FRONTIER

Michigan Technological University
Concrete Canoe
2010-2011 Design Paper

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Executive Summary

Michigan Technological University (Michigan Tech) is located in the northern region of Michigan's Upper Peninsula. The combination of the University's location and the team's forward-thinking attitude coincide with the state of Alaska's official slogan, "North to the Future." Michigan Tech's Concrete Canoe team took this motto, which resembles the University's slogan, "Create the Future," as a battle cry of its own. Furthermore, as tribute to the team's advisor – who spent 33 years in Alaska – the team chose an Alaskan theme for this year's concrete canoe.

The team learned that Michigan Tech had much in common with the state of Alaska including a fierce winter climate and low population density. Thus there are many shared interests, particularly in the team's favorite outdoor activities such as ice fishing, snowmobiling, and skiing, among many others. The team was fascinated by the native Tlingit art which is featured prominently on the exterior of this year's canoe. The vast forests inspired a cabin-like display area with many hours devoted to chopping and debarking timber before construction could begin. The team also learned from a local craftsman how to craft a totem pole and found a competitively-used dogsled to use as a display prop. The awe-inspiring natural beauty of Alaska was incorporated into every aspect of the team's design.

The Michigan Tech Concrete Canoe team has been participating in the North Central Conference since 1978 and has represented the conference at the national level eleven times, achieving fourth place in last year's competition. This year's most significant innovations were within the areas of empirical stress analysis and reinforcement design. Strain gages were used during dynamic testing to find stresses along the entire length of the competition's standardized hull. This involved a large commitment of time and energy, however the results of the analysis allowed for a truly engineered reinforcement scheme which completely justified the investment. With an Alaskan theme and many new innovations, the team is proud to present its 2010-2011 canoe, **FRONTIER** (see Tables 1 and 2 for canoe details).

Table 1: Canoe Characteristics

Name	FRONTIER
Weight	159 lbs
Length	20 feet
Width	31 3/16 inches
Depth	16 inches
Nominal Thickness	3/8 inch
Main Color	White
Complimentary Colors	Red, Light Blue, Light Green

Table 2: Canoe Engineering Properties

Unit Weight	56.47 pcf
28-day Compressive Strength	1,026 psi
28-day Tensile Strength	389 psi
Site-Specific Reinforcement	Chromarat C-Grid® CT275 Carbon Fiber Grid
Fiber Reinforcement	Nycon Kuralon™ RF4000 and RECS15 Polyvinyl Alcohol Fibers

Analysis

Michigan Tech returned home from the 2010 National Concrete Canoe Competition™ wondering about the accuracy of the team's Finite Element Analysis (FEA) and what the most critical loading scenario actually was. The team cast a prototype canoe and created a detailed plan to answer these questions.

This prototype canoe, *Ursula*, was designed to test the possibility of using minimal reinforcement. The team theorized that its concrete mix alone had reached a level where the tensile strength was able to withstand the stress calculated in the FEA. To maintain a tensile factor of safety of two, a four-inch strip of mesh reinforcement was placed along the upper edge of each gunwale in accordance with last year's FEA output. Minimal reinforcement eased placement, allowing trowelers to achieve a nominal hull thickness of 3/8 inches. With the reduced amount of concrete placed in *Ursula*, the canoe weighed 116 pounds.

While testing *Ursula*, a crack formed beneath a paddler, flooding the canoe. The team's extensive review of the failure discovered two flaws in the prototype: poor quality control procedures and an error in the punching shear analysis. After cutting *Ursula* into six-inch wide cross sections, the team found that certain areas had been cast too thin. The second flaw was within the team's FEA, which overlooked the concerns of punching shear stress. The loading area of the paddler weight was too large which skewed the punching shear results.

After *Ursula* broke, the team shifted its focus to determining the canoe's punching shear stress during race conditions. An exact modulus of elasticity (Young's modulus) of the team's reinforced concrete was needed to determine the stress on the canoe. Testing was performed using an adaptation of ASTM C469 for this year's concrete mix, Kodiak, as well as the 2008-2009 concrete mix, Accretion, which was used in both *Ursula* and **POLARIS**, the team's 2009 canoe. Kodiak produced an average Young's modulus of 453 ksi, while Accretion had a value of 506 ksi. Knowing the Young's modulus of the team's reinforcement material, Chromarat C-Grid® CT275 Carbon Fiber Grid (C-Grid®), allowed the team to find the strength of the composite material using the rule of mixtures. This rule relies on the volume fraction between the reinforcement material and the concrete around it to find the reinforced concrete's modulus of elasticity. As the thickness ratio between the concrete and reinforcement decreases, the Young's modulus increases. Applying this rule, the Young's modulus of **POLARIS**'s 3/5-inch reinforced concrete was found to be 896 ksi whereas a 3/8-inch thick, 2x2-foot plate, made from Kodiak, was 1,088 ksi.

To test punching shear stress, the team applied strain gages to the 2x2-foot plate with two layers of reinforcement. Maximum stresses of 330 psi and 310 psi were found under normal loading conditions for a paddler kneeling and sitting, respectively. This test was performed with a typical male paddler, weighing 200 lbs, holding an additional 40 lbs of weight to accommodate for a paddler's dynamic loading factor of 1.2. The team determined the dynamic loading factor after empirical tests showed that a paddler will create an additional downward force equivalent to 20% of their body weight while paddling. Two layers of reinforcement were deemed necessary after a plate with only one layer of reinforcement failed under the same loading conditions.

Last year's FEA results indicated the male sprint as the critical load case. To confirm this, 73 strain gages were placed at key locations on **POLARIS**. After many hours of testing, it was confirmed that **POLARIS** experienced its greatest tensile stress of 85 psi on its outside gunwale 10 feet, 2 inches from the bow during the men's sprint buoy turn as seen in Figure 1.

Through testing, the team found that all canoes have a proportional stress that is dependent on their thickness. Understanding this, the team used the bending moment equation to find the stress in a 3/8-inch thick canoe. The moment was found to be the same for all of the team's canoes. Thus, the team assumed that the second moment of inertia and the distance from the neutral axis are the basis of the factor needed to convert stress from POLARIS to any other canoe. The team found a maximum tensile strength requirement of 135 psi in FRONTIER.

Figure 1: Time-correlated video and testing data helped depict that posting created the highest gunwale stress.

Strain gage testing proved that the FEA was giving higher stress values in different locations than what was actually occurring. The team was confident in its strain gage data and broke away from its tradition of putting two layers of continuous reinforcement throughout the canoe. Thus, the team designed its first-ever site-specific reinforcement scheme.

The team's site-specific reinforcement scheme, as seen in Figure 2, was developed keeping two parameters in mind: stress requirements and constructability. The reinforcement scheme implemented two layers of reinforcement along the entire bottom of the canoe to accommodate for punching shear.

At the location of the paddlers in the men's and women's sprint races, one layer of reinforcement wraps up the gunwales. This insures that the paddlers will not break the gunwale while leaning against it during the buoy turn. A second layer of reinforcement was then run up the gunwale at midship to account for the increase in stress in the chines. Finally, a four-inch strip of reinforcement was placed along the gunwale caps to accommodate for any unforeseen loading scenarios.

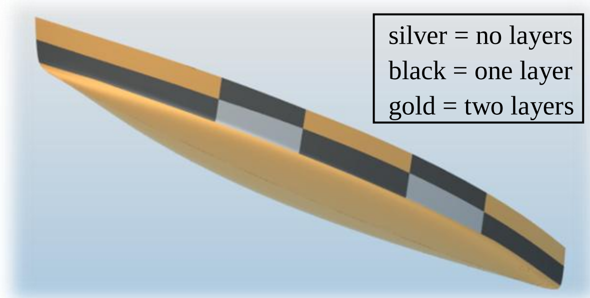


Figure 2: FRONTIER's reinforcement scheme as viewed from below.

Development and Testing

Due to matching hull designs and similar aesthetic demands, the team used the 2009-2010 mix, Kippis, as a baseline for this year's mix, Kodiak. Kippis was also chosen for its low unit weight and ample strength. Upon receiving this year's rules, the team commenced material research and testing. The team used a five-tier system to adjust binders, aggregates, fibers, water to cementitious materials ratio (w/c), and admixtures. These tiers are referred to as I, II, III, IV, and V, respectively.

During testing, one aspect of each batch was changed while all other variables were held constant. Kodiak was deemed adequate after 66 mixes were tested. The team based its final material selection on recycled content, availability, unit weight, and cost while ultimately considering the strength requirements established from the empirical test results.

The team tested binders while researching new sustainable aggregates. Tier I testing began using various ratios of Type I White Portland Cement, vitreous calcium aluminosilicate (VCAS™) 8 and 160 white pozzolans, and grade 120 ground granulated blast-furnace slag (GGBFS). Other binders were eliminated due to being dark in color before testing began; the final binder ratio was based on strength and workability.

Since the 2010-2011 rules require a minimum of two different sustainable aggregates, tier II began with the team searching for a recycled aggregate that could complement Poraver® glass spheres (a post-consumer recycled product). The team looked into recycled rubber, glass, concrete, foam, slag, and cork. Due to concerns regarding specific gravity, glass and concrete were eliminated. Foam, rubber, and cork were dismissed based on low strength characteristics. Despite being dark in color and heavy, Lafarge True Lite Lightweight Aggregate™ was chosen as a second recycled aggregate because of its strength. Ultimately, the aggregates used in Kodiak were Poraver® glass spheres, Lafarge True Lite Lightweight Aggregate™, and 3M™ K-1 microspheres.

While tiers I and II were being tested, fiber testing was also conducted. Loose-strand fiber reinforcement was deemed necessary for additional tensile strength. Prior knowledge indicated that workability would be compromised if fibers were too long or used in excess. Nycon Kuralon™ RF4000 (30mm) and RECS15 (8mm) polyvinyl alcohol (PVA) fibers were selected for the final mix in a 2:1 ratio, respectively, as the optimal workable blend.

In tier IV, the team experimented with the amount of water in each mix to optimize unit weight, strength, and workability. After testing 0.35, 0.40, and 0.45 w/c ratios, 0.35 was determined to yield the best combination of these characteristics.

With regards to tensile strength and unit weight, the top two mixes from tiers I and II were mixed with the fiber blend found in tier III and the w/c ratio from tier IV. Finally, admixtures were adjusted to further complement the final mix. The selection process relied on the compatibility of the admixtures with the proportions of the other concrete components. Xypex Xycrylic-Admix was used for its waterproofing quality, ability to reduce shrinkage, and to allow for an ambient cure; no dosage was specified by the manufacturer. A high-range water-reducer (HRWR), BASF Glenium® 3030 NS, was chosen to boost the workability of the mix while retaining the w/c ratio and consequently, the strength of the mix. To achieve the necessary workability, the HRWR manufacturer recommended 3-8 fl oz/cwt dosage was exceeded.

Six 2x4-inch cylinders were made for each batch tested. Compressive testing was performed in compliance with ASTM C39 and split-tensile tests were completed in accordance with ASTM C496. After numerous weeks of mixing and testing, the team found Kodiak to have ideal strength and unit weight properties, producing 1,026 psi in compression, 389 psi in tensile, and a unit weight of 56.47 pcf. Final structural mix components are shown in Appendix B.

In addition to Kodiak, a concrete finishing mix and an inlay/outlay mix were developed. The finishing mix was designed to optimize the canoe's surface for staining while the inlay/outlay mix was designed for vibrant color and ease of placement. During aesthetic mix testing, binders were held constant from the structural mix to maintain color. The team decided that Poraver® 1.0-2.0mm glass spheres were detrimental to aesthetic demands and excluded them from the mixes. Instead, the team used Poraver® 0.25-0.5mm and 0.5-1.0mm glass spheres in the inlay/outlay mix and Poraver® 0.25-0.5mm glass spheres in the finishing mix. Sieved Lafarge True Lite Lightweight Aggregate™ was used in both mixes to meet the required number of sustainable aggregates. Fibers were excluded from both mixes as they decreased workability and detracted from a uniform finish. The manufacturer recommended dosage of HRWR was exceeded to increase the workability of the mixes. After the binders, aggregates, and admixtures were chosen, Direct Colors pigments were tested in various amounts and combinations with the inlay/outlay mix.

Once final mixes were determined, the team focused on selecting a mesh reinforcement. Based on prior knowledge, the team chose Chromarat C-Grid® CT275 Carbon Fiber Grid as its primary reinforcement. This material has a percent open area of 84.75%, Young's modulus of 34,500 ksi, and a yield stress of 325 ksi. The reinforcement was cast into 2x2-foot plates and strain gages were applied to accurately determine the punching shear that the reinforced concrete could withstand.

Knowing that the reinforced concrete in a canoe will experience an out-of-plane bowing effect as paddlers exert pressure on the bottom, it can therefore, be deduced that the concrete would fail first. If this were to happen, water would begin seeping into the canoe, jeopardizing the paddlers' safety and the canoe's survivability. Understanding this, the team set the baseline for the factor of safety to be the concrete's tensile strength.

The team's strain gage analysis of the stresses in **POLARIS** revealed that previous years' FEAs had been overstating the normal in-plane stress while the punching shear stress was vastly underestimated. Table 3 shows the tensile stress created by paddlers kneeling and sitting during a normal loading scenario. A minimum factor of safety of 1.18 ensures that the concrete, under normal loading conditions, possesses adequate strength.

When designing Kodiak, it was determined that the critical factor of safety was dependent on the punching shear created by a kneeling paddler. In previous years the concrete's limiting factors of safety were the in-plane compressive and tensile stresses. However, the analysis this year concluded that both stresses were less than 150 psi. Comparing these values to the strength of Kodiak proved to the team that these were not the concrete's limiting factors of safety.

Table 3: Critical Material and Engineering Properties

	Kneeling Loading Conditions	Sitting Loading Conditions
Kodiak Plate Tensile Stresses (psi)	330	310
Kodiak/FRONTIER 28-day Tensile Strength (psi)	389	389
Factor of Safety	1.18	1.25

Project Management and Construction

As in years past, the team was led by both a senior and junior co-captain. Throughout all portions of the project, the team was overseen by a safety chair. To ensure all rules and regulations were met, a compliance chair was also appointed. The team was then split into three major categories: construction, engineering, and competition. The most important facets were led by experienced members of the team with an emphasis on interaction between newer and older members. This ensured knowledge could be passed down and increase potential for success in future years. More information can be found in the organization chart on page 7.

At the beginning of the academic year, the team participated in a general safety course lead by Michigan Tech's Civil and Environmental Engineering Department safety coordinator. This familiarized all team members with safety equipment, material safety data sheets, fire extinguishers, exit routes, and proper emergency contact information. The team's safety chair also explained proper power equipment use and care. An emphasis was made on using personal protective equipment when working on tasks related to testing and construction. In addition, the team's facility and construction methods were inspected by the University Health and Safety Department as a proactive safety measure.

The team was fortunate to have a majority of supplies and materials donated from affiliated sponsors. While this significantly reduced the costs for canoe design and construction, a strong emphasis remained on team fundraising. Donated materials were estimated to be $12,000, while the team has had to spend $3,000 on remaining necessary materials. Travel and competition expenses are estimated to be $6,000, due largely to both Michigan Tech's location relative to the North Central Conference competition and its large team size.

The team, comprised of 30 members, holds the belief that all members who contribute deserve to attend the competition. The Bill of Materials for FRONTIER can be found in Appendix C.

This year, the team spent an unprecedented amount of time on testing, research, and development, resulting in adjustments to the rest of the project schedule. This meant that the canoe could not be cast until early January.

To meet the demands of analysis and design, material decisions and procurement had to be completed early in the academic year. Material acquisition took place as soon as the competition rules were released, using remaining funds from the previous year. Mix testing commenced using residual and newly purchased materials.

Milestones were activities that completed a major segment of the project. These were determined using the 2009-2010 project schedule and are shown in Table 4. The milestones are indicated with a star on the project schedule, seen on page 8. These were met through hard work, commitment, and the guidance of project managers.

Table 4: Milestone Activities

Final Theme Decision – 10/13/10
Structural Mix Design Selection – 11/30/10
Final Analysis Results – 12/16/10
Reinforcement Selection – 12/16/10
Concrete Placement – 1/9/11
Determination of Paddlers – 2/10/11
Design Paper Submittal – 2/28/11
Display Components Complete – On Track
Finishes Complete – On Track
North Central Conference Competition – On Track

The critical path was based on any activity that, if not completed by its scheduled date, would postpone completion of the entire project. These activities are shown in Table 5 and can also be seen on the project schedule in red. To complete all of these tasks, the team worked 3,200 man-hours on development and testing, 118 man-hours casting FRONTIER, and is projected to spend 475 man-hours applying finishes.

The team was able to order a CNC milled, female-style mold made from 10% pre-consumer recycled high-density polystyrene foam. The mold was received in two sections – cut in half along the keel. Two layers of epoxy were applied to each section for the purposes of providing a stiff surface for concrete placement as well as creating a barrier to prevent water loss through the foam.

Table 5: Critical Path Activities

Analysis
Analysis Results
Reinforcement Selection
Procurement of Reinforcement
Pre-Cutting Reinforcement
Concrete Placement
Initial Cure with Mold
Sanding
Inlays, Outlays, and Staining
Sealing
Finishes Complete

After the epoxy set, the sections were put together and fastened by lining up the edges and attaching the mold to a rigid frame. This can be seen in the design drawing located on page 9. Holes were drilled at increments of eight inches along the keel, chines, and gunwales to enable the reinforcement to be anchored on casting day. Before casting, Huron Technologies Release Coating 7572 was applied. Manufacturer specifications state that the release agent is designed for use between concrete and epoxy surfaces for an aesthetically-appealing result.

Prior to and during casting day, the facility and materials were cooled and maintained at temperatures between 40°-50°F in order to retard the initial set of Kodiak. On casting day, three 1/8-inch layers of concrete were placed with two layers of C-Grid® CT275 site-specific reinforcement. Slump, unit weight, temperature, and air content were all measured during concrete placement in accordance with ASTM standards. Hull thickness was vigilantly monitored using custom depth gages at one-eighth, one-fourth, and three-eighths of an inch to correlate between the three layers of concrete.

Following completion of casting, the team began sanding the interior of the canoe after seven days of ambient curing. The canoe was de-molded after 14 days and outlays were placed soon after. A finishing mix was applied to both the interior and exterior of FRONTIER to finalize its smooth surface. Water-based stains were then used to enhance the overall aesthetic appeal. The canoe and school names were added using an inlay/outlay technique. Finally, a high-gloss sealer was applied to increase aesthetic appeal.

Innovation and Sustainability

This year, the team strived towards innovative and sustainable features, including additional testing procedures and new recycled materials. Through empirical testing, the team found the actual stresses and determined the most critical loading scenario of a canoe. These design uncertainties have perplexed competitors in the past.

The team used 73 strain gages placed at key locations along POLARIS (see Figure 3) to disprove the coinciding FEA scheme and determine the most critical loading scenario. To capture data from full scale races, the strain gages were connected to Narada transmitters. These transmitters, created by a professor at Michigan Tech, could capture and store six minutes of data before relaying the data to a computer on shore. The team performed extensive tests to definitively find the most critical loading scenario. As a result of these tests, the team created a site-specific reinforcement scheme after many years of using continuous reinforcement.

Another innovation this year was not using aggregate on the mold along the gunwales. In years past, this was done to assist with troweling on casting day. This year, during testing and troweling practices, it was concluded that Kodiak did not require the aggregate surface. This reduced the amount of time spent on sanding and finishing.

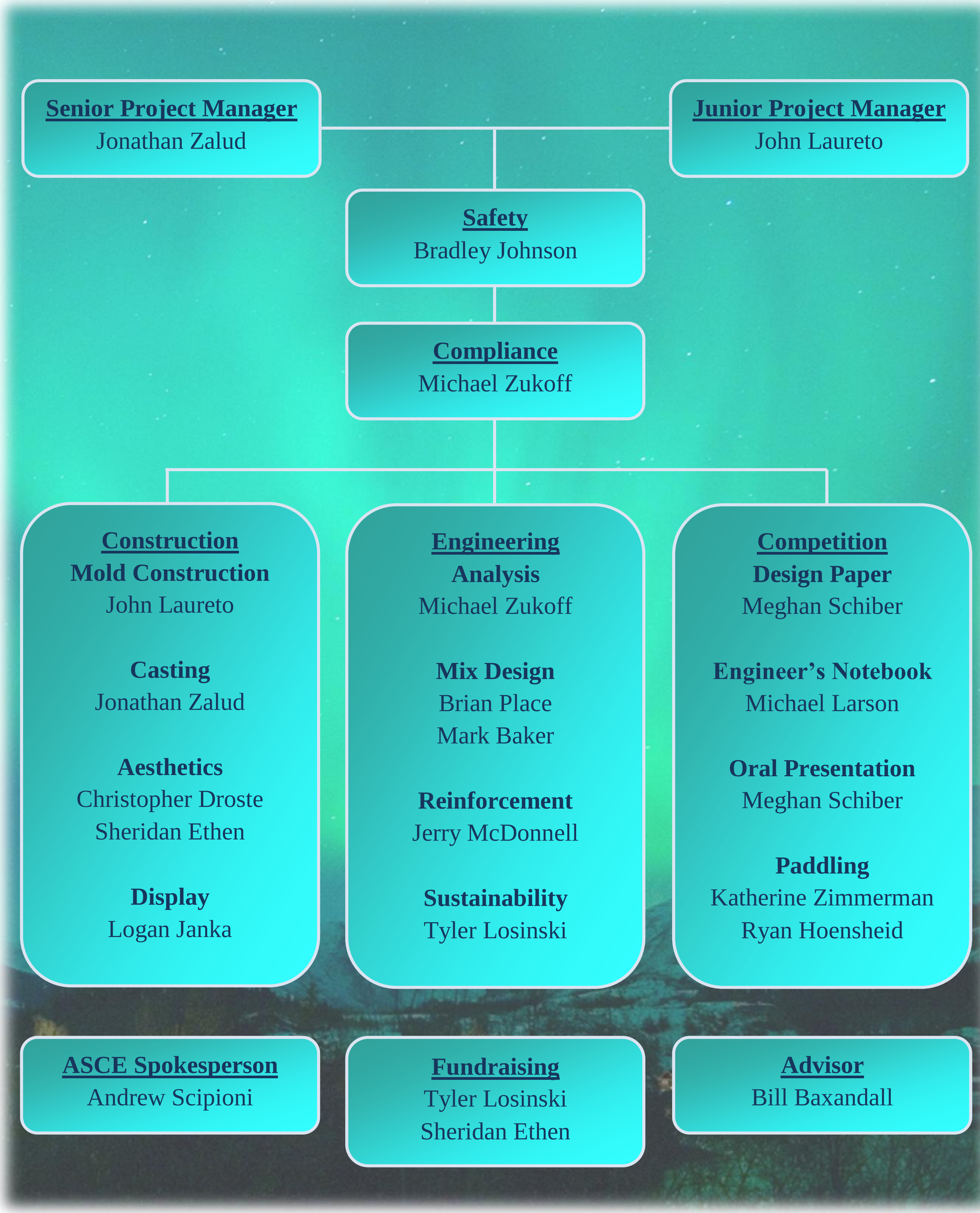
Figure 3: Testing circuits for each of the 73 strain gages on POLARIS.

In terms of sustainability, FRONTIER is composed of 47% by mass and nearly 32% by volume recycled materials. Several of the binders and two of the three aggregate sources are sustainable materials. The team's innovative reinforcement scheme allowed for the quantity of both mesh reinforcement and concrete to be reduced. All materials were used conservatively and reused or recycled whenever possible.

Another sustainable practice was the use of a release aid that was designed to separate concrete from an epoxy surface. This not only allowed for an easy de-molding of the canoe, but also caused no major damage to the mold, enabling the team to reuse this same mold in the future.

The team's effort and attention to detail led to many innovative and sustainable procedures. Less consumed raw material, a more in-depth analysis, a site-specific reinforcement scheme, and a more aesthetically-appealing yet structurally-sound mix all combined to make FRONTIER the best canoe ever produced by Michigan Tech.

Organization Chart



Appendix A – References

ASTM. (2007). "Standard Test Method for Bulk Density ("Unit Weight") and Voids in Aggregate." *C29/C29M-07,* 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 Test Method for Determining Density of Structural Lightweight Concrete."*C567-05a,* 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.

Callister, William D. (2008). "Fundamentals of Materials Science and Engineering: An Integrated Approach." John Wiley & Sons, Inc.

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

Michigan Tech Concrete Canoe. (2010). "Yooper." NCCC Design Paper, Michigan Technological University, Houghton, Michigan.

NCCC Rules. (2011). "2011 American Society of Civil Engineers National Concrete Canoe Competition Rules and Regulations," online at: http://content.asce.org/files/pdf/2011NCCCRules-Final091710.pdf

Appendix B – Mixture Proportions

	Mixture: Kodiak Structural				Design Proportions (Non SSD)		Actual Batch Proportions		Yielded Proportions	
Y_D	Design Batch Size (ft^3):		0.057							
Cementitious Materials				SG*	Amount (lb/yd^3)	Volume (ft^3)	Amount (lb)	Volume (ft^3)	Amount (lb/yd^3)	Volume (ft^3)
CM1	Federal White Type I White Portland Cement			3.15	336.57	1.712	0.70	0.004	345.65	1.758
CM2	Lafarge NewCem® GGBFS			2.99	168.34	0.902	0.35	0.002	172.88	0.927
CM3	VCAS™ 8			2.60	168.34	1.038	0.35	0.002	172.88	1.066
CM4	VCAS™ 160			2.60	168.34	1.038	0.35	0.002	172.88	1.066
	Total Cementitious Materials:				**841.59**	**4.690**	**1.76**	**0.010**	**864.28**	**4.816**
Fibers										
F1	Nycon Kuralon™ RF4000 30mm			1.30	10.53	0.130	0.02	0.000	10.82	0.133
F2	Nycon Kuralon™ RECS15 8mm			1.30	5.27	0.065	0.01	0.000	5.41	0.067
	Total Fibers:				**15.80**	**0.195**	**0.03**	**0.000**	**16.23**	**0.200**
Aggregates										
A1	Poraver® 1.0-2.0mm	Abs:	12.1	0.53	54.25	1.640	0.11	0.003	55.71	1.685
A2	Poraver® 0.5-1.0mm	Abs:	8.0	0.71	54.25	1.225	0.11	0.003	55.71	1.258
A3	Poraver® 0.25-0.5mm	Abs:	6.3	0.88	57.31	1.044	0.12	0.002	58.85	1.072
A4	3M™ K-1	Abs:	22.0	0.12	60.26	7.787	0.13	0.016	61.88	7.997
A5	Lafarge True Lite Aggregate™	Abs:	12.1	2.16	75.32	0.559	0.16	0.001	77.35	0.574
	Total Aggregates:				**301.39**	**12.255**	**0.63**	**0.025**	**309.51**	**12.585**
Water										
W1	Water for CM Hydration (W1a+W1b)			1.00	294.56	4.720	0.62	0.010	302.50	4.848
	W1a. Water from Admixtures^				94.93		0.002		97.49	
	W2b. Additional Water				199.63		0.61		205.01	
W2	Water for Aggregates, SSD			1.00	36.89		0.08		37.88	
	Total Water *(W1 +W2)*:				**331.44**	**4.720**	**0.69**	**0.010**	**340.38**	**4.848**
Solids Content of Latex Admixtures and Dyes										
S1	Xypex Xycrilic-Admix			1.05	112.19	1.712	0.23	0.004	115.22	1.758
	Total Solids of Admixtures:				**112.19**	**1.712**	**0.23**	**0.004**	**115.22**	**1.758**
Admixtures (including Pigments in Liquid Form)				% Solids	Dosage (fl oz/cwt)	Water‡ in Admixture (lb/yd^3)	Amount (fl oz)	Water‡ in Admixture (lb)	Dosage (fl oz/cwt)	Water‡ in Admixture (lb)
Ad1	Xypex Xycrilic-Admix	8.76	*lb/gal*	28.02	204.47	84.77	3.43	0.002	209.98	87.05
Ad2	BASF Glenium 3030® NS HRWR	9.18	*lb/gal*	20.27	21.12	10.16	0.01	0.000	21.69	10.44
	Water from Admixtures (W1a) :					**94.93**		**0.002**		**97.49**
	Cement-Cementitious Materials Ratio				0.40		0.40		0.40	
	Water-Cementitious Materials Ratio				0.35		0.35		0.35	
	Slump, Slump Flow, *in.*				1.00 +/ 0.50		0.50		0.50	
M	Mass of Concrete, *lbs*				1602.41		3.35		1645.61	
V	Absolute Volume of Concrete, ft^3				23.572		0.049		24.208	
T	Theoretical Density, lb/ft^3		= (M/V)		67.98		68.85		67.98	
D	Design Density, lb/ft^3		= (M/27)		59.35					
D	Measured Density, lb/ft^3						60.42		60.42	
A	Air Content, %	= [(T-D)/T x 100%]			12.70		12.24		11.12	
Y	Yield, ft^3		= (M/D)		27		0.056		27	
R_y	Relative Yield		= (Y/YD)				0.974			

Some numbers shown may be off (second and third decimal place) due to the use of Excel spreadsheet (rounding) *Abs. = Absorption (in %)*

** For aggregates, provide ASTM C 128 oven-dry bulk specific gravity* *‡ Water content of admixture*

^ If impact on w/cm is less than 0.01, enter zero

Mixture: Kodiak End Cap

				Design Proportions (Non SSD)		Actual Batch Proportions		Yielded Proportions	
Y_D	Design Batch Size (ft^3):	0.057							
Cementitious Materials			SG*	Amount (lb/yd^3)	Volume (ft^3)	Amount (lb)	Volume (ft^3)	Amount (lb/yd^3)	Volume (ft^3)
CM1	Federal White Type I White Portland Cement		3.15	328.36	1.671	0.70	0.004	330.03	1.679
CM2	Lafarge NewCem® GGBFS		2.99	164.23	0.880	0.35	0.002	165.07	0.885
CM3	VCAS™ 8		2.60	164.23	1.012	0.35	0.002	165.07	1.017
CM4	VCAS™ 160		2.60	164.23	1.012	0.35	0.002	165.07	1.017
	Total Cementitious Materials:			**821.06**	**4.575**	**1.76**	**0.010**	**825.24**	**4.599**
Aggregates									
A1	Poraver® 1.0-2.0mm	Abs: 12.1	0.53	52.93	1.600	0.11	0.003	53.20	1.609
A2	Poraver® 0.5-1.0mm	Abs: 8.0	0.71	52.93	1.195	0.11	0.003	53.20	1.201
A3	Poraver® 0.25-0.5mm	Abs: 6.3	0.88	55.91	1.018	0.12	0.002	56.19	1.023
A4	3M™ K-1	Abs: 22.0	0.12	58.79	7.598	0.13	0.016	59.09	7.636
A5	Lafarge True Lite Aggregate™	Abs: 12.1	2.16	73.48	0.545	0.16	0.001	73.86	0.548
	Total Aggregates:			**294.04**	**11.956**	**0.63**	**0.026**	**295.53**	**12.017**
Water									
W1	Water for CM Hydration (W1a+W1b)		1.00	287.37	4.605	0.62	0.010	288.83	4.629
	W1a. Water from Admixtures^			92.61		0.00		93.09	
	W2b. Additional Water			194.76		0.61		195.75	
W2	Water for Aggregates, SSD		1.00	35.99		0.08		36.17	
	Total Water *(W1 +W2)*:			**323.36**	**4.605**	**0.69**	**0.010**	**325.00**	**4.629**
Solids Content of Latex Admixtures and Dyes									
S1	Xypex Xycrilic-Admix		1.05	109.45	1.671	0.23	0.004	110.01	1.679
	Total Solids of Admixtures:			**109.45**	**1.671**	**0.23**	**0.004**	**110.01**	**1.679**

Admixtures (including Pigments in Liquid Form)				% Solids	Dosage (fl oz/cwt)	Water‡ in Admixture (lb/yd^3)	Amount (fl oz)	Water‡ in Admixture (lb)	Dosage (fl oz/cwt)	Water‡ in Admixture (lb)
Ad1	Xypex Xycrilic-Admix	8.76	*lb/gal*	28.02	204.47	82.70	3.43	0.002	205.51	83.12
Ad2	BASF Glenium 3030® NS HRWR	9.18	*lb/gal*	20.27	21.12	9.91	0.01	0.000	21.23	9.97
	Water from Admixtures (W1a) :					**92.61**		**0.002**		**93.09**

			Design Proportions (Non SSD)	Actual Batch Proportions	Yielded Proportions
	Cement-Cementitious Materials Ratio		0.40	0.40	0.40
	Water-Cementitious Materials Ratio		0.35	0.35	0.35
	Slump, Slump Flow, *in.*		2.00 +/ 0.50	1.50	1.50
M	Mass of Concrete, *lbs*		1547.91	3.32	1555.79
V	Absolute Volume of Concrete, *ft*^{3}		22.807	0.049	22.923
T	Theoretical Density, *lb/ft*^{3}	= (M/V)	67.87	67.87	67.87
D	Design Density, *lb/ft*^{3}	= (M/27)	57.33		
D	Measured Density, *lb/ft*^{3}			58.55	58.55
A	Air Content, %	= [(T-D)/T x 100%]	15.53	13.73	13.73
Y	Yield, ft^3	= (M/D)	27	0.057	27
R_y	Relative Yield	= (Y/YD)		0.995	

Some numbers shown may be off (second and third decimal place) due to the use of Excel spreadsheet (rounding) *Abs. = Absorption (in %)*
** For aggregates, provide ASTM C 128 oven-dry bulk specific gravity* *‡ Water content of admixture*
^ If impact on w/cm is less than 0.01, enter zero

				Design Proportions (Non SSD)		Actual Batch Proportions		Yielded Proportions	
Mixture: Kodiak Finishing									
Y_D	Design Batch Size (ft^3):	0.057							
Cementitious Materials			SG*	Amount (lb/yd^3)	Volume (ft^3)	Amount (lb)	Volume (ft^3)	Amount (lb/yd^3)	Volume (ft^3)
CM1	Federal White Type I White Portland Cement		3.15	395.95	2.014	0.85	0.004	389.91	1.984
CM2	Lafarge NewCem® GGBFS		2.99	247.49	1.326	0.53	0.003	243.72	1.306
CM3	VCAS™ 8		2.60	148.45	0.915	0.32	0.002	146.19	0.901
CM4	VCAS™ 160		2.60	197.97	1.220	0.43	0.003	194.95	1.202
	Total Cementitious Materials:			**989.87**	**5.476**	**2.13**	**0.012**	**974.77**	**5.393**
Aggregates									
A1	Poraver® 0.25-0.5mm	Abs: 6.3	0.88	205.05	3.734	0.44	0.008	201.92	3.677
A2	3M™ K-1	Abs: 22.0	0.12	51.26	6.625	0.11	0.014	50.48	6.524
A3	Lafarge True Lite Aggregate™	Abs: 12.1	2.16	85.40	0.634	0.18	0.001	84.10	0.624
	Total Aggregates:			**341.71**	**10.993**	**0.73**	**0.024**	**336.50**	**10.825**
Water									
W1	Water for CM Hydration (W1a+W1b)		1.00	346.45	5.552	0.74	0.012	341.17	5.467
	W1a. Water from Admixtures^			144.42		0.00		142.22	
	W2b. Additional Water			202.03		0.74		198.95	
W2	Water for Aggregates, SSD		1.00	34.53		0.07		34.00	
	Total Water *(W1 +W2)*:			**380.98**	**5.552**	**0.82**	**0.012**	**375.17**	**5.467**
Solids Content of Latex Admixtures and Dyes									
S1	Xypex Xycrilic-Admix		1.05	164.96	2.518	0.35	0.005	162.44	2.479
	Total Solids of Admixtures:			**164.96**	**2.518**	**0.35**	**0.005**	**162.44**	**2.479**
Admixtures (including Pigments in Liquid Form)			% Solids	Dosage (fl oz/cwt)	Water† in Admixture (lb/yd^3)	Amount (fl oz)	Water† in Admixture (lb)	Dosage (fl oz/cwt)	Water† in Admixture (lb)
Ad1	Xypex Xycrilic-Admix	8.8 *lb/gal*	28.02	255.60	124.64	5.18	0.003	251.70	122.74
Ad2	BASF Glenium 3030® NS HRWR	9.2 *lb/gal*	20.27	34.95	19.78	0.02	0.000	34.42	19.48
	Water from Admixtures (W1a) **:**				**144.42**		**0.004**		**142.22**
Cement-Cementitious Materials Ratio				0.40		0.40		0.40	
Water-Cementitious Materials Ratio				0.35		0.35		0.35	
Slump, Slump Flow, *in.*				4.50 +/ 0.50		5.00		5.00	
M	Mass of Concrete, *lbs*			1877.52		4.04		1848.88	
V	Absolute Volume of Concrete, *ft^3*			24.539		0.053		24.164	
T	Theoretical Density, *lb/ft^3*	= (M/V)		76.51		76.51		76.51	
D	Design Density, *lb/ft^3*	= (M/27)		69.54					
D	Measured Density, *lb/ft^3*					69.75		69.75	
A	Air Content, %	= [(T-D)/T x 100%]		9.12		8.84		8.84	
Y	Yield, ft^3	= (M/D)		27		0.058		27	
R_y	Relative Yield	= (Y/YD)				1.015			

Some numbers shown may be off (second and third decimal place) due to the use of Excel spreadsheet (rounding) *Abs. = Absorption (in %)*

** For aggregates, provide ASTM C 128 oven-dry bulk specific gravity* *† Water content of admixture*

^ If impact on w/cm is less than 0.01, enter zero

Mixture: Kodiak Red Finishing					Design Proportions (Non SSD)		Actual Batch Proportions		Yielded Proportions	
Y_D	Design Batch Size (ft^3):		0.057							
Cementitious Materials				SG*	Amount (lb/yd^3)	Volume (ft^3)	Amount (lb)	Volume (ft^3)	Amount (lb/yd^3)	Volume (ft^3)
CM1	Federal White Type I White Portland Cement			3.15	300.48	1.529	0.64	0.003	303.36	1.543
CM2	Lafarge NewCem® GGBFS			2.99	187.74	1.006	0.40	0.002	189.53	1.016
CM3	VCAS™ 8			2.60	112.64	0.694	0.24	0.001	113.72	0.701
CM4	VCAS™ 160			2.60	150.19	0.926	0.32	0.002	151.63	0.935
	Total Cementitious Materials:				**751.05**	**4.155**	**1.60**	**0.009**	**758.23**	**4.195**
Aggregates										
A1	Poraver® 0.5-1.0mm	Abs:	8.0	0.71	140.96	3.182	0.30	0.007	142.31	3.212
A2	Poraver® 0.25-0.5mm	Abs:	6.3	0.88	253.71	4.620	0.54	0.010	256.13	4.664
A3	3M™ K-1	Abs:	22.0	0.12	28.21	3.646	0.06	0.008	28.48	3.681
A4	Lafarge True Lite Aggregate™	Abs:	12.1	2.16	140.96	1.046	0.30	0.002	142.31	1.056
	Total Aggregates:				**563.84**	**12.494**	**1.20**	**0.027**	**569.22**	**12.613**
Water										
W1	Water for CM Hydration (W1a+W1b)			1.00	262.87	4.213	0.56	0.009	265.38	4.253
	W1a. Water from Admixtures^				94.81		0.00		95.71	
	W2b. Additional Water				168.06		0.56		169.67	
W2	Water for Aggregates, SSD			1.00	50.52		0.11		51.01	
	Total Water *(W1 +W2)***:**				**313.39**	**4.213**	**0.67**	**0.009**	**316.39**	**4.253**
Solids Content of Latex Admixtures and Dyes										
S1	Xypex Xycrilic-Admix			1.05	100.20	1.529	0.21	0.003	101.15	1.544
S2	Red Pigment			8.05	11.41	0.023	0.02	0.000	11.52	0.023
	Total Solids of Admixtures:				**100.20**	**1.529**	**0.21**	**0.003**	**101.15**	**1.544**
Admixtures (including Pigments in Liquid Form)				% Solids	Dosage (fl oz/cwt)	Water‡ in Admixture (lb/yd^3)	Amount (fl oz)	Water‡ in Admixture (lb)	Dosage (fl oz/cwt)	Water‡ in Admixture (lb)
Ad1	Xypex Xycrilic-Admix	8.76	*lb/gal*	28.02	204.62	75.70	2.97	0.002	206.57	76.43
Ad2	BASF Glenium 3030® NS HRWR	9.18	*lb/gal*	20.27	44.48	19.10	0.68	0.000	44.91	19.29
	Water from Admixtures (W1a) **:**					**94.81**		**0.002**		**95.71**
Cement-Cementitious Materials Ratio					0.40		0.40		0.40	
Water-Cementitious Materials Ratio					0.35		0.35		0.35	
Slump, Slump Flow, *in.*					4.00 +/ 0.50		4.50		4.50	
M	Mass of Concrete, *lbs*				1728.48		3.67		1745.00	
V	Absolute Volume of Concrete, *ft^3*				22.391		0.048		22.605	
T	Theoretical Density, *lb/ft^3*	= (M/V)			77.20		77.20		77.20	
D	Design Density, *lb/ft^3*	= (M/27)			64.02					
D	Measured Density, *lb/ft^3*						65.07		65.07	
A	Air Content, %	= [(T-D)/T x 100%]			17.07		15.71		15.71	
Y	Yield, ft^3	= (M/D)			27		0.056		27	
R_y	Relative Yield	= (Y/YD)					0.991			

Some numbers shown may be off (second and third decimal place) due to the use of Excel spreadsheet (rounding) *Abs. = Absorption (in %)*

* *For aggregates, provide ASTM C 128 oven-dry bulk specific gravity* ‡ *Water content of admixture*

^ *If impact on w/cm is less than 0.01, enter zero*

	Mixture: Kodiak Blue Finishing			Design Proportions (Non SSD)		Actual Batch Proportions		Yielded Proportions	
Y_D	Design Batch Size (ft^3):	0.057							
Cementitious Materials			SG*	Amount (lb/yd^3)	Volume (ft^3)	Amount (lb)	Volume (ft^3)	Amount (lb/yd^3)	Volume (ft^3)
CM1	Federal White Type I White Portland Cement		3.15	300.48	1.529	0.64	0.003	304.15	1.547
CM2	Lafarge NewCem® GGBFS		2.99	187.74	1.006	0.40	0.002	190.03	1.018
CM3	VCAS™ 8		2.60	112.64	0.694	0.24	0.001	114.02	0.703
CM4	VCAS™ 160		2.60	150.19	0.926	0.32	0.002	152.02	0.937
	Total Cementitious Materials:			**751.05**	**4.155**	**1.60**	**0.009**	**760.21**	**4.206**
Aggregates									
A1	Poraver® 0.5-1.0mm	Abs: 8.0	0.71	140.96	3.182	0.30	0.007	142.68	3.220
A2	Poraver® 0.25-0.5mm	Abs: 6.3	0.88	253.71	4.620	0.54	0.010	256.80	4.677
A3	3M™ K-1	Abs: 22.0	0.12	28.21	3.646	0.06	0.008	28.56	3.691
A4	Lafarge True Lite Aggregate™	Abs: 12.1	2.16	140.96	1.046	0.30	0.002	142.68	1.059
	Total Aggregates:			**563.84**	**12.494**	**1.20**	**0.027**	**570.71**	**12.646**
Water									
W1	Water for CM Hydration (W1a+W1b)		1.00	262.87	4.213	0.56	0.009	266.07	4.264
	W1a. Water from Admixtures^			94.81		0.00		95.96	
	W2b. Additional Water			168.06		0.56		170.11	
W2	Water for Aggregates, SSD		1.00	50.52		0.11		51.14	
	Total Water *(W1 +W2)*:			**313.39**	**4.213**	**0.67**	**0.009**	**317.21**	**4.264**
Solids Content of Latex Admixtures and Dyes									
S1	Xypex Xycrilic-Admix		1.05	100.20	1.529	0.21	0.003	101.42	1.548
S2	Blue Pigment		2.69	0.31	0.002	0.00	0.000	0.31	0.002
	Total Solids of Admixtures:			**100.20**	**1.529**	**0.21**	**0.003**	**101.42**	**1.548**
Admixtures (including Pigments in Liquid Form)			% Solids	Dosage (fl oz/cwt)	Water‡ in Admixture (lb/yd^3)	Amount (fl oz)	Water‡ in Admixture (lb)	Dosage (fl oz/cwt)	Water‡ in Admixture (lb)
Ad1	Xypex Xycrilic-Admix	8.76 *lb/gal*	28.02	204.62	75.70	2.97	0.002	207.11	76.63
Ad2	BASF Glenium 3030® NS HRWR	9.18 *lb/gal*	20.27	44.48	19.10	0.68	0.000	45.02	19.34
	Water from Admixtures (W1a) :				**94.81**		**0.002**		**95.96**
	Cement-Cementitious Materials Ratio			0.40		0.40		0.40	
	Water-Cementitious Materials Ratio			0.35		0.35		0.35	
	Slump, Slump Flow, *in.*			4.00 +/ 0.50		4.50		4.50	
M	Mass of Concrete, *lbs*			1728.48		3.67		1749.56	
V	Absolute Volume of Concrete, ft^3			22.391		0.048		22.664	
T	Theoretical Density, lb/ft^3	= (M/V)		77.20		77.20		77.20	
D	Design Density, lb/ft^3	= (M/27)		64.02					
D	Measured Density, lb/ft^3					65.24		65.24	
A	Air Content, %	= [(T-D)/T x 100%]		17.07		15.49		15.49	
Y	Yield, ft^3	= (M/D)		27		0.056		27	
R_y	Relative Yield	= (Y/YD)				0.988			

Some numbers shown may be off (second and third decimal place) due to the use of Excel spreadsheet (rounding) *Abs. = Absorption (in %)*

** For aggregates, provide ASTM C 128 oven-dry bulk specific gravity* *‡ Water content of admixture*

^ If impact on w/cm is less than 0.01, enter zero

	Mixture: Kodiak Green Finishing				Design Proportions (Non SSD)		Actual Batch Proportions		Yielded Proportions	
Y_D	Design Batch Size (ft^3):		0.057							
Cementitious Materials				SG*	Amount (lb/yd^3)	Volume (ft^3)	Amount (lb)	Volume (ft^3)	Amount (lb/yd^3)	Volume (ft^3)
CM1	Federal White Type I White Portland Cement			3.15	300.48	1.529	0.64	0.003	302.56	1.539
CM2	Lafarge NewCem® GGBFS			2.99	187.74	1.006	0.40	0.002	189.04	1.013
CM3	VCAS™ 8			2.60	112.64	0.694	0.24	0.001	113.42	0.699
CM4	VCAS™ 160			2.60	150.19	0.926	0.32	0.002	151.23	0.932
	Total Cementitious Materials:				**751.05**	**4.155**	**1.60**	**0.009**	**756.25**	**4.184**
Aggregates										
A1	Poraver® 0.5-1.0mm	Abs:	8.0	0.71	140.96	3.182	0.30	0.007	141.93	3.204
A2	Poraver® 0.25-0.5mm	Abs:	6.3	0.88	253.71	4.620	0.54	0.010	255.46	4.652
A3	3M™ K-1	Abs:	22.0	0.12	28.21	3.646	0.06	0.008	28.41	3.671
A4	Lafarge True-Lite Lightweight Aggregate™	Abs:	12.1	2.16	140.96	1.046	0.30	0.002	141.93	1.053
	Total Aggregates:				**563.84**	**12.494**	**1.20**	**0.027**	**567.74**	**12.580**
Water										
W1	Water for CM Hydration (W1a+W1b)			1.00	262.87	4.213	0.56	0.009	264.69	4.242
	W1a. Water from Admixtures^				94.81		0.00		95.46	
	W2b. Additional Water				168.06		0.56		169.22	
W2	Water for Aggregates, SSD			1.00	50.52		0.11		50.87	
	Total Water *(W1 +W2)*:				**313.39**	**4.213**	**0.67**	**0.009**	**315.56**	**4.242**
Solids Content of Latex Admixtures and Dyes										
S1	Xypex Xycrilic-Admix			1.05	100.20	1.529	0.21	0.003	100.89	1.540
S2	Green Pigment			6.63	2.07	0.005	0.00	0.000	2.09	0.005
	Total Solids of Admixtures:				**100.20**	**1.529**	**0.21**	**0.003**	**100.89**	**1.540**
Admixtures (including Pigments in Liquid Form)				% Solids	Dosage (fl oz/cwt)	Water‡ in Admixture (lb/yd^3)	Amount (fl oz)	Water‡ in Admixture (lb)	Dosage (fl oz/cwt)	Water‡ in Admixture (lb)
Ad1	Xypex Xycrilic-Admix	8.76	*lb/gal*	28.02	204.62	75.70	2.97	0.002	206.03	76.23
Ad2	BASF Glenium 3030® NS HRWR	9.18	*lb/gal*	20.27	44.48	19.10	0.68	0.000	44.79	19.24
	Water from Admixtures (W1a) :					**94.81**		**0.002**		**95.46**
	Cement-Cementitious Materials Ratio				0.40		0.40		0.40	
	Water-Cementitious Materials Ratio				0.35		0.35		0.35	
	Slump, Slump Flow, *in.*				4.00 +/ 0.50		4.50		4.50	
M	Mass of Concrete, *lbs*				1728.48		3.67		1740.44	
V	Absolute Volume of Concrete, ft^3				22.391		0.048		22.546	
T	Theoretical Density, lb/ft^3	= (M/V)			77.20		77.20		77.20	
D	Design Density, lb/ft^3	= (M/27)			64.02					
D	Measured Density, lb/ft^3						64.90		64.90	
A	Air Content, %	= [(T-D)/T x 100%]			17.07		15.93		15.93	
Y	Yield, ft^3	= (M/D)			27		0.057		27	
R_y	Relative Yield	= (Y/YD)					0.993			

Some numbers shown may be off (second and third decimal place) due to the use of Excel spreadsheet (rounding) *Abs. = Absorption (in %)*

** For aggregates, provide ASTM C 128 oven-dry bulk specific gravity* *‡ Water content of admixture*

^ If impact on w/cm is less than 0.01, enter zero

Appendix C – Bill of Materials

Material	Units	Quantity	Unit Price	Amount
Federal White Portland Cement	lbs	57.1	$ 0.27	$ 15.41
Lafarge NewCem® GGBFS	lbs	28.5	$ 0.0054	$ 0.15
VCAS™ 8	lbs	28.5	$ 0.35	$ 9.99
VCAS™ 160	lbs	28.5	$ 0.35	$ 9.99
Poraver® 1.0-2.0mm	lbs	11.8	$ 0.85	$ 10.00
Poraver® 0.5-1.0mm	lbs	8.8	$ 0.85	$ 7.51
Poraver® 0.25-0.5mm	lbs	11.8	$ 0.85	$ 10.00
Lafarge True Lite Lightweight Aggregate™	lbs	14.7	$ 0.003	$ 0.04
3M™ K-1	lbs	11.8	$ 11.03	$ 129.82
Nycon Kuralon™ RECS15 (8mm) PVA	lbs	0.99	$ 6.60	$ 6.53
Nycon Kuralon™ RF4000 (30mm) PVA	lbs	1.98	$ 6.90	$ 13.66
Xypex Xycrylic-Admix	lbs	14.1	$ 5.10	$ 71.95
BASF Glenium® 3030 NS	gal	0.16	$ 15.00	$ 2.38
Chromarat C-Grid® CT275	sq. ft.	105	$ 1.91	$ 200.67
Direct Colors Red Pigment	oz	1.17	$ 0.74	$ 0.87
Direct Colors Light Green Pigment	oz	0.07	$ 0.74	$ 0.05
Direct Colors Light Blue Pigment	oz	0.04	$ 0.74	$ 0.03
Ameripolish Water-Based Concrete Dye Black	gal	0.2	$ 68.95	$ 13.79
Ameripolish Water-Based Concrete Dye Blue	gal	0.1	$ 68.95	$ 6.90
Ameripolish Water-Based Concrete Dye Green	gal	0.05	$ 68.95	$ 3.45
Ameripolish Water-Based Concrete Dye Red	gal	0.1	$ 68.95	$ 6.90
Ameripolish Water-Based Concrete Dye Yellow	gal	0.05	$ 68.95	$ 3.45
ChemMasters Crystal Clear-A	gal	1	$ 22.00	$ 22.00
Huron Technologies Release Coating 7572	gal	0.3	$ 22.50	$ 5.63
Mold	L.S.	1.0	$1,702.10	$ 1,702.10
			Total Production Cost	**$ 2,253.25**