shown are lb/gal (US Dry), oz/cwt or oz, where appropriate.
‡ Water content of admixture.
§ If impact on w/cm is less than 0.01 enter zero.
∞ Masses in this row are not included in w/cm calculation.

Mixture: KIPPIS Crème Finishing

Batch Size (ft^3): 0.0580

		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 Type I White Portland Cement	3.15	374.36	1.905	0.79	0.004	359.35	1.828
2. Ground Granulated Blast Furnace Slag	2.99	160.44	0.860	0.34	0.002	154.01	0.825
3. VCAS-160	2.60	229.20	1.413	0.48	0.003	220.01	1.356
Total of All Cementitious Materials:		763.99	4.177	1.62	0.009	733.37	4.010
Fibers							
1. 30 mm PVA	1.30	0.00	0.000	0.00	0.000	0.00	0.000
2. 8 mm PVA	1.30	0.00	0.000	0.00	0.000	0.00	0.000
Total of All Fibers:		0.00	0.000	0.00	0.000	0.00	0.000
Aggregates							
1. Poraver 0.5-1.0mm Abs.: 8.0% ; MC: 0.1%	0.65	274.47	6.736	0.58	0.014	263.47	6.466
2. Extendospheres HA 350 Abs.: 13.2% ; MC: 0.1%	0.75	297.35	6.354	0.63	0.013	285.43	6.099
Total of All Aggregates:		571.82	13.090	1.21	0.028	548.90	12.565
Water							
1. Total Batched Water^	1.00	262.30	4.204	0.55	0.009	251.79	4.035
2. Water Added for Agg. Absorption▼ ∞	1.00	60.64	0.972	0.13	0.002	58.21	0.933
3. Total Water from All Admixtures§	1.00	54.11	0.867	0.11	0.002	51.94	0.832
Total Water:		316.42	5.071	0.67	0.011	303.73	4.868
Solids Content of Latex Modifiers							
1. Xycrylic; Lb/gal: 9.18	1.10	50.93	0.743	0.11	0.002	48.89	0.713
Total Latex Solids:		50.93	0.743	0.11	0.002	48.89	0.713
Admixtures	% Solids	Amount (fl oz/cwt)	Water‡ in Admixture (lb/yd^3)	Amount (fl oz)	Water‡ in Admixture (lb)	Amount (fl oz/cwt)	Water‡ in Admixture (lb/yd^3)
1. Air Entrainer; Lb/gal: 8.48	6.7	2.51		0.041		2.41	
2. High-Range Water-Reducer; Lb/gal: 8.76	20.27	41.86	17.45	0.676	0.037	40.18	16.75
3. Creme Pigment■; Lb/gal: 61.31	100.00	0.57	0.00	0.009	0.000	0.55	0.00
Cement-Cementitious Materials Ratio		0.49		0.49		0.49	
Water-Cementitious Materials Ratio (w/cm)		0.33		0.33		0.33	
Slump, Slump Flow, in. (Flow Table, %)		8 ± 1		8.25		8.25	
Design Air Content, %		20.00					
Density (Unit Weight), lb/ft^3		62.01		59.52		59.52	
Gravimetric Air Content, %				23.21		23.21	
Yield, ft^3		27.00		0.058		27.00	

Abs. = Absorption; MC = Batched moisture content;
^ Including water added for aggregate absorption;
** For aggregates, provide ASTM C 128 oven-dry bulk specific gravity.*
▼ *Volumes in this row are not used in the density calculation.*
■ *Denotes solid admixture; units shown are lb/gal (US Dry), oz/cwt or oz, where appropriate.*
‡ Water content of admixture.
§ If impact on w/cm is less than 0.01 enter zero.
∞ Masses in this row are not included in w/cm calculation.

Mixture: KIPPIS Black Finishing

Batch Size (ft3): 0.0580

		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 Type I Gray Portland Cement	3.15	373.80	1.902	0.79	0.004	356.90	1.816
2. Ground Granulated Blast Furnace Slag	2.99	160.20	0.859	0.34	0.002	152.96	0.820
3. VCAS-160	2.60	228.85	1.411	0.48	0.003	218.51	1.347
Total of All Cementitious Materials:		762.85	4.171	1.62	0.009	728.37	3.982
Fibers							
1. 30 mm PVA	1.30	0.00	0.000	0.00	0.000	0.00	0.000
2. 8 mm PVA	1.30	0.00	0.000	0.00	0.000	0.00	0.000
Total of All Fibers:		0.00	0.000	0.00	0.000	0.00	0.000
Aggregates							
1. Poraver 0.5-1.0mm Abs.: 8.0% ; MC: 0.1%	0.65	274.06	6.726	0.58	0.014	261.68	6.422
2. Extendospheres HA 350 Abs.: 13.2% ; MC: 0.1%	0.75	296.90	6.344	0.63	0.013	283.49	6.057
Total of All Aggregates:		570.97	13.070	1.21	0.028	545.16	12.479
Water							
1. Total Batched Water^	1.00	261.91	4.197	0.55	0.009	250.07	4.008
2. Water Added for Agg. Absorption▼ ∞	1.00	60.55	0.970	0.13	0.002	57.81	0.926
3. Total Water from All Admixtures§	1.00	54.03	0.866	0.11	0.002	51.59	0.827
Total Water:		315.94	5.063	0.67	0.011	301.66	4.834
Solids Content of Latex Modifiers							
1. Xycrylic; Lb/gal: 9.18	1.10	50.86	0.742	0.11	0.002	48.56	0.708
Total Latex Solids:		50.86	0.742	0.11	0.002	48.56	0.708
Admixtures	% Solids	Amount (fl oz/cwt)	Water‡ in Admixture (lb/yd^3)	Amount (fl oz)	Water‡ in Admixture (lb)	Amount (fl oz/cwt)	Water‡ in Admixture (lb/yd^3)
1. Air Entrainer; Lb/gal: 8.48	6.7	2.51		0.041		2.40	
2. High-Range Water-Reducer; Lb/gal: 8.76	20.27	41.86	17.43	0.676	0.037	39.97	16.64
3. Black Pigment■; Lb/gal: 48.56	100.00	4.68	0.00	0.076	0.000	4.47	0.00
Cement-Cementitious Materials Ratio		0.49		0.49		0.49	
Water-Cementitious Materials Ratio (w/cm)		0.33		0.33		0.33	
Slump, Slump Flow, in. (Flow Table, %)		8 ± 1		8.25		8.25	
Design Air Content, %		20.00					
Density (Unit Weight), lb/ft^3		62.34		59.52		59.52	
Gravimetric Air Content, %				23.61		23.61	
Yield, ft^3		27.00		0.058		27.00	

Abs. = Absorption; MC = Batched moisture content;
^ Including water added for aggregate absorption;
** For aggregates, provide ASTM C 128 oven-dry bulk specific gravity.*
▼ Volumes in this row are not used in the density calculation.
■ Denotes solid admixture; units shown are lb/gal (US Dry), oz/cwt or oz, where appropriate.
‡ Water content of admixture.
§ If impact on w/cm is less than 0.01 enter zero.
∞ Masses in this row are not included in w/cm calculation.

Mixture: KIPPIS Brown Finishing

Batch Size (ft3): 0.0580

		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 Type I White Portland Cement	3.15	373.73	1.901	0.79	0.004	356.90	1.816
2. Ground Granulated Blast Furnace Slag	2.99	160.17	0.858	0.34	0.002	152.96	0.820
3. VCAS-160	2.60	228.81	1.410	0.48	0.003	218.51	1.347
Total of All Cementitious Materials:		762.72	4.170	1.62	0.009	728.37	3.982
Fibers							
1. 30 mm PVA	1.30	0.00	0.000	0.00	0.000	0.00	0.000
2. 8 mm PVA	1.30	0.00	0.000	0.00	0.000	0.00	0.000
Total of All Fibers:		0.00	0.000	0.00	0.000	0.00	0.000
Aggregates							
1. Poraver 0.5-1.0mm Abs.: 8.0% ; MC: 0.1%	0.65	274.02	6.725	0.58	0.014	261.68	6.422
2. Extendospheres HA 350 Abs.: 13.2% ; MC: 0.1%	0.75	296.85	6.343	0.63	0.013	283.49	6.057
Total of All Aggregates:		570.87	13.068	1.21	0.028	545.16	12.479
Water							
1. Total Batched Water^	1.00	261.87	4.197	0.55	0.009	250.07	4.008
2. Water Added for Agg. Absorption▼ ∞	1.00	60.53	0.970	0.13	0.002	57.81	0.926
3. Total Water from All Admixtures§	1.00	54.02	0.866	0.11	0.002	51.59	0.827
Total Water:		315.89	5.062	0.67	0.011	301.66	4.834
Solids Content of Latex Modifiers							
1. Xycrylic; Lb/gal: 9.18	1.10	50.85	0.741	0.11	0.002	48.56	0.708
Total Latex Solids:		50.85	0.741	0.11	0.002	48.56	0.708
Admixtures	% Solids	Amount (fl oz/cwt)	Water‡ in Admixture (lb/yd^3)	Amount (fl oz)	Water‡ in Admixture (lb)	Amount (fl oz/cwt)	Water‡ in Admixture (lb/yd^3)
1. Air Entrainer; Lb/gal: 8.48	6.7	2.51		0.041		2.40	
2. High-Range Water-Reducer; Lb/gal: 8.76	20.27	41.86	17.42	0.676	0.037	39.98	16.64
3. Brown Pigment■; Lb/gal: 45.62	100.00	3.83	0.00	0.062	0.000	3.66	0.00
4. Gold Pigment■; Lb/gal: 40.79	100.00	1.28	0.00	0.021	0.000	1.23	0.00
Cement-Cementitious Materials Ratio		0.49		0.49		0.49	
Water-Cementitious Materials Ratio (w/cm)		0.33		0.33		0.33	
Slump, Slump Flow, in. (Flow Table, %)		8 ± 1		8.25		8.25	
Design Air Content, %		20.00					
Density (Unit Weight), lb/ft^3		62.33		59.52		59.52	
Gravimetric Air Content, %				23.60		23.60	
Yield, ft^3		27.00		0.058		27.00	

Abs. = Absorption; MC = Batched moisture content;
^ Including water added for aggregate absorption;
** For aggregates, provide ASTM C 128 oven-dry bulk specific gravity.*
▼ Volumes in this row are not used in the density calculation.
■ Denotes solid admixture; units shown are lb/gal (US Dry), oz/cwt or oz, where appropriate.
‡ Water content of admixture.
§ If impact on w/cm is less than 0.01 enter zero.
∞ Masses in this row are not included in w/cm calculation.

Appendix C – Gradation Curve and Table

Concrete Aggregate:	Poraver® 1.0-2.0mm Glass Spheres
Sample Weight (g)	217.7
Specific Gravity	0.51
Fineness Modulus	4.69

Table C1: Poraver® 1.0-2.0mm Glass Spheres Gradation Table

Sieve Size (U.S.)	Diameter (mm)	Weight Retained (g)	Cumulative Weight Retained (g)	Percent Finer (%)
3/8 inch	9.5	0	0	100.0
No. 4	4.75	0	0	100.0
No. 8	2.36	151.9	151.9	30.2
No. 16	1.18	64.8	216.7	0.5
No. 30	0.6	0.7	217.4	0.1
No. 50	0.3	0.1	217.5	0.1
No. 100	0.15	0.1	217.6	0.0

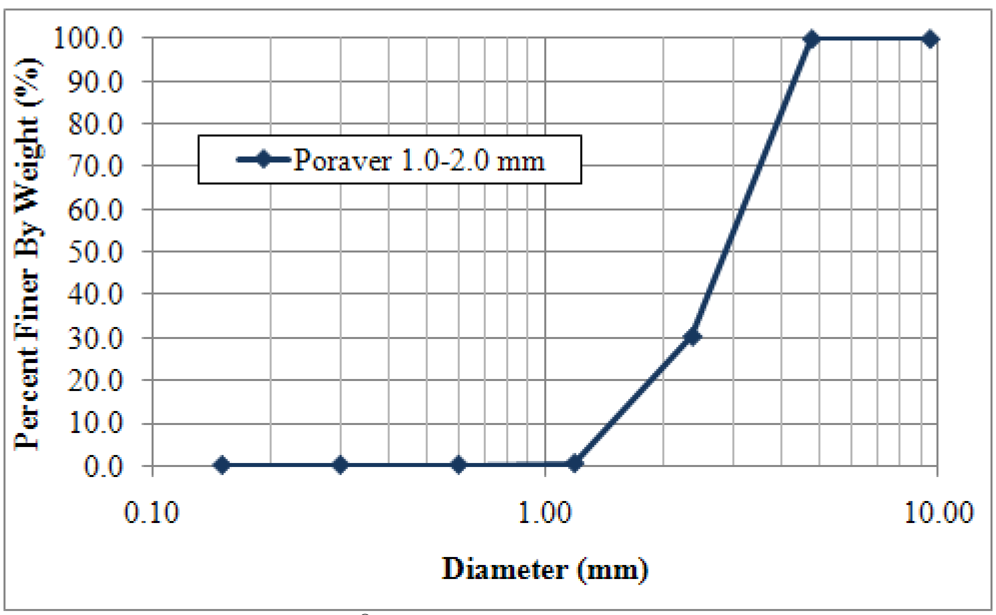


Figure C1: Poraver® 1.0-2.0mm Glass Spheres Gradation Curve

Concrete Aggregate:	Poraver® 0.5-1.0mm Glass Spheres
Sample Weight (g)	244.6
Specific Gravity	0.65
Fineness Modulus	3.89

Table C2: Poraver® 0.5-1.0mm Glass Spheres Gradation Table

Sieve Size (U.S.)	Diameter (mm)	Weight Retained (g)	Cumulative Weight Retained (g)	Percent Finer (%)
3/8 inch	9.5	0	0	100.0
No. 4	4.75	0	0	100.0
No. 8	2.36	0	0	100.0
No. 16	1.18	218	218	10.9
No. 30	0.6	26.5	244.5	0.0
No. 50	0.3	0.1	244.6	0.0
No. 100	0.15	0	244.6	0.0

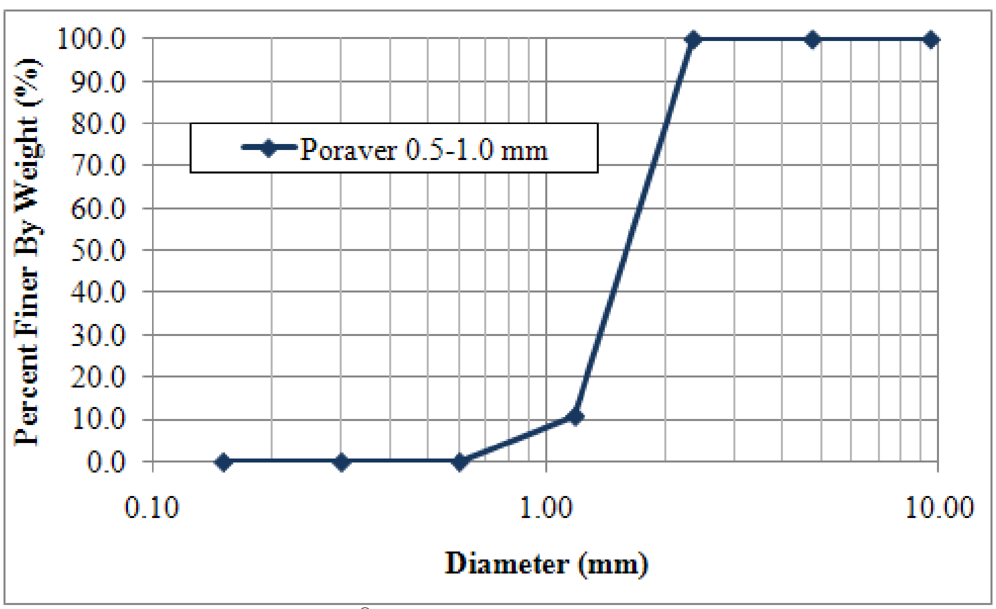


Figure C2: Poraver® 0.5-1.0mm Glass Spheres Gradation Curve

Concrete Aggregate:	Extendospheres™ SG Ceramic Spheres
Sample Weight (g)	162.6
Specific Gravity	0.72
Fineness Modulus	1.89

Table C3: Extendospheres™ SG Ceramic Spheres Gradation Table

Sieve Size (U.S.)	Diameter (mm)	Weight Retained (g)	Cumulative Weight Retained (g)	Percent Finer (%)
3/8 inch	9.5	0	0	100.0
No. 4	4.75	0	0	100.0
No. 8	2.36	0	0	100.0
No. 16	1.18	0	0	100.0
No. 30	0.6	14.1	14.1	91.3
No. 50	0.3	123.1	137.2	15.6
No. 100	0.15	18.6	155.8	4.2

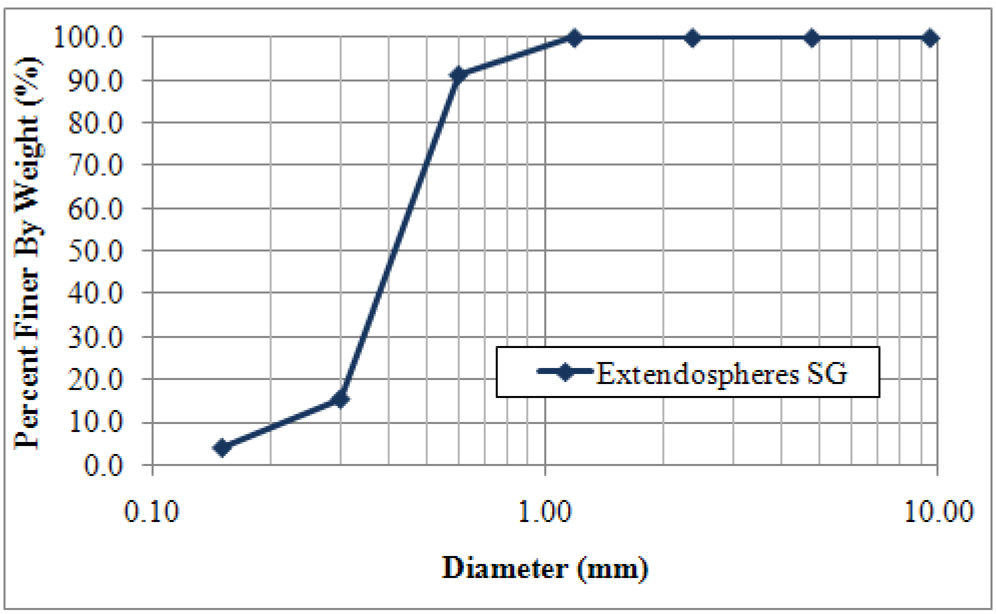


Figure C3: Extendospheres™ SG Ceramic Spheres Gradation Curve

Concrete Aggregate:	Extendospheres™ HA 350 Ceramic Spheres
Sample Weight (g)	191.7
Specific Gravity	0.75
Fineness Modulus	2.49

Table C4: Extendospheres™ HA 350 Ceramic Spheres Gradation Table

Sieve Size (U.S.)	Diameter (mm)	Weight Retained (g)	Cumulative Weight Retained (g)	Percent Finer (%)
3/8 inch	9.5	0	0	100.0
No. 4	4.75	0	0	100.0
No. 8	2.36	0	0	100.0
No. 16	1.18	0	0	100.0
No. 30	0.6	115.3	115.3	39.9
No. 50	0.3	58.2	173.5	9.5
No. 100	0.15	15.4	188.9	1.5

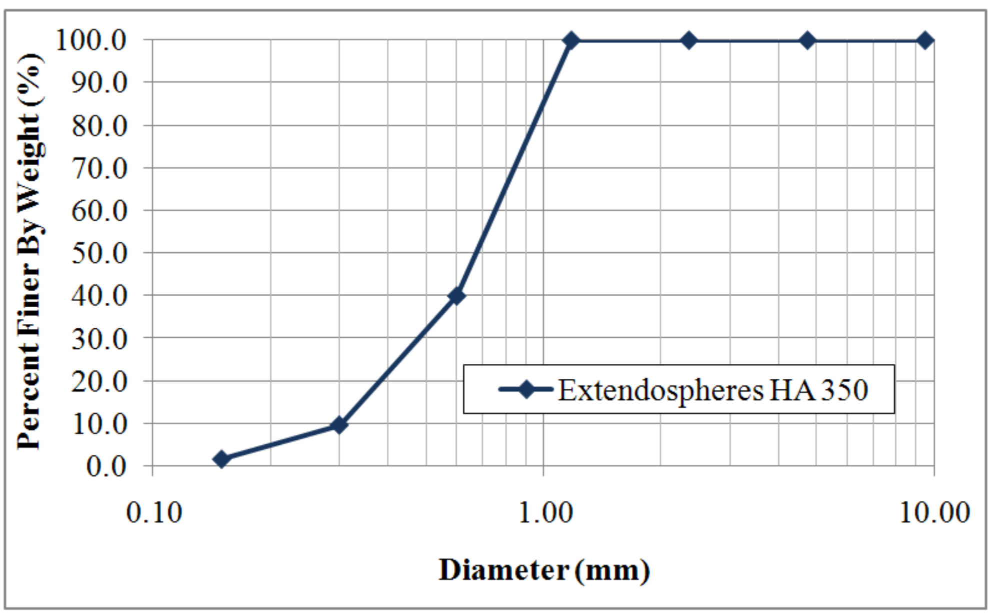


Figure C4: Extendospheres™ HA 350 Ceramic Spheres Gradation Curve

Concrete Aggregate:	Structural Concrete Mix (Kippis) Composite
Sample Weight (g)	200.3
Specific Gravity	0.60
Fineness Modulus	2.60

Table C5: Structural Concrete Mix (Kippis) Composite Gradation Table

Sieve Size (U.S.)	Diameter (mm)	Weight Retained (g)	Cumulative Weight Retained (g)	Percent Finer (%)
3/8 inch	9.50	0.0	0.0	100.0
No. 4	4.75	0.0	0.0	100.0
No. 8	2.36	0.0	0.0	100.0
No. 16	1.18	55.9	55.9	72.1
No. 30	0.60	75.6	131.5	34.3
No. 50	0.30	11.9	143.5	28.4
No. 100	0.15	47.1	190.5	4.9

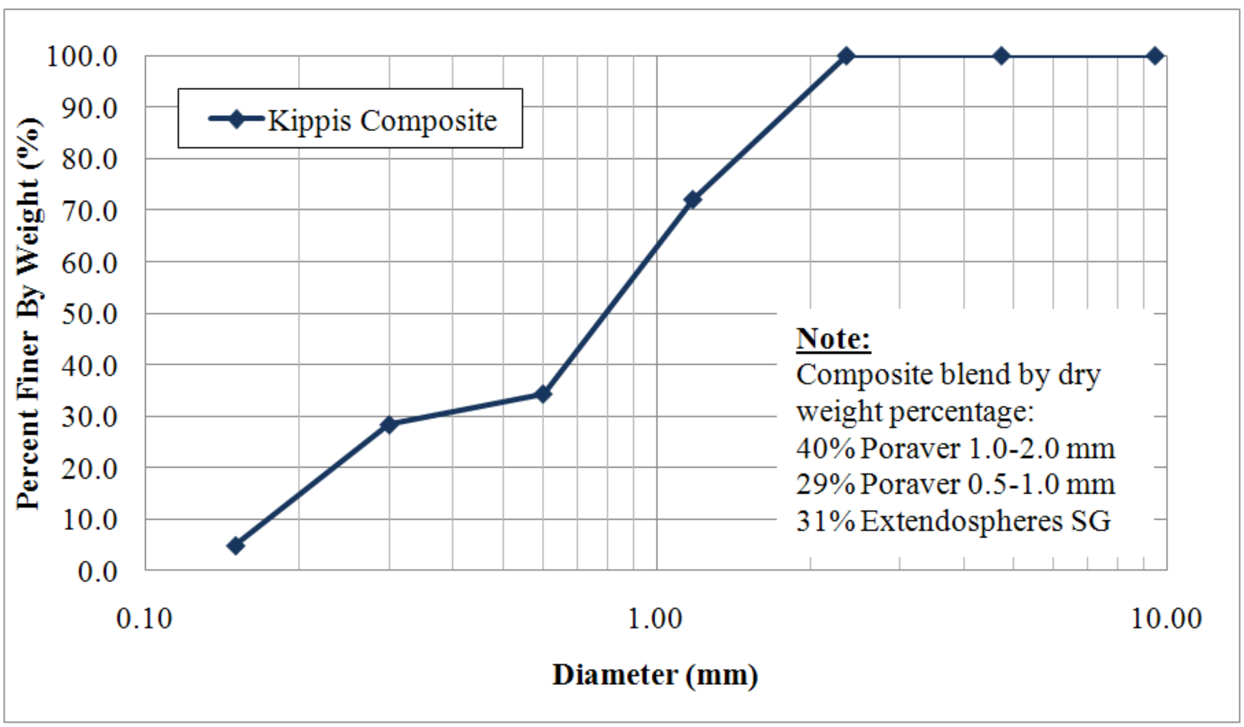


Figure C5: Structural Concrete Mix (Kippis) Gradation Curve

Concrete Aggregate:	Finishing Concrete Mix Composite
Sample Weight (g)	227.20
Specific Gravity	0.70
Fineness Modulus	3.16

Table C6: Finishing Concrete Mix Composite Gradation Table

Sieve Size (U.S.)	Diameter (mm)	Weight Retained (g)	Cumulative Weight Retained (g)	Percent Finer (%)
3/8 inch	9.50	0.0	0.0	100.0
No. 4	4.75	0.0	0.0	100.0
No. 8	2.36	0.0	0.0	100.0
No. 16	1.18	97.2	97.2	57.2
No. 30	0.60	82.9	180.1	20.7
No. 50	0.30	35.9	216.0	4.9
No. 100	0.15	9.5	225.5	0.8

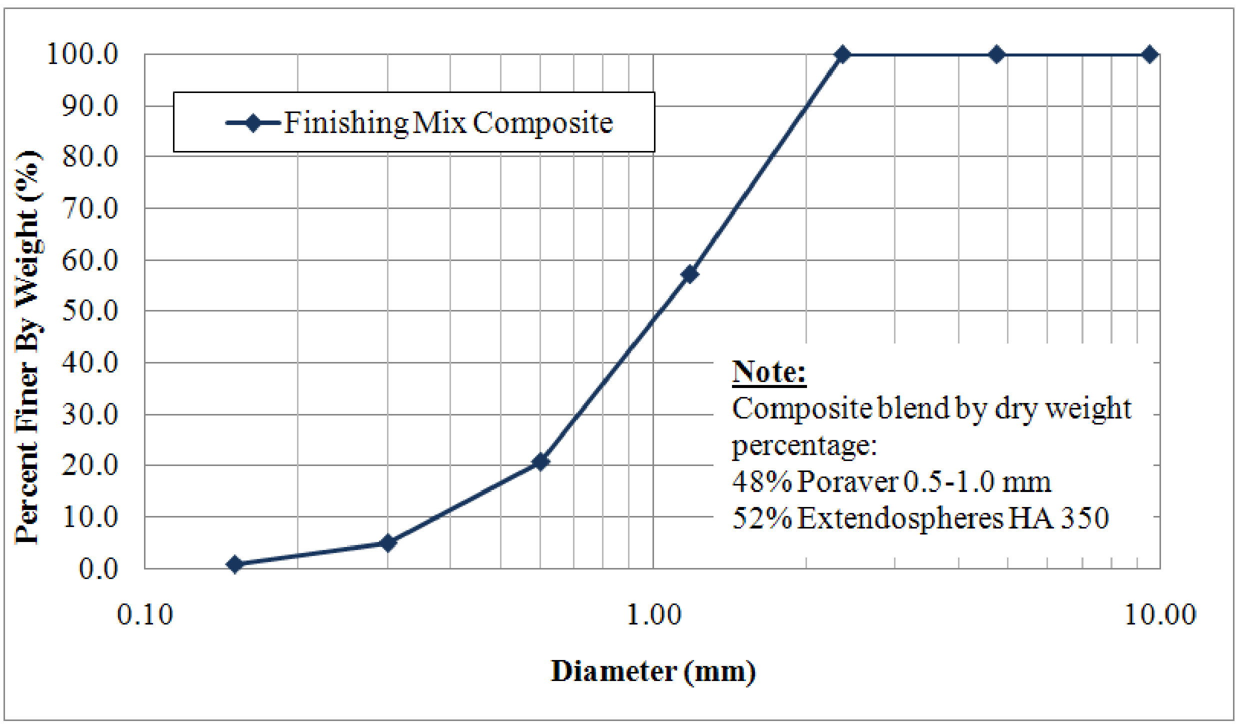


Figure C6: Finishing Concrete Mix Composite Gradation Curve