Table of Contents

COMPLIANCE CERTIFICATE

Michigan Technological University's 2010-2011 Concrete Canoe team hereby certifies that the construction and finishing of the canoe, FRONTIER, has been completed in compliance with the rules and regulations set forth by the National Concrete Canoe Competition. Additionally, the canoe has been completely built within the current academic year of the competition. The ten (10) registered participants are qualified, eligible student members and National Student Members of ASCE as specified in the rules and regulations of the National Competition. The team acknowledges that all material technical data sheets (MSDS) have been read by the project management team and acknowledges receipt of the *Frequently Asked Questions* (FAQ).

Registered Members of the 2010-2011 Michigan Tech Concrete Canoe Team

Sheridan Ethen	968665	Chris Droste	1022511
Cassandra Kussow	1020416	Logan Janka	1020420
Carissa Maes	1019863	Brian Place	1019866
Meghan Schiber	1019899	Jonathan Zalud	968666
Ashley Smokoska	968568	Michael Zukoff	936415

Table 1: FRONTIER Characteristics

FRONTIER Dimensions	
Maximum Length	20'
Maximum Width	31.1875"
Maximum Depth	16.0"
Nominal Thickness	0.375"
Overall Weight	164 lbs
Kodiak Structural Mix Properties	
Concrete Density (Unit Weight)	56.47 pcf (905 kg/m^3)
28 - day Compressive Strength	1026 psi (7.07 MPa)
28 - day Tensile Strength	389 psi (2.68 MPa)
Volumetric Air Content	11.12 ft^3
Composite Properties	
28 - day Flexural Strength	240 in-lbs/in (27.12 m-N/m)

We certify that the aforementioned information is valid.

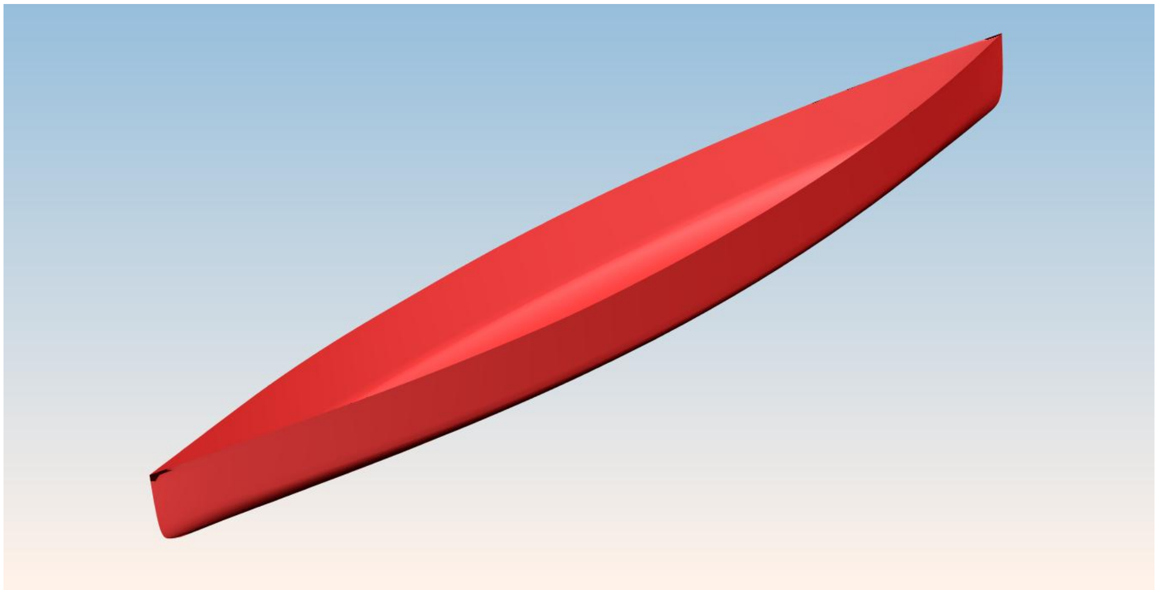
5/7/11 Date

Jonathan W. Zalud
Senior Concrete Canoe Captain
(989) 330-0779
jwzalud@mtu.edu

5/7/11 Date

Frank W. Baxandall
Michigan Tech Concrete Canoe Advisor
(906) 483-2372
fwbaxand@mtu.edu

Mold Construction



After receiving the 2010-2011 canoe dimensions, a Unigraphics model of the canoe was created. The team's CNC milling industry partner used the model to mill the 10% pre-consumer recycled high-density polystyrene mold to the canoe dimensions.

Two coats of epoxy were applied to the interior of the mold.

The two mold pieces were aligned and attached to a custom table top to provide stability during casting.

Exterior inlays were cut from vinyl placemats and secured to the mold using staples.

To prevent the two layers of reinforcement from floating on casting day, approximately one hundred anchor holes were drilled along the mold's gunwales, chines and keel. More details on the anchoring process can be found in the Canoe Construction section, page B-6.

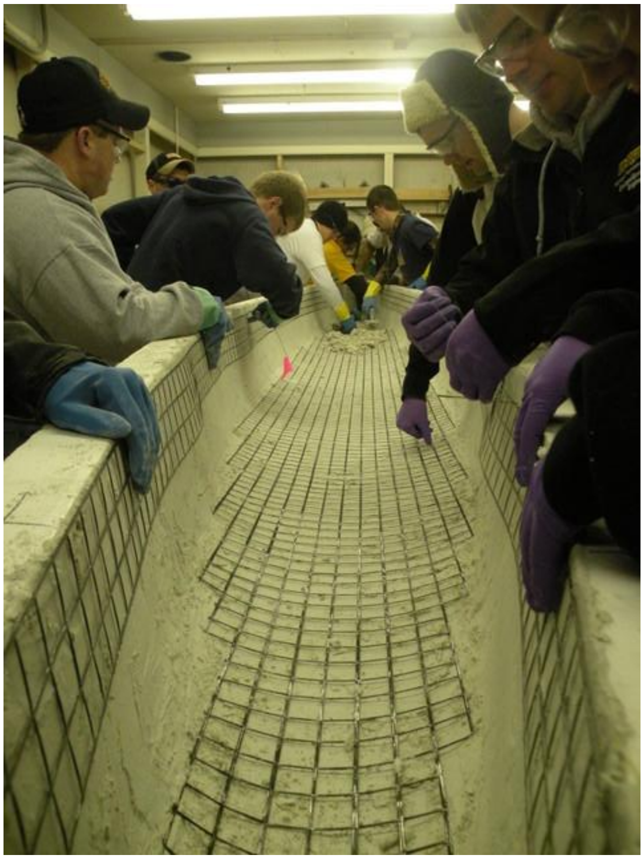
An oil-based release aid was applied to the assembled mold prior to casting.

Canoe Construction

On casting day, a hand drill and mixing paddle were used to mix pre-batched concrete mixes at the rate trowelers were placing. This prevented premature setting of the concrete before it could be troweled and also minimized excess concrete production.

Concrete was troweled onto the mold in three separate layers, each $^{1}/_{8}$" thick. Steel trowels, magnesium floats, and steel hawks aided trowelers in placing the concrete. A quality control supervisor was assigned to each troweler and used custom depth gauges to monitor the hull thickness.

Throughout the construction of FRONTIER the volumetric air content of the concrete was tested to maintain uniformity.



Two layers of C-Grid® CT275 reinforcement separated the three layers of concrete. The first layer of reinforcement consisted of an elliptical pattern on the bottom of the hull, and a linear pattern along the top third of the gunwales. The second layer of reinforcement embodied the interior of the canoe at the bow, mid-ship, and stern with small sections of reinforcement lining the bottom of the hull in-between the embodied sections.

To prevent the reinforcement from floating during troweling, the two layers of reinforcement were anchored in key locations. This was done by attaching fishing line to the reinforcement and passing it through the predrilled holes in the mold and casting table. The fishing line was then held down by attaching weights.

End caps were cast into both ends of the canoe for strength and aesthetic appeal.

Finishing Techniques

The exterior of the hull was patched with Kodiak Endcap mix, filling any minor defects and voids formed during the casting and de-molding processes. In addition, both the exterior and interior of FRONTIER's hull were hand sanded to 220 grit.

After sanding the canoe, concrete inlays were placed in the hull by casting pigmented concrete into the voids left by the vinyl placemats. Outlays were then formed on top of the inlays to obtain the Michigan Tech and FRONTIER logos. Outlays were also formed on the inner gunwales to create distinct raised images of the Alaskan Mountains and forests.

Water based stains were applied to both the interior and exterior of the hull to make **FRONTIER** aesthetically pleasing. The exterior designs were created by masking the canoe with tape and cutting out the designs with a knife. The stain was then applied by hand, using varying brush sizes.

The entire canoe was then sealed, completing **FRONTIER**.

Hull Thickness Calculations

Calculations per Section 4.3.1

Annotation

$T_1 := 0.0425\,in$ Thickness of both the first and second layer of reinforcement, C-Grid® CT275, measured in accordance with Section 4.3.1

$T_h := 0.375\,in$ Thickness of the canoe hull

Determine that the reinforcement at any point in the canoe will not exceed 50% of the total hull thickness.

Solution

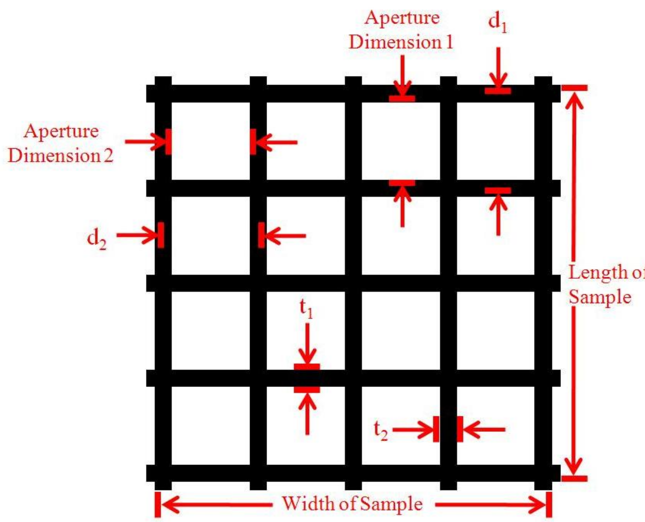
A maximum of two layers of mesh were used in site-specific locations with the hull.

$\frac{2T_1}{T_h} = 22.67\%$ The two layers of reinforcement make up approximately 22.67% of the hull. This value is less than the maximum value of 50% outlined in section 4.3.1, so it is compliant.

Percent Open Area Calculations

Calculations per Section 4.3.2

Sample 1: C-Grid® CT275



Sample of Reinforcement

Given

$n_1 = 4$	Number of apertures along length
$n_2 = 4$	Number of apertures along width
$t_1 = .150$ in	Average thickness of reinforcement along len
$t_2 = .107$ in	Average thickness of reinforcement along wi

Aperture_Dimension_1 = 1.492 in

Aperture_Dimension_2 = 1.482 in

d_1 = Aperture_Dimension_1 + 2*(t_1/2) $d_1 = 1.642$ in — Average spacing of reinforcement (center-to-center) along the sample length.

d_2 = Aperture_Dimension_1 + 2*(t_2/2) $d_2 = 1.589$ in — Average spacing of reinforcement (center-to-center) along the sample width.

Determine Percent Open Area for the first layer of reinforcement, C-Grid® CT275.

Solution

$Lengh_{Sample} = n_1 \cdot d_1$ $Width_{Sample} = n_2 \cdot d_2$

$Lengh_{Sample} = 6.568$ in $Width_{Sample} = 6.356$ in

$Area_{Open} = n_1 \cdot n_2 \cdot$ Aperture_Dimension_1 $\cdot$ Aperture_Dimension_2

$Area_{Total} = Length_{Sample} \cdot Width_{Sample}$

$Area_{Open} = 35.378\ in^2$ $Area_{Total} = 41.746\ in^2$

$POA = (Area_{Open}/Area_{Total}) \cdot 100\%$ $\boxed{POA = 84.75\%}$

The POA is greater than the 40% minimum required, demonstrating compliance.

Technical Data Sheet

ASTM C-150

PRODUCT NAME:
White Portland Cement: Federal White Type I
ASTM Designation C-150

MANUFACTURER:

Federal White Cement
P.O. Box 548
Woodstock, Ontario
Canada
N4S 7Y5

Phone: 800-265-1806
519-485-5410
FAX: 519-485-5892

DESCRIPTION:

Federal White Type I Cement is a true portland cement manufactured with selected raw materials to insure negligible amounts of iron and manganese oxides so as not to produce the gray color of normal portland cement.

BASIC USE:

Federal White Cement can be used for all types of architectural or structural concrete construction where a whiter or brighter color may be needed for aesthetic or safety reasons. Such application as pre-cast panels and systems, cast-in-place, masonry units, tilt-up panel systems, roofing tiles, terrazzo floors, highway median barriers, tile grout, swimming pools, stucco, colored masonry products, cement paints and coatings and ornamental precast concrete items lend themselves to using **Federal White Cement**. **Federal White Cement** may also be used to satisfy low alkali requirements.

INSTALLATION:

Architect should approve the color and surface texture of samples submitted by the contractor or precaster.
Contact **Federal White Cement** for further information or assistance.

TECHNICAL DATA:

Federal White Portland Cement is manufactured to conform to all current requirements of ASTM Designation C-150.

See table for physical properties.

AVAILABILITY AND COST:

Federal White Cement can be shipped to most destinations in the United States and Canada from our manufacturing plant or terminal. Cement shipments can be made by rail or truck in bags or in bulk.

The price, F.O.B. destination, of **Federal White Cement** will be furnished by the manufacturer upon request.

WARRANTY:

Federal White Type I Portland Cement complies with the current ASTM C-150. **Federal White Cement** makes no guarantee or warranty, expressed or implied, including, without limitation, warranties of fitness or merchantability with respect to this product.

MAINTENANCE:

Concrete and other products manufactured with **Federal White Cement** should require no additional maintenance if designed and constructed following proper and accepted procedures.

TECHNICAL SERVICES:

Technical service, consultation, and additional product information are available by contacting **Federal White Cement.**

PHYSICAL PROPERTY	FEDERAL WHITE Typical Type I	ASTM C – 150 Specification Type I
Fineness:		
Specific Surface (sq. m / kg)	400	280 minimum
Setting Time – Vicat		
Minutes	120	
not less than		45
not more than		375
Air Content %	8	12 maximum
Compressive Strength, psi(MPa)		
1 day	2000 (13.8)	--
3 day	3900 (26.9)	1740 (12.0) minimum
7 day	4800 (33.1)	2760 (19.0) minimum
28 day	6500 (44.8)	--

GLENIUM® 3030 NS

Full-Range Water-Reducing Admixture

Description

Glenium 3030 NS ready-to-use full-range water-reducing admixture is a patented new generation of admixture based on polycarboxylate chemistry. Glenium 3030 NS admixture is very effective in producing concretes with different levels of workability including applications that require the use of Rheodynamic® Self-Consolidating Concrete (SCC). Glenium 3030 NS admixture meets ASTM C 494/C 494M requirements for Type A, water-reducing, and Type F, high-range water-reducing, admixtures.

Applications

Recommended for use in:

- Concrete where high flowability, high-early and ultimate strengths and increased durability are needed
- Self-consolidating concrete
- Concrete where normal, mid-range, or high-range water-reduction is desired
- Concrete where normal setting times are required
- 4x4™ Concrete for fast track construction
- Pervious Concrete
- Self-consolidating grout

Features

- Reduced water content for a given slump
- Dosage flexibility for normal, mid and high-range water reduction
- Produces cohesive and non-segregating concrete mixture
- Increased compressive strength and flexural strength performance at all ages
- Providing faster setting times and strength development
- Enhanced finishability and pumpability

Benefits

- Providing economic benefits to the entire construction team through higher productivity and reduced variable costs

Performance Characteristics

Mixture Data: 600 lb/yd^3 of Type I cement (360 kg/m^3); slump, 8.5-9.25 in. (210-235 mm); non-air-entrained concrete; dosage rate adjusted to obtain 25-30% water reduction.

Setting Time

Mixture	Initial Set (h:min)	Difference (h:min)
Plain	4:24	–
Conventional Superplasticizer	6:00	+ 1.36
Glenium 3030 NS admixture	5:00	+0.36

Compressive Strength

Mixture	1 day		7 days	
psi	psi	MPa	psi	MPa
Plain	1700	12	4040	28
Conventional Superplasticizer	3460	24	6380	44
Glenium 3030 NS admixture	4120	28	7580	52

Slump Retention - in. (mm)

Mixture	Minutes		
	15	30	45
Plain	8.5 (215)	8.5 (215)	7.5 (200)
Conventional Superplasticizer	8.5 (215)	4.25 (110)	3.5 (90)
Glenium 3030 NS admixture	9.25 (235)	9.25 (235)	8.25 (210)

Rate of Hardening: Glenium 3030 NS admixture is formulated to produce normal setting characteristics throughout its recommended dosage range. Setting time of concrete is influenced by the chemical and physical composition of the basic ingredients of the concrete, temperature of the concrete and ambient conditions. Trial mixtures should be made with actual job materials to determine the dosage required for a specified setting time and a given strength requirement.

Guidelines for Use

Dosage: Glenium 3030 NS admixture has a recommended dosage range of up to 3 fl oz/cwt (195 mL/100 kg) for Type A applications, 3-6 fl oz/cwt (195-390 mL/100 kg) for mid-range use and up to 18 fl oz/cwt (1,170 mL/100 kg) for Type F applications. The dosage range is applicable to most concrete mixtures using typical concrete ingredients. However, variations in job conditions and concrete materials, such as silica fume, may require dosages outside the recommended range. In such cases, contact your local BASF Construction Chemicals representative.

Mixing: Glenium 3030 NS admixture can be batched with the initial mixing water or as a delayed addition. However, optimum water reduction is generally obtained with a delayed addition.

Product Notes

Corrosivity – Non-Chloride, Non-Corrosive: Glenium 3030 NS admixture will neither initiate nor promote corrosion of reinforcing steel embedded in concrete, prestressed concrete or of galvanized steel floor and roof systems. Neither calcium chloride nor other chloride-based ingredients are used in the manufacture of Glenium 3030 NS admixture.

Compatibility: Glenium 3030 NS admixture is compatible with most admixtures used in the production of quality concrete, including normal, mid-range and high-range water-reducing admixtures, air-entrainers, accelerators, retarders, extended set control admixtures, corrosion inhibitors, and shrinkage reducers.

Do not use Glenium 3030 NS admixture with admixtures containing beta-naphthalene-sulfonate. Erratic behaviors in slump, slump flow, and pumpability may be experienced.

For directions on the proper evaluation of Glenium 3030 NS admixture in specific applications, contact your BASF Construction Chemicals representative.

Storage and Handling

Storage Temperature: If Glenium 3030 NS admixture freezes, thaw at 45 °F (7 °C) or above and completely reconstitute by mild mechanical agitation. ***Do not use pressurized air for agitation.***

Shelf Life: Glenium 3030 NS admixture has a minimum shelf life of 12 months. Depending on storage conditions, the shelf life may be greater than stated. Please contact your BASF Construction Chemicals representative regarding suitability for use and dosage recommendations if the shelf life of Glenium 3030 NS admixture has been exceeded.

Packaging

Glenium 3030 NS admixture is supplied in 55 gal (208 L) drums, 275 gal (1040 L) totes and by bulk delivery.

Related Documents

Material Safety Data Sheets: Glenium 3030 NS admixture.

Additional Information

For additional information on Glenium 3030 NS admixture or its use in developing concrete mixes with special performance characteristics, contact your BASF Construction Chemicals representative.

The Admixture Systems business of BASF Construction Chemicals is a leading provider of innovative admixtures for specialty concrete used in the ready-mixed, precast, manufactured concrete products, underground construction and paving markets throughout the North American region. The Company's respected Master Builders brand products are used to improve the placing, pumping, finishing, appearance and performance characteristics of concrete.

BASF Construction Chemicals
Admixture Systems
www.masterbuilders.com
United States 23700 Chagrin Boulevard, Cleveland, Ohio 44122-5544 ● Tel: 800 628-9990 ● Fax: 216 839-8821
Canada 1800 Clark Boulevard, Brampton, Ontario L6T 4M7 ● Tel: 800 387-5862 ● Fax: 905 792-0651

NSF Certified to NSF/ANSI 61

Master Builders

XYPEX
CHEMICAL CORPORATION

E-MAIL TRANSMISSION

March 1, 2010

To: Ryan Hoensheid

From: Dave Ross – Xypex Chemical Corp.

Re: Confirmation Regarding ASTM C-1438 Type II for Xycrylic Admix

Dear Ryan,

This letter will confirm that Xypex Xycrylic Admix will meet the requirements of ASTM C-1438 Type II and this has been verified per our material supplier, Rohm and Hass.

I hope that this letter takes care of your concerns.

Sincerely,

Dave Ross

Dave Ross
Technical Services Manager

XYPEX

XYCRYLIC ADMIX

DESCRIPTION

XYCRYLIC ADMIX is a water-based, high solids, polymer dispersion specifically designed for fortifying portland cement compositions. This liquid is milky-white in color and improves curing qualities, enhances bond, imparts excellent water and weather resistance, and reduces shrinkage cracking. Xycrylic Admix is also used to fortify Xypex Patch'n Plug.

RECOMMENDED FOR:

- Patching and Concrete Repairs
- Resurfacing Floor Underlayments
- Terrazzo Flooring
- Spray and Fill Coats
- Highway and Bridge Deck Repair

ADVANTAGES

- Hardens and toughens cement mortars for improved durability
- Enhances adhesion capabilities to a wide variety of surfaces
- Increases resistance to many industrial chemicals
- Eliminates water curing

DURABILITY AND STRENGTH

Cement mortars modified with Xycrylic Admix are hard, tough and durable. Compared with unmodified mortars, Xycrylic modified mortars have far superior flexural, adhesive and impact strengths as well as excellent abrasion resistance. They are especially useful where thin sections are desirable and where excessive vibration and heavy traffic is encountered.

ADHESION

Xycrylic Admix modified mortars have excellent adhesion to a variety of surfaces such as concrete, masonry, brick, wood, metals and others.

RESISTANCE PROPERTIES

Cement mortars modified with Xycrylic Admix are resistant to many industrial chemicals as well as ultraviolet light and heat. Mortars containing Xycrylic Admix dry to a uniform color.

PACKAGING

Xycrylic Admix is available in 128 fl. oz. (3.79 litre) and 5 gallon (18.95 litre) bottles.

STORAGE

Keep Xycrylic Admix from freezing.

MIXING

Xycrylic Admix may be used full strength or diluted with clean water depending on application requirements.

TEST DATA

PHYSICAL STRENGTH OF CEMENT MORTARS

ASTM Standard Test Method	Mixing Liquid: Full Strength	1:1 Water	1:2 Water	No Xycrylic	
C-190-85 Tensile Strength	610 (4.2)	440 (3.0)	375 (2.6)	235 (1.6)	psi (MPa)
C-109-88 Compressive Strength	5700 (39.3)	4530 (31.2)	3830 (26.4)	2390 (16.5)	psi (MPa)
C-348-86 Flexural Strength	1570 (10.8)	1130 (7.8)	960 (6.6)	610 (4.2)	psi (MPa)
Shear Bond Adhesion	640 (4.4)	360 (2.5)	260 (1.8)	45 (0.31)	psi (MPa)

Note 1: Strength properties are based on cement mortar prepared as 3 parts sand to 1 part cement by volume.

Note 2: Strengths are based on a 28 day air cure. Wet cure strengths may be less.

XYPEX CHEMICAL CORPORATION

XYPEX®

3 Concrete Restoration 03900
Patching and Resurfacing

APPLICATION PROCEDURES

Xycrylic Admix may be used full strength or diluted with clean water depending on application requirements.

FOR USE WITH CEMENT MORTAR

1. Thoroughly premix sand and cement (1 part cement to 2 parts sand).

2. Blend Xycrylic Admix with water according to strength, bonding and resistance requirements.

3. Add the Xycrylic mixing liquid (whether full strength or diluted with water) to the sand and cement.

4. Mix thoroughly until desired workable consistency is reached. Always withhold some Xycrylic mixing liquid so that the mortar will not be too fluid and so that mixing liquid can be carefully gauged near end of mixing cycle (2 - 4 minutes).

FOR USE WITH PATCH'N PLUG

1. Blend Xycrylic Admix with clean water (1 part Xycrylic to 1 part water by volume).

2. Add Xycrylic mixing liquid to the Patch'n Plug powder at a rate of 1 part liquid to 3.5 parts Patch'n Plug.

3. Mix to a stiff putty consistency. Do not mix more than can be used in three minutes.

CURING

For optimum physical properties, cement mortars modified with Xycrylic Admix should be air-cured at ambient temperature and relative humidity.

TECHNICAL SERVICES

For more instructions, alternative application methods, or information concerning the compatibility of the Xypex treatment with other products or technologies, contact the Technical Department of Xypex Chemical Corporation or your local Xypex representative.

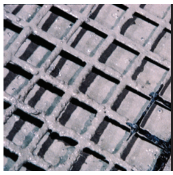
SAFE HANDLING INFORMATION

Xycrylic Admix is alkaline and has a slight ammoniacal odor. This product may be a mild to moderate skin and eye irritant. In addition, many of the components of the cementitious products that are used in conjunction with the Xycrylic Admix may also possess significant skin and eye irritation potential. Directions for treating these problems are clearly detailed on all Xypex pails and packaging. The Manufacturer also maintains comprehensive and up-to-date Material Safety Data Sheets on all its products. Each sheet contains health and safety information for the protection of workers and customers. The Manufacturer recommends you contact Xypex Chemical Corporation or your local Xypex representative to obtain copies of Material Safety Data Sheets prior to product storage or use.

WARRANTY

The Manufacturer warrants that the products manufactured by it shall be free from material defects and will be consistent with its normal high quality. Should any of the products be proven defective, the liability to the Manufacturer shall be limited to replacement of the product ex factory. The Manufacturer makes no warranty as to merchantability or fitness for a particular purpose and this warranty is in lieu of all other warranties expressed or implied. The user shall determine the suitability of the product for his intended use and assume all risks and liability in connection therewith.

13731 Mayfield Place, Richmond, British Columbia, Canada V6V 2G9
Tel: (604) 273-5265 Fax: (604) 270-0451
E-mail: info@xypex.com Website: www.xypex.com



CT275 & CT550

Carbon Fiber Reinforcing Grids for Concrete Décor Products

C-GRID® REINFORCED

DESCRIPTION **C-GRID® CT275 and CT550** are high strength carbon fiber grids for reinforcing concrete countertops and other thin concrete décor products.

FEATURES

- No corrosion or bleed-through
- Minimizes crack width and crack spread
- Grid design and epoxy chemistry provide excellent bond to concrete
- Easier to cut and handle versus welded wire mesh or fabric
- Available in roll form for ease of use
- Greater tensile strength than steel by weight

APPLICATIONS

- Concrete countertops
- Architectural detailing
- Fireplace surrounds and mantels
- Vanity units and bathtubs
- Backsplash walls
- Corporate interiors
- Custom designed products

CT275 GRID PROPERTIES

Composition	carbon fiber and epoxy resin
Color	black
Grid geometry (longitudinal x transverse spacing)	1.5″x 1.5″
Typical longitudinal tensile strength	2,000 lbs/ft
Typical transverse tensile strength	2,000 lbs/ft
Supply form (rolls)	36″x 25 yds

CT550 GRID PROPERTIES

Composition	carbon fiber and epoxy resin
Color	black
Grid geometry (longitudinal x transverse spacing)	1.8″x 1.6″
Typical longitudinal tensile strength	4,000 lbs/ft
Typical transverse tensile strength	4,500 lbs/ft
Supply form (rolls)	47.5″x 25 yds

Notes:

1) Centerline-to-centerline spacing between strands is nominal and based on the average number of strands per unit width. Actual spacing may vary by ± 0.10 inch.
2) The longitudinal direction is in the direction of the roll and the transverse direction is across the width of the roll. For example, if a roll of C-GRID® is 47.5″ wide the carbon strands in the transverse direction are 47.5″ in length. If a roll of C-GRID® is 25 yards long, the longitudinal strands are 25 yards in length.

<u>Application Use Note:</u>
C-GRID® is a relatively new material without the extensive performance history of traditional construction materials. For that reason, it is recommended that C-GRID® not be used in critical life-safety applications or fire-rated structures until additional experience and testing are obtained. Reported properties are average values, not design values. Structures and applications utilizing C-GRID® should be designed using appropriate safety factors or load and strength reduction factors. All applications utilizing C-GRID® should be designed and reviewed by a licensed engineer experienced with FRP materials. The data expressed herein is believed to be accurate at the time of publication; however, it is subject to change without notice.

Chomarat North America C-GRID® REINFORCED

2901 New Pond Road
Anderson, SC 29624

Phone: 864 260-3355
Fax: 864 260-3364
www.chomaratna.com

AMERICAN
DECORATIVE CONCRETE
120 Commercial Ave. Lowell, Arkansas 72745 479.725.0033

Leed IEQ Credit 4.2 requirements state that:

Concrete, wood, bamboo and cork floor finishes such as sealer, stain and finish must meet the requirements of South Coast Air Quality Management District (SCAQMD) Rule 1113, Architectural Coatings, rules in effect on
January 1, 2004.

According to the Table of Standards for VOC limits for Floor Coverings the requirement is that a finish have 100 grams or less of voc content per liter.

Ameripolish Water-Based Concrete Dye contains 1.8-3.7 grams per liter so therefore conforms to the requirements for application in a LEED certified project.

Ameripolish Solvent-Based Concrete Dye contains 0 grams per liter so therefore conforms to the requirements for application in a LEED certified project.

Solids content present in AmeriPolish Water Based Dye is 2.8% by volume.

Alex Darmstaedter
Marketing Manager
American Decorative Concrete Supply Co
alexd@adcsc.com
479-725-0033

Stamped concrete colored with Direct Colors Concrete Pigment dispersed in Antique Release and Tinted Sealer (Photo Courtesy of Decocrete)

1. Product Name
Direct Colors Concrete Pigments

2. Manufacturer
Direct Colors, Inc. (DCI)
430 East 10th Street
Shawnee, OK 74801
(877) 255-2656
(405) 275-6657
Fax: (405) 275-2815
E-mail: info@directcolors.com
www.directcolors.com

3. Product Description
BASIC USE

Direct Colors Concrete Pigment, also known as Integral Color, is designed to color concrete, stucco, plaster, mortar, grout, overlay and other cementitious materials. Integral Colors have been used in thousands of different commercial and residential applications to create beautiful and unique surfaces.

DCI Concrete Pigments are widely used to color cultured and architectural stone, statuary and an assortment of other garden decor.

DCI Pigments are also added to tint concrete sealers and Liquid Antique Release Solutions in order to bring rich color to a variety of indoor and outdoor flooring applications. Additionally, concrete dyes made with DCI Concrete Pigments are applied to existing concrete surfaces that cannot be acid stained or colored by any other means.

COMPOSITION & MATERIALS

Direct Colors Pigments are made from metal oxides of iron, chromium, cobalt or titanium. They are man-made, synthetic, inorganic pigments that are tested to and meet ASTM C979 standards. They do not contain carbon black, or other materials that may be unstable or non-lightfast in many cementitious applications.

SIZES

Direct Colors Concrete Pigments are available in 1 lb (0.5 kg), 5 lb (2 kg), 10 lb (4.5 kg), 20 lb (9 kg), 50 lb (23 kg), 500 lb (227 kg) and 2000 lb (907 kg) quantities. Custom batch quantities are also available.

COLOR

Direct Colors Concrete Pigments deliver superior uniformity in color, strength and lightfastness and are available in over 100 colors. See Tables 1 and 2. Accurate traceability is provided by use of batch identification codes. View visual color representations online at www.directcolors.com.

BENEFITS

- High quality pigments at an affordable price
- Superior customer service and technical support
- Free freight in the lower 48 states
- No minimum orders

ACCESSORIES

- Concrete sealers
- Multipurpose wax
- Concrete dyes
- DCI overlays
- Colored Liquid Antique
- Release agent
- Decorative aggregates
- Stamps and stencils

LIMITATIONS

- Direct Colors, Inc., color charts for integral color/concrete pigments are intended to match what can generally be expected from a final color as closely as possible. However, the color and condition of preexisting concrete will affect the final result of the new concrete color, so color samples are approximations only

Close-up of stamped concrete walkway as shown above (Photo Courtesy of Decocrete)

- Efflorescence, a naturally occurring deposit found on the surface of concrete, is more noticeable on dark colors because of its whitish appearance. Although it will eventually cease, there is no known method to achieve 100% prevention. Efflorescence can quickly be removed by acid washing, but over time, natural weathering will achieve the same effect. See "Reducing Efflorescence" under "Installation" below for techniques to help reduce the occurrence of efflorescence

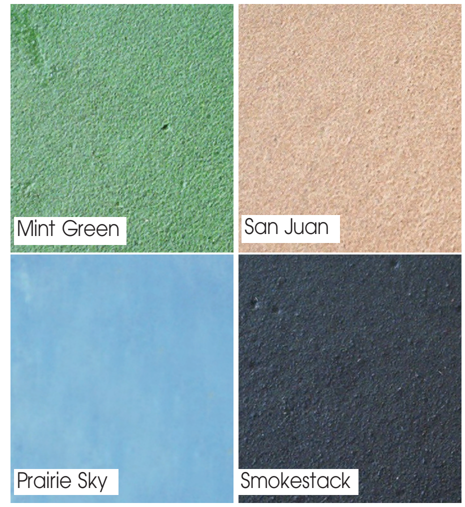
Direct Colors, Inc.

TABLE 1 INTEGRAL COLOR CHART, GRAY CEMENT BASE, TO ASTM C979

Color mixture	Brick Red	Sun Dried Tomato	Merlot	Evening Shadow	Terra Cotta
Pigment type	1835	1835	126	126	560
Pound rating	4 lb	1 lb	3 lb	1 lb	5 lb
Color mixture	Majestic Sunrise	Dawn	Earthen Red	Desert Rouge	Desert Vista
Pigment type	1830	1830	1115	1115	560
Pound rating	4 lb	1 lb	3 lb	1 lb	3 lb
Color mixture	Navajo	Uplands	Caramel	San Juan	Frontier Buff
Pigment type	543	543	543	543	533
Pound rating	5 lb	3 lb	2 lb	1 lb	1 lb
Color mixture	Burnished Copper	Sandstone	Canyon Brown	Santa Fe Tan	Smokestack
Pigment type	553	553	553	533	230
Pound rating	4 lb	1 lb	5 lb	3 lb	5 lb
Color mixture	Weathered Tin	Deep Bronze	Milk Chocolate	Rattan	Golden Buff
Pigment type	230	680	680	609	609
Pound rating	1 lb	3 lb	1 lb	4 lb	2 lb
Color mixture	Cocoa Brown	Walnut	Petrified Wood	Mint Green	Briar Buff
Pigment type	653	649	649	5376	500
Pound rating	3 lb	4 lb	2 lb	3 lb	3 lb
Color mixture	Taupe	Pecan	Maple	Rocky Crag	Wildwood Buff
Pigment type	653	627	627	623	500
Pound rating	1 lb	3 lb	1 lb	3 lb	2 lb
Color mixture	Wheat Buff	Winterfield Buff	Mocha	Tarnished Brass	Sunray
Pigment type	500	1198	623	1311	1311
Pound rating	1 lb	1 lb	1 lb	3 lb	1 lb
Color mixture	Venetian Red	Umber	Slate Blue	Prussian Blue	Sapphire
Pigment type	1880	1880	5151	5151	15.3
Pound rating	5 lb	3 lb	1 lb	3 lb	5 lb
Color mixture	Midnight Blue	Mint Green	Forest Green		
Pigment type	15.3	5376	5376		
Pound rating	5 lb	3 lb	5 lb		

TABLE 2 INTEGRAL COLOR CHART, WHITE CEMENT BASE, TO ASTM C979

Color mixture	Cayenne	Blush	Sequoia	Plum	Fire Rose
Pigment type	1830	1830	126	126	1115
Pound rating	3 lb	1 lb	3 lb	1 lb	3 lb
Color mixture	Morning Mist	Dusty Rose	Wildflower	Terran	Peach
Pigment type	1115	1835	1835	553	553
Pound rating	1 lb	3 lb	1 lb	3 lb	1 lb
Color mixture	Autumn	Leaf Fall	Pumpkin	Sun Dust	October Bronze
Pigment type	560	560	543	543	533
Pound rating	3 lb	1 lb	3 lb	1 lb	3 lb
Color mixture	Sunwashed Clay	New Bark	Everland Buff	Cake Buff	Beachfront Buff
Pigment type	533	623	623	609	609
Pound rating	1 lb	3 lb	1 lb	3 lb	1 lb
Color mixture	Canyon Wall	Cinnamon	Espresso	Pebble	Camel
Pigment type	627	627	653	653	500
Pound rating	3 lb	1 lb	3 lb	1 lb	3 lb
Color mixture	Sunset Tan	Tawny	Cream Beige	Café	Cottage Brown
Pigment type	500	1198	1198	649	649
Pound rating	1 lb	3 lb	1 lb	3 lb	1 lb
Color mixture	Malayan Bluff	Lotus Pond	Crème Mint	Hunter Green	Vineyard
Pigment type	1311	5376	5376	5376	1880
Pound rating	1 lb	3 lb	1 lb	5 lb	5 lb
Color mixture	Vineyard	Mauve	Tea Rose	Prairie Blue	Skye Blue
Pigment type	1880	1880	1880	5151	5151
Pound rating	5 lb	3 lb	1 lb	1 lb	3 lb
Color mixture	Electric Blue	Ultramarine			
Pigment type	15.3	15.3			
Pound rating	3 lb	5 lb			



Colors cast in Gray Cement

4. Technical Data

APPLICABLE STANDARDS

ASTM International (ASTM) - ASTM C979 Standard Specification for Pigments for Integrally Colored Concrete

APPROVALS

Occupational Safety and Health Administration (OSHA) Hazard Communication Standard, 29 CFR 1910.1200

PHYSICAL/CHEMICAL PROPERTIES

- Lightfast
- Alkali and weather resistant
- UV stable
- Non-hazardous
- Color consistent

Colors cast in White Cement

- Chemically inert
- Insoluble in water
- Inorganic
- Synthetic
- Specific gravity - Heavier than water
- Evaporation rate - None
- Reddish-brown appearance
- Odorless

FIRE PERFORMANCE

Direct Colors Concrete Pigments are nonflammable, noncombustible and nonexplosive.

5. Installation

PREPARATORY WORK

Store materials in an area protected from exposure to harmful environmental conditions and at temperature and humidity conditions recommended by the manufacturer.

Verify that site conditions are acceptable for installation. Do not proceed with installation until unacceptable conditions are corrected.

METHODS

Mixing

Color charts and codes are based on pounds of pigment per 94 lb (43 kg) of cement material, including Portland cement, silica fume, fly ash and lime. Sand and aggregates are not used in this ratio. The maximum level of pigment to cement is 10% by weight. Using less than 1% pigment can result in a washed-out appearance. Blue pigments should be mixed dry with any cement-based material to ensure even color distribution.

Stamped walkway colored with Direct Colors Pigment (Photo Courtesy of Mark Douglass)

Swim-up pool bar countertop colored with 1311 Concrete Pigment, English Red Acid Stain and English Red Deco Gel (Photo Courtesy of Susan Turfle)

When an exact color match is required, complete a test pour, mixing the exact ingredients and ratios that will be used onsite. When custom blends are made for countertops, ready mixes, overlays, curbing, mortar, grouts and other concrete based products, the colors hold true within an acceptable range to most users, especially when the mixture has been adjusted to meet the specific needs of the mix and the project application.

Truck Pours

For a standard mix, the simplest method to convert the values on the color chart to a specific pour is to multiply the poundage on the chart by 5 to determine how much pigment per yard is needed. Consistency with the pigment per yard ratio is critical in achieving matching pours. The water level and mix ratios in each load are critical as well. It is essential to know how much concrete is in the truck, not just how much will be poured.

Dispense the pigment in the back of the truck, using the hose to clean the fins and ensuring that no loose pigment remains to cause streaking. Spinning the mix for 10 - 15 minutes is generally sufficient to properly disperse the pigment. Place and work the concrete as normal.

As the concrete sets, the color will appear to fade. This is caused by the concrete dispensing powder on the surface and will be resolved by sealing this in the same way as a decorative concrete would be sealed. Once sealed, the color should be stable and considerably darker than at first appearance pre-seal.

Color Calculator

Color calculators and measurement examples are available at www.directcolors.com to measure required pigment per yard and per custom batch of concrete.

PRECAUTIONS

Safety

- To avoid inhaling dust and contact with face and eyes, wear full face mask, eye protection and rubber gloves
- Avoid contact with inorganic acids
- Wash with soap and water after exposure. Chronic overexposure can cause slight skin irritation

Performance

- For optimal results, use the same brand of cement, aggregates and sand, as well as the same cement to pigment ratio, until project completion
- In order to avoid undesired discoloration, do not use calcium chloride as a set accelerator
- Difference in slump may produce a noticeable difference in color between batches
- Use local exhaust or baghouse for ventilation
- If material is released or spilled, scoop or vacuum the floor and wash with water
- To avoid color variation, be consistent in all stages of the batching, mixing, forming/placing and hardening of concrete

Stairs colored with Direct Colors Black Pigment

Reducing Efflorescence

- Ensure that the aggregate-cement ratio is sufficient to enable the cement paste to completely fill the voids between the aggregate particles after compaction
- To minimize air voids that remain after complete cement hydration, add to the concrete mix only the minimum amount of water needed to achieve required workability
- Select sands and aggregates for the mix design carefully, as appropriate particle size and shape can help to improve mechanical compaction, effectively squeezing air voids and allowing them to be replaced with the cement paste
- There is some evidence that certain cement additives and chemical admixtures can help to inhibit efflorescence. Consult Direct Colors, Inc., for more information
- Ensure concrete cures sufficiently to achieve not only strength, durability and reduced cracking, but surfaces that are as dense as possible to limit the concrete's ability to absorb water
- A variety of concrete coatings, including water and solvent based concrete sealers offered by Direct Colors, are available for application to the surface, blocking pores and forming an impermeable barrier at the concrete's exposed surface. This prevents the movement of water to the surface, restricting the migration of efflorescence forming compounds. Consult Direct Colors, Inc., for more information

BUILDING CODES

Installation and waste disposal must comply with the requirements of all applicable local, state and federal code jurisdictions.

6. Availability & Cost

AVAILABILITY

Products can be purchased at www.directcolors.com, or by calling (877) 255-2656. Products are also available from certified distributors. Contact the manufacturer or check online at www.directcolors.com for local availability information.

COST

Current pricing is available online at www.directcolors.com.

7. Warranty

The conditions of use and application of concrete pigment products are beyond the control of Direct Colors, Inc. Direct Colors makes no warranty regarding workmanship and other variables that do not involve the performance of pigments. Buyer's sole remedy shall be the purchase price paid by the user or buyer for the quantity of the Direct Colors product involved. For details, consult Direct Colors, Inc.

8. Maintenance

None required.

9. Technical Services

Technical assistance, including more detailed information, product literature, test results, project lists, assistance in preparing project specifications and arrangements for application supervision, is available by contacting Direct Colors, Inc. For questions or custom solutions, call (877)-255-2656 or email info@directcolors.com.

10. Filing Systems

- MANU-SPEC®
- Additional product information is available from the manufacturer upon request.

ChemMasters

SPECIALTY CONSTRUCTION PRODUCTS

CRYSTAL CLEAR-A

LOW VOC, SOLVENT-BASED HIGHEST GLOSS SEALER & CURING COMPOUND FOR CONCRETE

P R O D U C T   D A T A

DESCRIPTION

Crystal Clear-A is premium quality, super high gloss, non yellowing, curing and sealing compound. Crystal Clear-A is a state-of-the-art proprietary formulation which creates the highest gloss possible on concrete.

Crystal Clear-A is a solvent based product which meets the VOC requirements of the Ozone Transport Commission, in effect as of Jan. 1st, 2005.

Crystal Clear-A coats concrete with a chemically bonded siliconized acrylic film that deepens the color and enhances the look of pigmented or decorative concrete. Crystal Clear-A completely resists discoloration from ultraviolet light exposure. It keeps its high gloss finish much longer than standard concrete sealers. Crystal Clear-A will retard efflorescence while resisting oil, grease and food stains. Crystal Clear-A eliminates concrete dusting, while protecting concrete against salt and water penetration.

USES

Use on exterior plain, colored, textured or exposed aggregate concrete to

- Cure freshly poured concrete where superior curing efficiency is required
- Seal, harden and dustproof existing concrete, particularly architectural or residential concrete exposed to freeze-thaw or Ultra Violet light.
- Enhance the color and and gloss of pigmented or stamped concrete

ADVANTAGES

- Crystal Clear-A is much tougher than acrylic sealers. The high gloss created by Crystal Clear lasts up to 70% longer.
- Crystal Clear-A completely resists discoloration from ultraviolet light exposure.
- Complies with the VOC standards for concrete sealers in the following states: California, Delaware, New Jersey, New York, Oregon, Pennsylvania, Virginia, Washington and other area that require the VOC limits on curing & sealing compounds to be less than 350 grams per liter
- Crystal Clear-A cures concrete to ASTM C1315 standards to minimize cracking and increase the strength of concrete.
- Protects surfaces against deicing chemicals, fertilizers, salts, grease, oil, alkalies, mild acids and detergents.

TECHNICAL DATA

Crystal Clear-A has been tested for gloss retention and non yellowing against standard concrete sealers with the following results.

Gloss Retention

After 1,000 hours QUV exposure

(All panels begin with 95 gloss rating)

	Gloss	Percent Original
Crystal Clear-A	89.8	95%
Moisture Cure Urethane	79.1	83%
Pure Acrylic	73.6	77%
Styrene Acrylic	55.4	58%

Yellowing Index

After 1,000 hours QUV exposure

Equivalent to approx 10 years of Florida sunlight

(All panels begin with 0 yellow rating)

	Yellowing
Crystal Clear-A	0.00
Moisture Cure Urethane	3.00
Pure Acrylic	4.77
Styrene Acrylic	9.48

(Visable yellowing begins at 3.00)

ChemMasters
An American Owned & Operated Company
300 EDWARDS STREET • MADISON, OHIO 44057-3112
(440) 428-2105 • FAX (440) 428-7091 • ORDER LINE: (800) 486-7866
www.chemmasters.net

Revised March 2006

- ASTM C-1315, Type I , Class A & B,
- ASTM C-309, Type I, Class A & B,
- USDA approved, when cured, for incidental contact

V.O.C. content		350 gr/L	
Moisture retention (ASTM C-156)		0.035 gms/cm^2	
Flash point		over 0ºF (-18ºC)	
Drying time@70ºF (21ºC) and 50% RH			
	Tack free	2 hours	
	Light foot traffic	8 hours	
	Maximum hardness	7 days	

Packaging
Crystal Clear-A is available in 5 gallon (18.9 liter) metal pails and 55 gallon (208 liter) drums.

Estimating Guide
Coverage is dependent upon surface texture and porosity. These are guidelines only

	Ft.^{2}/gal	M^2/L
Curing	300	7
Sealing Concrete		
First Coat	350	8
Second coat	450	11

Directions
Mixing: Do not dilute. Crystal Clear-A is packaged ready to use and requires no mixing.

Application: Always test application in a small area to verify appearance. In cold temperatures (below 50ºF), warm material to room temperature to ease application. In hot weather avoid applying in direct sunlight or in windy conditions. In hot weather, apply Crystal Clear-A early in the morning.

Because Crystal Clear-A dries very quickly, a low pressure, spray application is recommended. A pump up sprayer equipped with a slit-type orifice rated between 0.5 - 1.0 gallons per minute is recommended. If spraying, hold spray tip 6-8 inches from the surface and apply a continuous film leaving no pinholes or gaps. The optimum spray pattern is an 8-12 inch fan. When using a hand pressurized sprayer it is important to maintain as high an air pressure as possible to aid in spraying. Do not allow material to puddle. If roller application is necessary, regularly dip the roller in a solvent like xylene or Polyseal Solvent to keep the roller from drying. If the roller dries out, cob-webbing or stringiness will result.

Curing: Apply Crystal Clear-A after all bleed water has dissipated and application will not mar the surface. For maximum gloss and protection, apply a second sealer coat after curing process is completed (minimum 28 days later).

Sealing: When sealing older concrete, clean concrete thoroughly removing any dirt, dust, paints, oil, grease or other contaminants that prevent adhesion. Allow the surface to dry before application of Crystal Clear-A. For best protection and highest gloss, apply two thin coats of Crystal Clear-A. Allow first coat to dry tack free before application of second coat.

Cleanup
Clean tools immediately after use with Polyseal Solvent™ or xylene.

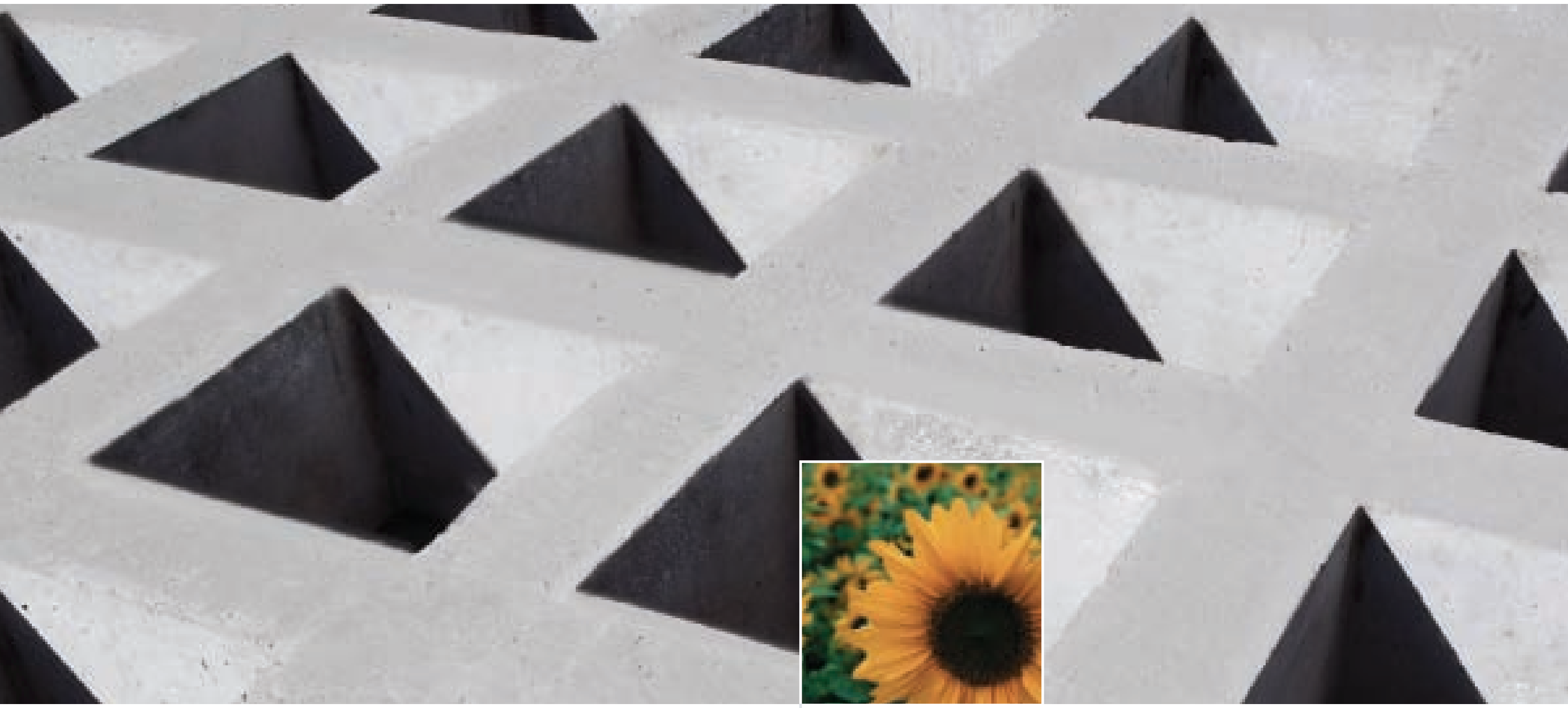
Storage
Store tightly sealed containers in cool, dry area away from direct sunlight and sources of heat. Shelf life is one year from date of manufacture.

Limitations
- Strong organic solvents, xylene, toluene, lacquer thinner, will lift Crystal Clear-A. Gasoline, hydraulic fluids, peanut oil and cooking oils soften and lift Crystal Clear if spills are not removed quickly.
- Do not apply to joints or channels scheduled to receive elastomeric caulks.
- Do not use if ambient or surface temperature is below 40°F (4°C). For best results, condition material to a minimum of 50°F (10°C) prior to application.
- Quality curing or sealing compounds and floor treatments darken or highlight the subtle color variations naturally present in concrete. When the difference in shading caused by absorptive deviation or finishing techniques is objectionable, consult ChemMasters technical staff prior to concrete placement for recommendations.

Caution
Flammable liquid: Keep away from heat or open flames. Use with adequate ventilation. May cause skin, eye and respiratory tract irritation. Do not take internally.

This Product is Formulated and Labeled for Industrial and Commercial Use Only

FOR BEST RESULTS AND SAFEST USAGE, USER IS SPECIFICALLY DIRECTED TO CONSULT THE CURRENT MATERIAL SAFETY DATA SHEET AND PACKAGE LABEL FOR THIS PRODUCT



LAFARGE

NewCem® Slag Cement

Provides flexibility in concrete proportioning to assist in achieving:

Reduced Permeability

Reduced Ingress of Chlorides

Sulfate Resistance

Resistance to Alkali Silica Reaction

Greater Strength Potential

Lower Temperatures for Mass Concrete

Improved Workability

A Lighter, More Pleasing Color

Reduced Impact on the Environment

LAFARGE

Lafarge NewCem® slag cement is a finely ground, granulated blast furnace slag (GGBFS), a product of the iron-making process. Through our extensive distribution system, NewCem is available for blending with conventional portland cement at the concrete plant to produce high-quality, durable concrete.

Front cover photo:
NewCem was used to construct the thick walls and floor of the Peel Reservoir which serves the Regional Municipality of Peel, Ontario.

Slag is produced during the iron-manufacturing process. During the manufacturing process the materials are heated in a blast furnace to a molten state. The slag rises to the top and is separated from the iron for further processing. When slag is separated from iron and rapidly cooled with water (granulated), the morphology of the slag changes. This morphology change provides the slag with its cementitious properties. The granulated slag is then ground to a controlled fineness, typically greater than that of Type I portland cement, and the finished product is ready for shipment to our customers.

The NewCem® Slag Cement Advantage

To produce top-quality slag, a producer needs to have slag with an ideal chemistry from a consistent source and needs to have a granulator close to the slag source to provide rapid quenching of the slag. Lafarge plants have been designed with these criteria in mind.

Lafarge engineers and scientists have led North America in the research and development of specifications for slag. Today, Lafarge's knowledge and technical experience is unequaled by any other producer of GGBFS. Lafarge's technical staff is available to ready-mixed concrete producers, engineers and specifiers for questions about the proper use of NewCem in any application.

NewCem® Slag Cement and the Environment

NewCem is a product derived from the iron-making process. It makes use of by-product material that might otherwise be landfilled. The use of NewCem in concrete saves virgin raw materials that would otherwise be needed for the production of portland cement. NewCem also requires less energy to produce than portland cement, so the amount of greenhouse gases released into the environment is reduced when NewCem partially replaces portland cement in concrete. The result is superior concrete with less environmental impact.

U.S. GREEN BUILDING COUNCIL MEMBER

CANADA GREEN BUILDING COUNCIL • CONSEIL DU BÂTIMENT DURABLE DU CANADA • MEMBER / MEMBRE

Lafarge NewCem provides a significant contribution to sustainable construction. The use of NewCem in concrete production consumes less energy and offers improved efficiency and building performance. NewCem can also be used to help achieve LEED (Leadership in Energy and Environmental Design) points in the USGBC's (U.S. Green Building Council) and CaGBC's (Canada Green Building Council) LEED programs.

Advantages of Lafarge NewCem® Slag Cement

Hartsfield International Airport, Atlanta, Georgia

Strength

When properly used, NewCem can increase the 28-day strength of the concrete by 5 to 25 percent. The highest strength increases are found when the replacement level approaches 50 percent. High strength for concrete subjected to repeated flexural loads is critical for the long-term service life of highways, roads and airfield runways. NewCem provides strength and enhances the placeability and finishing characteristics of low-slump concrete. NewCem can also improve the consistency of concrete strengths. Most fluctuations in concrete strengths occur in the summer when high temperatures can cause slump loss and increased water demand. NewCem naturally retards the initial setting time of concrete, which leads to more consistent strengths.

Durability

Long-term durability is a recognized need for all concrete structures. Concrete durability is affected by such variables as strength, permeability, consistency, resistance to extreme environmental conditions and resistance to chemical attack. When properly used, NewCem can increase the durability of concrete by improving resistance to sulfate attack, mitigating alkali silica reactions, reducing concrete permeability and decreasing concrete temperatures. NewCem's ability to dramatically increase the durability of concrete makes it an ideal ingredient for high-performance concrete. Many state DOT's have specified NewCem for their high-performance concrete mixes.

Permeability

A concern with concrete structures exposed to de-icing salts is deterioration of the structure due to salt-induced corrosion of the reinforcing steel. When reinforcing steel corrodes, it takes up more volume than the original steel. This places the concrete around the reinforcing steel in tension. Because concrete tensile strength is about 1/10 of the compressive strength, the corroding steel can cause the concrete to crack. Once a crack develops, chlorides or other aggressive agents are provided a path to the reinforcing steel and further deterioration can occur. When used properly, concrete containing NewCem can reduce the permeability of the concrete; this reduces the ingress of chlorides and extends the life of the structure.

ASR

The deterioration of concrete by the action of alkali silica reaction (ASR) is a concern in many areas of North America. ASR is a chemical reaction that occurs between the alkalies in portland cement and certain siliceous aggregates. These aggregates, when placed in a highly alkaline solution and in the presence of moisture, form an expansive gel that can cause the concrete to crack. If the crack reaches the surface of the concrete, a path is opened for the ingress of additional moisture, which will further fuel the reaction.

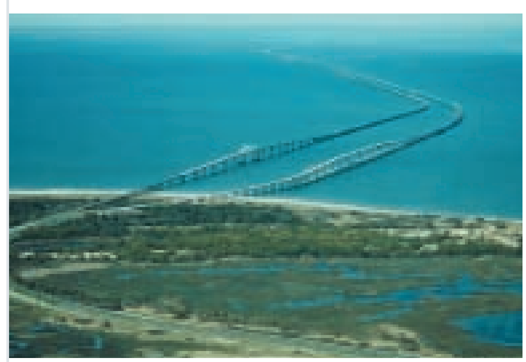
NewCem can reduce this potential expansion. It reduces the effective alkalies loading of the concrete. It reacts with the effective alkalies in portland cement and makes them unavailable to react with the reactive aggregates. Finally, NewCem can reduce the permeability of the concrete, which reduces the ingress of moisture that is available for the reaction.

Sulfate Resistance

Sulfates, present in seawater and in some soils and wastewater, react with the alumina in hardened portland cement paste to cause deleterious expansion. Concrete containing NewCem can provide superior resistance to sulfate attack due to a decrease in the cement compounds that can cause expansion. Also contributing to sulfate resistance is the decrease in permeability of the concrete, which reduces the movement of sulfate solutions in the concrete.

Resistance to sulfate attack may vary according to the chemistry of the cement and the slag cement used. Any combination of these materials should be tested to assure that desired sulfate resistance levels are achieved. Consult a Lafarge Cement Technical Representative before using NewCem in sulfate environments.

National Archives - Silver Spring, Maryland



Chesapeake Bay Bridge Tunnel, Virginia

Applications for Lafarge NewCem® Slag Cement

High-Strength Concrete

In 1995, after the tragedy of the Oklahoma City bombing, engineers had to take a new look at how they designed structures, especially federal buildings. For example, construction was stopped on the new FBI building in Washington, D.C. while engineers and architects worked together to develop a design that would be more resistant to terrorist attack. One of the special designs employed in the FBI building was for a very high-strength blast wall. The concrete producer used a mix of 50 percent NewCem with 50 percent portland cement.

Another high-strength concrete project utilizing 50 percent NewCem and 50 percent portland cement is Lincoln Square in Washington, D.C. The specified strengths for this project ranged on the high end from 8,000 psi to 12,000 psi. Design strengths were usually achieved in about seven days, and 28-day strength results were often over 15,000 psi.

Light rail tunnel leading to the Minneapolis-St.Paul International Airport

Precast/Prestress

One of the earliest uses of NewCem was in precast and prestressed concrete. There were some initial concerns with using NewCem for these applications because of NewCem's natural tendency to reduce the early strength of the concrete. It was shown; however, that NewCem can react well when concrete is cured at elevated temperatures.

The light rail tunnels leading to the Minneapolis-St. Paul International Airport are constructed with precast concrete tunnel liners containing NewCem. This concrete met the low-permeability rating specification.

FBI Building, Washington, D.C.

Mass Concrete

A primary consideration in designing any mass concrete structure is the development of thermal cracks due to temperature differentials within the concrete. Cement produces heat during the hydration process. In the center of a mass concrete section the temperature of the concrete can build up quickly because there is no way for the heat to dissipate. On the exterior of the concrete section the heat dissipates much more rapidly. When the temperature differential between the center of the concrete mass and the exterior of the concrete becomes large enough, thermal cracking can develop.

Used in high percentages, NewCem has been very effective in reducing both the maximum temperature of the concrete and the rate of temperature rise, resulting in a lower temperature differential between the center of the concrete mass and the exterior of the concrete.

NewCem is produced in accordance with ASTM C 989 *Standard Specification for Ground Granulated Blast-Furnace Slag for Use in Concrete and Mortars*, AASHTO M302 *Standard Specification for Ground Granulated Blast-Furnace Slag for Use in Concrete and Mortars*, and CSA A3000 *Cementitious Materials Compendium*.

Lincoln Square, Washington, D.C.

Properties of "Fresh Concrete" – NewCem® Slag Cement

Water Requirements: Concrete mixes containing NewCem will require about the same amount of water for a given slump as concrete containing only portland cement.

Air Content: The use of NewCem as a partial replacement for portland cement will not appreciably change the dosage rate requirements of air entraining agents. When changing mix ingredients, it is recommended to check dosage rates and adjust if necessary.

Bleeding: The bleeding characteristics of concrete containing NewCem will not be appreciably affected.

Segregation: There is no segregation issue related to the use of NewCem.

Heat of Hydration: NewCem can be used to moderate the development of heat in mass concrete. It is recommended that replacement factors of 60% or greater be used for this type of application. It is highly recommended that mix designs be assessed on an individual basis.

Setting Time: Concrete containing NewCem may have extended set times compared to straight portland mixes, especially at lower ambient/concrete temperatures and higher replacement levels. At normal summertime temperatures, set times will only be slightly affected.

Finishability: The finishability of concrete is generally improved with the use of NewCem.

Pumping: Concrete containing NewCem generally has improved pumpability.

Proportioning: NewCem has a lower specific gravity than normal portland cement. Consequently, the mix design should be modified to accommodate this change. ACI 211 should be followed for proportioning and mix proportions should be verified.

Curing: Proper curing of all concrete is essential. It is recommended that the procedures in ACI 308 *Standard Practice for Curing Concrete* and CSA A23.1 be followed.

Properties of "Hardened Concrete" – NewCem® Slag Cement

Strength: Generally, later strengths (beyond 7 days) both compressive and flexural, are enhanced with NewCem. Early strengths (up to 14 days) can be reduced when compared to straight portland mixes, especially at higher replacement rates and at cooler temperatures.

Permeability and Absorption: When properly proportioned, concrete containing NewCem is less permeable and has a lower absorption rate than mixes containing only portland cement.

Concrete Color: Concrete made with NewCem as a replacement for portland cement will be lighter in color. A green or blue-green color may occasionally be observed in freshly cured concrete; however, this is very rare and will only occur under certain conditions. This tint normally disappears once the concrete surface is exposed to air and dries out.

Alkali-Silica Reactivity: Concrete containing NewCem can help mitigate ASR. This is dependent on the qualities of the aggregate and the replacement rate as well as other variables. Concrete mixtures should be assessed on an individual basis.

Resistance to Sulfate Attack: NewCem can be used as part of a system to improve the resistance of concrete to sulfate attack. The degree of resistance achieved is dependent on the replacement rate and other factors. Mixes should be assessed individually.

Resistance to sulfate attack may vary according to the chemistry of the cement and the slag cement used. Any combination of these materials should be tested to assure that desired sulfate resistance levels are achieved. Consult a Lafarge Cement Technical Representative before using NewCem in sulfate environments.

Corrosion of Embedded Steel: There is a direct relationship between permeability and corrosion resistance. Corrosion can be reduced by replacing part of the portland cement with NewCem in concrete mixtures.

Carbonation: When used in a properly designed concrete mix, and with appropriate finishing and curing procedures applied in the field, the use of NewCem will not significantly affect the depth of carbonation.

Freeze-Thaw Resistance: When used in a properly designed concrete mix with an adequate air–void system and with proper finishing and curing procedures applied in the field, the use of NewCem will not detract from the freeze-thaw resistance of concrete.

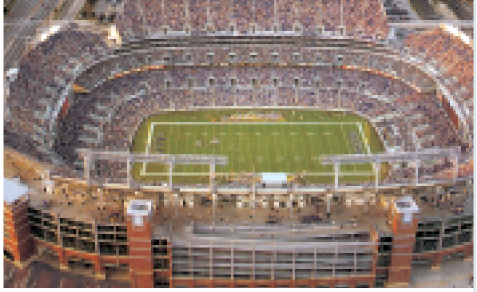
Deicer Salt Scaling: When using NewCem as a replacement for portland cement in concrete that will be exposed to deicing salts, the limits specified in ACI 318 *Building Code Requirements for Structural Concrete,* ACI 301 *Specifications for Structural Concrete* and CSA A23.1 must be followed.

Chemical Resistance: Reduced permeability, and therefore improved chemical resistance, can be achieved through the use of NewCem in concrete mixtures.

Note: Appropriate testing should be conducted with different NewCem/portland levels to assure desired results are achieved. Results may vary with the use of different portland cements.

I-895 Interchange near Richmond, Virginia

Liberty View Towers - Jersey City, New Jersey



Ravens' Stadium, Baltimore, MD

Lafarge NewCem® Slag Cement

Company Profile

Lafarge in North America is part of the Lafarge Group. The world leader in building materials, active on five continents, the Lafarge Group holds top-ranking positions in cement, aggregates, concrete and gypsum.

By focusing on the development and improvement of building materials, Lafarge puts the customer at the core of its strategy and offers the construction industry and the general public innovative solutions that will bring more safety, comfort and beauty to our everyday lives.

Please consult a Lafarge Cement Technical Representative prior to using NewCem in specialized applications.

Precautions

Direct contact with wet cement should be avoided. If contact occurs, the skin should be washed with water as soon as possible. Exposure can cause serious, potentially irreversible tissue destruction in the form of chemical (caustic) burns. If cement gets into the eyes, immediately rinse thoroughly with water and seek medical attention. For more information, reference the applicable Lafarge Material Safety Data Sheet (MSDS). The MSDS should be consulted prior to use of this product and is available upon request and online at www.lafarge-na.com.

For more than three decades, NewCem has been used in conjunction with regular portland cement to produce improved concrete properties for architects, engineers, contractors, ready-mixed concrete and concrete products producers. Today, Lafarge maintains NewCem's market leadership through consistent product quality backed by solid technical expertise.

Please contact your Lafarge Office for specific product information, availability and ordering.

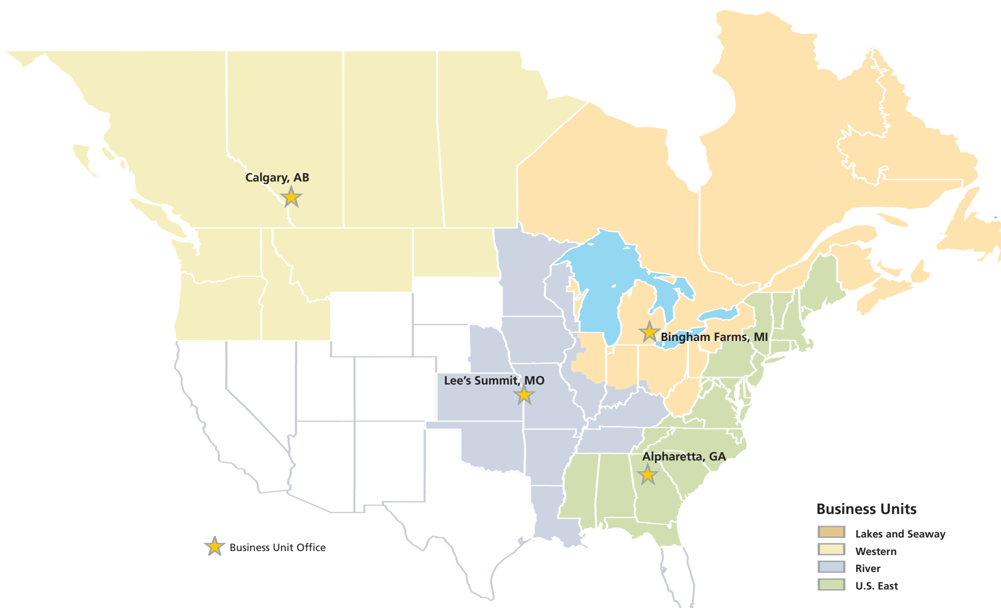
Lakes and Seaway Business Unit
Bingham Farms, Michigan
Phone: 248-594-1991

River Business Unit
Lee's Summit, Missouri
Phone: 816-251-2100

U.S. East Business Unit
Alpharetta, Georgia
Phone: 678-746-2000

Western Business Unit
Calgary, Alberta
Phone: 403-271-9110

Lafarge North America Cement Operating Areas



Limited Warranty

Lafarge warrants that Lafarge NewCem slag cement meets the requirements of ASTM C 989 and CSA-A3001. Lafarge makes no other warranty, whether of merchantability or fitness for a particular purpose with respect to Lafarge NewCem slag cement. Having no control over its use, Lafarge will not guarantee finished work in which Lafarge NewCem slag cement is used.

PBNCE 1/07

Lafarge North America Inc.
12950 Worldgate Drive, Suite 500
Herndon, VA 20170

Lafarge Canada Inc.
606 Cathcart Street
Montréal, Québec H3B 1L7

LAFARGE NORTH AMERICA

CEMENT

Printed on recycled paper

www.lafarge-na.com

VCAS™ White Pozzolans

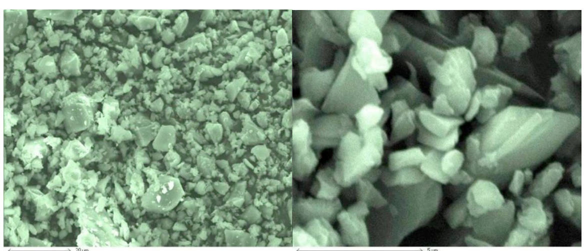
Custom-engineered, high performance, pozzolanic mineral additives for use in white cement, mortar, and concrete products

www.vitrominerals.com

Product Description

VCAS™ (vitreous calcium aluminosilicate) pozzolans are new custom-engineered, high performance supplementary cementing materials for use in white Portland cement, mortar, and concrete products. They are manufactured by heating a blend of ground silica, lime, and alumina compounds to a molten state which is then solidified by quench cooling, processed, and ground to a fine white powder with highly-reactive pozzolanic characteristics.

After primary sizing and drying, the feedstock is finely ground and processed through high efficiency classifiers to produce a fine bright white powder with quality assured physical properties. The consistent chemical composition and tightly controlled particle size distribution result in highly reactive and superior quality pozzolans for concrete applications. Currently, the VCAS™ patented technology produces pozzolans in three grades, **VCAS-8, VCAS-140, and VCAS-160**, described in this technical summary.



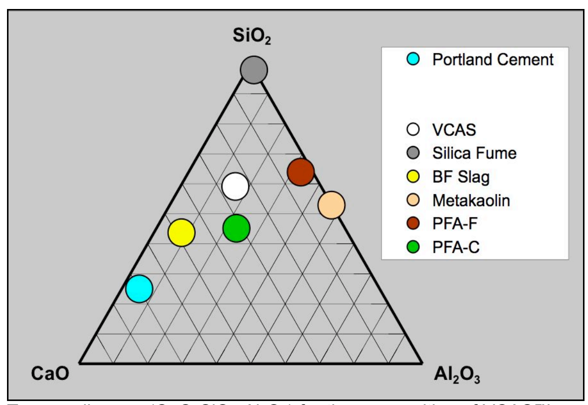
Unlike silica fume, coal fly ash, ground granulated blast furnace slag, and other by-products, VCAS™ pozzolans are free of iron, manganese, and other undesirable color-inducing impurities, making them ideally suited for all applications using white cement and in pigmented concrete.

VCAS™ pozzolans are value-added supplementary cementing materials that exhibit pozzolanic activity comparable to silica fume and metakaolin when tested in accordance with ASTM C618 and ASTM C1240. VCAS™ pozzolans react with calcium hydroxide produced during the hydration of Portland cement to form additional cementitious compounds such as calcium silicate and alumino-silicate hydrates. Pozzolans are widely used in cement and concrete technology to increase concrete strength, density, and resistance to chemical attack as well as control efflorescence.

Chemical Composition of VCAS™ Pozzolans

Silica, SiO_2	50–55%	Titania, TiO_2	<1%
Alumina, Al_2O_3	15–20%	Phosphorus oxide, P_2O_5	<0.1%
Iron oxide, Fe_2O_3	<1%	Manganese oxide, MnO	<0.01%
Calcia, CaO	20–25%	Boron oxide, B_2O_3	0–6%
Magnesia, MgO	<1%	Sulphur oxide, SO_3	<0.1%
Sodium oxide, Na_2O	<1%	Chloride, Cl	<0.01%
Potassium oxide, K_2O	<0.2%	Loss on ignition, LOI	<0.5%

Chemically, VCAS™ pozzolans are comprised largely of oxides of silicon, aluminum and calcium with no deleterious impurities. The CaO-SiO_2-Al_2O_3 proportions, the low alkali metal content, and the amorphous structure are ideal for a pozzolanic additive in hydraulic concrete. The low iron content makes them particularly well suited for applications using white cement, such as mortars, stuccos, terrazzo, artificial stone, and cast-in-place or precast concrete products.



Ternary diagram (CaO-SiO_2-Al_2O_3) for the composition of VCAS™ pozzolans relative to Portland cement and the common pozzolans.

VCAS™ pozzolans have superior powder handling compared with silica fume and metakaolin. Tight process control provides consistent product quality and physical properties.

Physical Properties of VCAS™ Pozzolans

	VCAS-8	*VCAS-140*	*VCAS-160*
Specific Gravity	2.6	2.6	2.6
Bulk Density, Loose lb/ft^3	50-55	50-55	45-50
Passing No. 325 Mesh, %	95	95	98
Specific Surface Area, cm^2/g	4,000	4,000	6,000
Brightness, %	90	86	86
Melting Point, °C	1200	1200	1200
Hardness, Mohs	5.5	5.5	5.5

Vitro Minerals
832 E. Hightower Trail, PO Box 1169, Social Circle, GA 30043, Phone: 678-990-5652 Fax: 678-990-2658

Benefits of VCAS™ Pozzolans

Fresh Concrete:

- Improved workability
- Reduction in water requirements
- Ease of dispersability
- Reduction in superplasticizer
- Reduction in bleeding
- Reduction in aggregate segregation

Hardened Concrete:

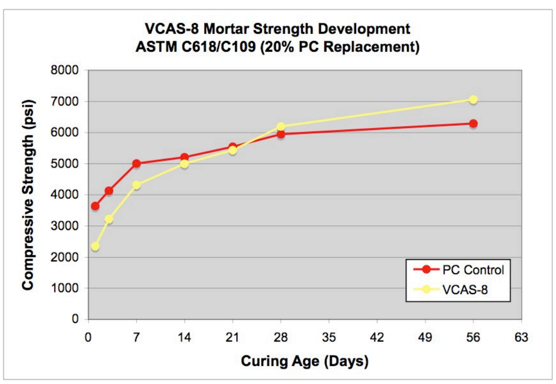
- Increased compressive strength
- Decreased permeability
- Increased durability

Added-Value:

- Mix-color neutrality and brightness
- Improved retention of mold detail
- Sustainability

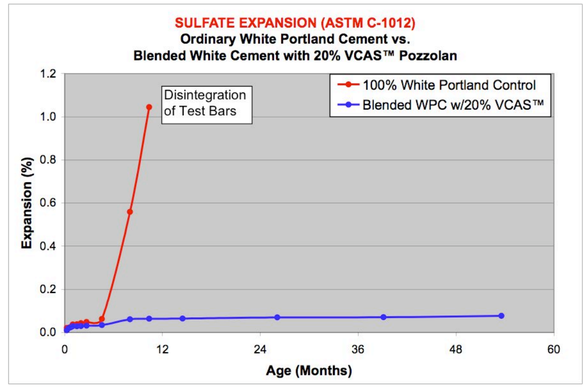
Performance

VCAS pozzolans meet the technical requirements of ASTM C618 for use as supplementary cementious materials in concrete. Blended pozzolanic cements produced with VCAS pozzolans also exceed the requirements of ASTM C1157: Standard Performance Specification for Hydraulic Cement. A typical strength curve for VCAS-8 at 20% cement replacement is shown below. Coupled with low water demand, reduced efflorescence, and improved chloride resistance, VCAS™ pozzolans are extremely cost effective.



Enhanced Durability

VCAS™ pozzolans provide white Portland cement with superior resistance to sulfate attack (ASTM C1012). The graph below shows the excellent dimensional stability of a white cement mortar with 20% VCAS replacement after over 4 years of exposure. Under these harsh test conditons, the 100% white cement control mortar disintegrated in less than 200 days. VCAS is also very effective at controlling expansion due to the alkali-silica reaction (ASTM C441) and reducing chloride ion penetration (ASTM C1202).



Comparison with Other Pozzolans

VCAS™ pozzolans are excellent high reactivity materials for use with white cement to produce durable, high performance architectural concrete structures and reflective highway barriers.

Environmental, Health & Safety

VCAS™ pozzolans have an important role to play in sustainable construction by increasing service life and reducing the net greenhouse gas emissions (GHG) for a cubic yard of concrete.

VCAS™ pozzolans are non-toxic, contain no crystalline silica, and are classed as a nuisance dust, in common with other common fine particulate industrial minerals.

Product Availability

VCAS™ pozzolans are sold in bulk tanker trucks, 1-ton super-sacks, and 50 lb bags.

Vitro Minerals
832 E. Hightower Trail, PO Box 1169, Social Circle, GA 30043, Phone: 678-990-5652 Fax: 678-990-2658

VCAS™ White Pozzolans

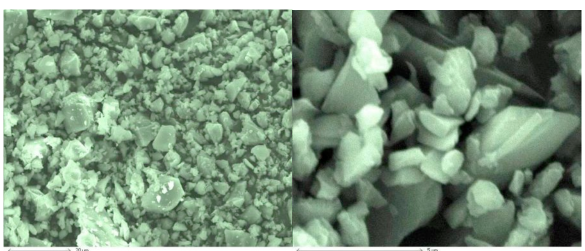
Custom-engineered, high performance, pozzolanic mineral additives for use in white cement, mortar, and concrete products

www.vitrominerals.com

Product Description

VCAS™ (vitreous calcium aluminosilicate) pozzolans are new custom-engineered, high performance supplementary cementing materials for use in white Portland cement, mortar, and concrete products. They are manufactured by heating a blend of ground silica, lime, and alumina compounds to a molten state which is then solidified by quench cooling, processed, and ground to a fine white powder with highly-reactive pozzolanic characteristics.

After primary sizing and drying, the feedstock is finely ground and processed through high efficiency classifiers to produce a fine bright white powder with quality assured physical properties. The consistent chemical composition and tightly controlled particle size distribution result in highly reactive and superior quality pozzolans for concrete applications. Currently, the VCAS™ patented technology produces pozzolans in three grades, **VCAS-8, VCAS-140, and VCAS-160**, described in this technical summary.



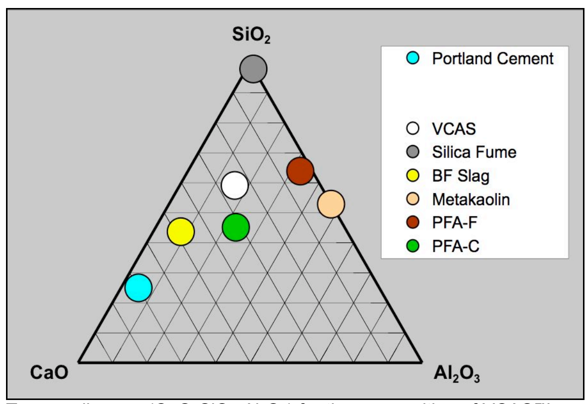
Unlike silica fume, coal fly ash, ground granulated blast furnace slag, and other by-products, VCAS™ pozzolans are free of iron, manganese, and other undesirable color-inducing impurities, making them ideally suited for all applications using white cement and in pigmented concrete.

VCAS™ pozzolans are value-added supplementary cementing materials that exhibit pozzolanic activity comparable to silica fume and metakaolin when tested in accordance with ASTM C618 and ASTM C1240. VCAS™ pozzolans react with calcium hydroxide produced during the hydration of Portland cement to form additional cementitious compounds such as calcium silicate and alumino-silicate hydrates. Pozzolans are widely used in cement and concrete technology to increase concrete strength, density, and resistance to chemical attack as well as control efflorescence.

Chemical Composition of VCAS™ Pozzolans

Silica, SiO_2	50–55%	Titania, TiO_2	<1%
Alumina, Al_2O_3	15–20%	Phosphorus oxide, P_2O_5	<0.1%
Iron oxide, Fe_2O_3	<1%	Manganese oxide, MnO	<0.01%
Calcia, CaO	20–25%	Boron oxide, B_2O_3	0–6%
Magnesia, MgO	<1%	Sulphur oxide, SO_3	<0.1%
Sodium oxide, Na_2O	<1%	Chloride, Cl	<0.01%
Potassium oxide, K_2O	<0.2%	Loss on ignition, LOI	<0.5%

Chemically, VCAS™ pozzolans are comprised largely of oxides of silicon, aluminum and calcium with no deleterious impurities. The CaO-SiO_2-Al_2O_3 proportions, the low alkali metal content, and the amorphous structure are ideal for a pozzolanic additive in hydraulic concrete. The low iron content makes them particularly well suited for applications using white cement, such as mortars, stuccos, terrazzo, artificial stone, and cast-in-place or precast concrete products.



Ternary diagram (CaO-SiO_2-Al_2O_3) for the composition of VCAS™ pozzolans relative to Portland cement and the common pozzolans.

VCAS™ pozzolans have superior powder handling compared with silica fume and metakaolin. Tight process control provides consistent product quality and physical properties.

Physical Properties of VCAS™ Pozzolans

	VCAS-8	*VCAS-140*	*VCAS-160*
Specific Gravity	2.6	2.6	2.6
Bulk Density, Loose lb/ft^3	50-55	50-55	45-50
Passing No. 325 Mesh, %	95	95	98
Specific Surface Area, cm^2/g	4,000	4,000	6,000
Brightness, %	90	86	86
Melting Point, °C	1200	1200	1200
Hardness, Mohs	5.5	5.5	5.5

Vitro Minerals
832 E. Hightower Trail, PO Box 1169, Social Circle, GA 30043, Phone: 678-990-5652 Fax: 678-990-2658

Benefits of VCAS™ Pozzolans

Fresh Concrete:

- Improved workability
- Reduction in water requirements
- Ease of dispersability
- Reduction in superplasticizer
- Reduction in bleeding
- Reduction in aggregate segregation

Hardened Concrete:

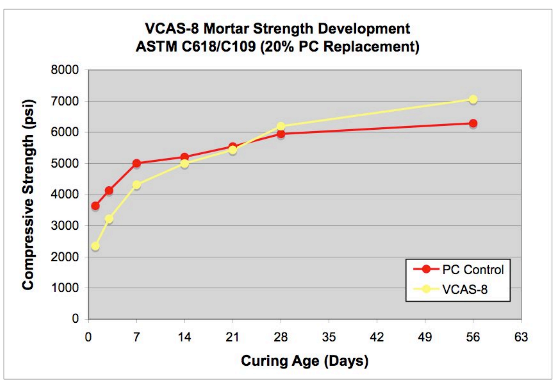
- Increased compressive strength
- Decreased permeability
- Increased durability

Added-Value:

- Mix-color neutrality and brightness
- Improved retention of mold detail
- Sustainability

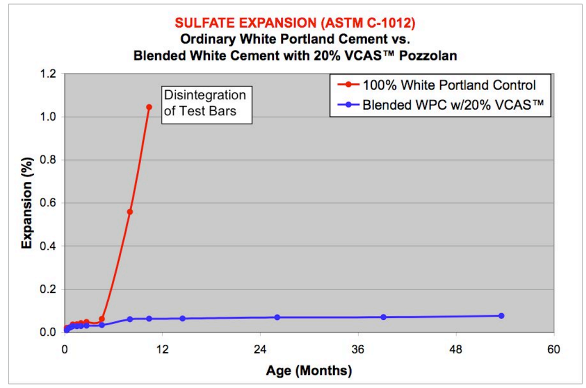
Performance

VCAS pozzolans meet the technical requirements of ASTM C618 for use as supplementary cementious materials in concrete. Blended pozzolanic cements produced with VCAS pozzolans also exceed the requirements of ASTM C1157: Standard Performance Specification for Hydraulic Cement. A typical strength curve for VCAS-8 at 20% cement replacement is shown below. Coupled with low water demand, reduced efflorescence, and improved chloride resistance, VCAS™ pozzolans are extremely cost effective.



Enhanced Durability

VCAS™ pozzolans provide white Portland cement with superior resistance to sulfate attack (ASTM C1012). The graph below shows the excellent dimensional stability of a white cement mortar with 20% VCAS replacement after over 4 years of exposure. Under these harsh test conditons, the 100% white cement control mortar disintegrated in less than 200 days. VCAS is also very effective at controlling expansion due to the alkali-silica reaction (ASTM C441) and reducing chloride ion penetration (ASTM C1202).



Comparison with Other Pozzolans

VCAS™ pozzolans are excellent high reactivity materials for use with white cement to produce durable, high performance architectural concrete structures and reflective highway barriers.

Environmental, Health & Safety

VCAS™ pozzolans have an important role to play in sustainable construction by increasing service life and reducing the net greenhouse gas emissions (GHG) for a cubic yard of concrete.

VCAS™ pozzolans are non-toxic, contain no crystalline silica, and are classed as a nuisance dust, in common with other common fine particulate industrial minerals.

Product Availability

VCAS™ pozzolans are sold in bulk tanker trucks, 1-ton super-sacks, and 50 lb bags.

832 E. Hightower Trail, PO Box 1169, Social Circle, GA 30043, Phone: 678-990-5652 Fax: 678-990-2658

Product specifications

according to DIN EN 13055-1

Designation	Poraver® basic granular sizes						Special granular sizes			
Granular size mm	0.1-0.3	0.25-0.5	0.5-1	1 - 2	2 - 4	4 - 8	0.04-0.125	high-strength 0.2-0.7	0.5-1.25	8 - 16
Bulk density lb/ft³ Nominal	25	21.2	16.9	14.4	11.9	11.2	33.1	33.1	16.2	8.7
Apparent granular density lb/ft³ Nominal	56.2	36.8	29.3	24.3	20	18.8	*	59.3	28.7	16.9
Compressive strength PSI	406	377	290	232	203	174	–	942.5	246.5	116
Oversize grains	≦ 10 M. %									
Undersize grains	≦ 15 M. %									

* on request

The following data are valid for all grain sizes:

pH value	9 - 12									
Moisture content on delivery	< 0.5 %									
Softening point	approx. 700° C									
Colour	creamy white									
Thermal conductivity W/mK	–	–	–	–	0.07**	0.07**	–	–	–	–

** Calculated values DIBt according to Approval Z-23.11-114

The Poraver® strengths may vary within the tolerance range of the bulk density.

The availability and delivery conditions for special grain sizes will be agreed on an individual basis.

poraver® North America

Apparent bulk density

How to determine apparent bulk density

in accordance with DIN EN 1097-3

Pour loose Poraver® into a 1 litre measuring vessel and carefully level off any test material left on top.
Then weigh the test material in the vessel. The bulk density is the quotient of the weight and the volumes in lb/ft³.

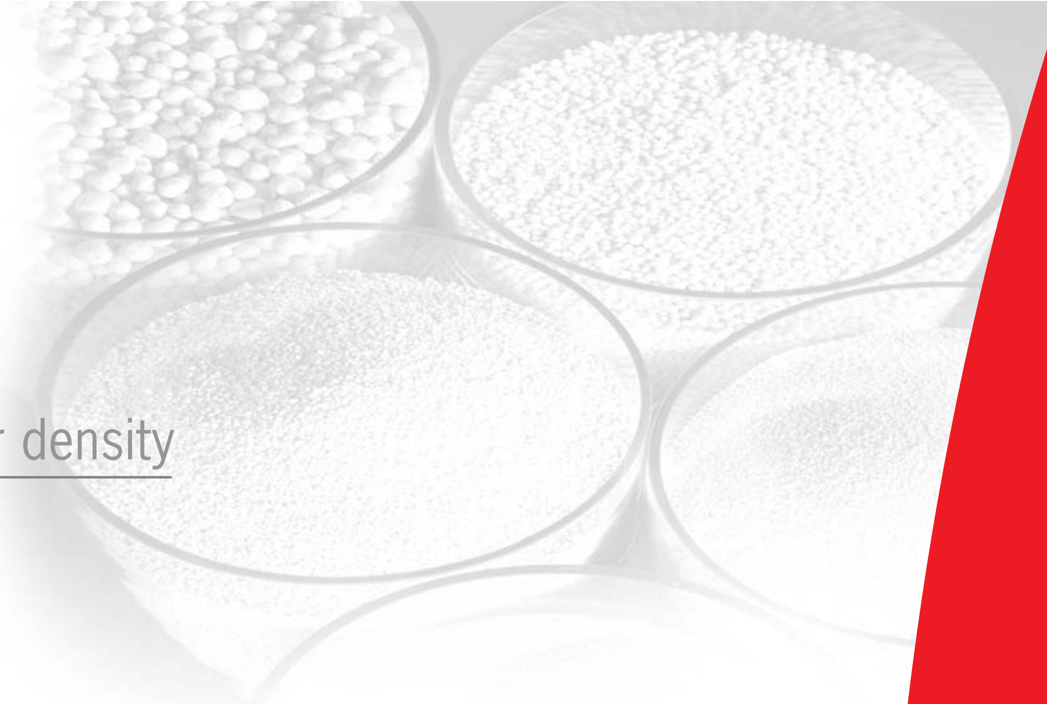
Standard granular size mm	0.1 - 0.3	0.25 - 0.5	0.5 - 1	1 - 2	2 - 4	4 - 8
Apparent bulk density in lb/ft³	25	21.2	16.9	14.4	11.9	11.2

Special granular size in mm	0.04 - 0.125	high-strength 0.2 - 0.7	0.5 - 1.25	8 - 16
Apparent bulk density in lb/ft³	33.1	33.1	16.2	8.7

The following deviations from the given DIN apply:

- There is no drying, because Poraver® is generally supplied dry.
- The equilibrium moisture does not require conditioning.
- The measuring vessel indicates a volume of 1 litre even with granular sizes greater than 4 mm.
- One measuring value is given for each test.

poraver®
North America



Apparent granular density

How to determine apparent granular density

in accordance with DIN 4226

What is required to determine apparent granular density (ρ) is approx. 400ml of material that is weighed (m). Place the granular material into a cylinder with 1 litre nominal capacity and add 0.5 litre of water. Tap the measuring vessel to remove any air bubbles. Push a plunger with known volumes (Vs) into the measuring cylinder to prevent granular material from floating to the surface. After reading off the total volume (V) in cm^3, you can calculate the granular density in lb/ft^3 by using the following formula:

Calculation formula:

$$\rho = \frac{m}{V - (Vs + 500)}$$

Standard granular size in mm	0.1 - 0.3	0.25 - 0.5	0.5 - 1	1 - 2	2 - 4	4 - 8
Apparent granular density in lb/ft^3	56.2	36.8	29.3	24.3	20	18.8

Special granular size in mm	0.04 - 0.125	high-strength 0.2 - 0.7	0.5 - 1.25	8 - 16
Apparent granular density in lb/ft^3	*	59.3	28.7	16.9

* on request

The following deviations from the given DIN apply:

- There is no drying, because Poraver® is generally supplied dry.
- This testing method is used for Poraver® granular sizes from 0.1 – 16 mm.
- One measuring value is given for each test.

The ball that does it all

Compressive strength

How to determine granular compressive strength

in accordance with DIN EN 13055-1

To determine the compressive strength, pour 1 litre of Poraver® into a defined steel cylinder and compress. To do this, use an attached plunger to press down the granular material in this cylinder by 20 mm with a compressor. The force required for this is indicated as the granular strength.

Standard granular size in mm	0.1 - 0.3	0.25 - 0.5	0.5 - 1	1 - 2	2 - 4	4 - 8
Compressive strength PSI	406	377	290	232	203	174

Special granular size in mm	0.04 - 0.125	high-strength 0.2 - 0.7	0.5 - 1.25	8 - 16
Compressive strength PSI	–	942.5	246.5	116

The following deviations from the given DIN apply:

- Undersize and oversize grains are not removed within individual granular groups.
- Force is applied at a constant speed of 0.15 kN/s for all granular sizes.
- One measuring value is given for each test.

poraver® North America

Water absorption

How to determine water absorption

in accordance with DIN V 18004

To determine water absorption, weigh approx. 0.4 litre of Poraver® to an accuracy of 0.1 g.

Procedure 1:

For granular sizes below 2 mm, store the water in a suction filter, and extract the water by means of a water-operated vacuum pump to dry the surface.

Procedure 2:

For granular sizes in excess of 2 mm, store the water in a density bottle. Here, dab the sample to dry the surface.

The difference between the mass of the surface-damp condition and the dry sample in relation to the dry sample is water absorption W in M.-%.

Calculation formula

$$WA\ [M.\%] = (M_f - M_{tr}) / M_{tr}$$

$$WA\ [V.\%] = WA\ [Vol.\%] \times KRD$$

Mw - Mass of water absorbed [g]
Mtr - Mass of sample dry [g]
KRD - Apparent granular density [kg/m³]

Standardgranular size in mm	0.1 - 0.3	0.25 - 0.5	0.5 - 1	1 - 2	2 - 4	4 - 8
Water absorption in WA	35 M.%	30 M.%	25 M.%	20 M.%	15 M.%	10 M.%

Special granular size in mm	0.04 - 0.125	high-strength 0.2 - 0.7	0.5 - 1.25	8 - 16
Water absorption in WA	–	20 M.%	22 M.%	15 M.%

The following deviations from the given DIN apply:

- There is no drying, because Poraver® is generally supplied dry.
- Procedure 1 is used for granular sizes up to 2 mm, Procedure 2 only being used for granular sizes greater than 2 mm.
- Water storage of approx. 5 min. is used as standard in both procedures.

poraver North America

Chemical analysis

in accordance with test report 043077.1 of the MPA Hanover

Serial No.	Constituent	Applied to the sample dried at 105°C	Heat-loss-free (%)	Analysis method
1	Heat loss	0.3	–	DIN EN 1744-1
2	Insoluble residue	91.5	–	EN 196-2
3	CaO	8.9	9.0	
4	SiO_2	71.7	71.9	
5	Al_2O_3	2.5	2.5	
6	TiO_2	0.1	0.1	spectrally
7	Fe_2O_3	0.4	0.4	photometric
8	Mn_2O_3	0	0	atomic emission
9	MgO	2.1	2.1	
10	K_2O	0.8	0.8	
11	Na_2O	13.2	13.2	
12	SO_3	0.1	0.1	coulometric
13	Cl	–	–	argentometric
14	Remaining	– 0.1	– 0.1	–
15	Total 1, 3–14	100.0	100.0	–
16	Na_2O equivalent	13.7	–	calculated from 10+11

The analysis was conducted on a sample ground and dried to a granular size of < 0.125 mm.

3M

Product Information

Scotchlite™ Glass Bubbles K Series S Series

Introduction

3M™ Scotchlite™ Glass Bubbles are engineered hollow glass microspheres that are alternatives to conventional fillers and additives such as silicas, calcium carbonate, talc, clay, etc., for many demanding applications. These low density particles are used in a wide range of industries to reduce part weight, lower costs and enhance product properties.

The unique spherical shape of Scotchlite glass bubbles offers a number of important benefits, including: higher filler loading, lower viscosity/improved flow and reduced shrinkage and warpage. It also helps the Scotchlite glass bubbles blend readily into compounds and makes them adaptable to a variety of production processes including spraying, casting and molding.

The chemically-stable soda-lime-borosilicate glass composition of Scotchlite glass bubbles provides excellent water resistance, to create more stable emulsions. They are also non-combustible and non-porous, so they do not absorb resin. And, their low alkalinity gives Scotchlite glass bubbles compatibility with most resins, stable viscosity and long shelf life.

3M™ Scotchlite™ Glass Bubbles K Series and S Series are specially formulated for a high strength-to-weight ratio. This allows greater survivability under demanding processing conditions, such as injection molding. They also produce stable voids, which results in low thermal conductivity and a low dielectric constant. Scotchlite glass bubbles are available in a variety of sizes and grades to help you meet your specific product and processing requirements.

Not for specification purposes

Nitrogen Isostatic Crush Strength

	Product	Test Pressure (psi)	Target Fractional Survival	Minimum Fractional Survival
K Series	K1	250	90%	80%
	K15	300	90%	80%
	K20	500	90%	80%
	K25	750	90%	80%
	K37	3,000	90%	80%
	K46	6,000	90%	80%
S Series	S15	300	90%	80%
	S22	400	90%	80%
	S32	2,000	90%	80%
	S35	3,000	90%	80%
	S38	4,000	90%	80%
	S38HS	5,500	90%	80%
	S60	10,000	90%	80%
	S60HS	18,000	90%	90%

True Density

	Product	Typical	True Density (g/cc) Minimum	True Density (g/cc) Maximum
K Series	K1	0.125	0.10	0.14
	K15	0.15	0.13	0.17
	K20	0.20	0.18	0.22
	K25	0.25	0.23	0.27
	K37	0.37	0.34	0.40
	K46	0.46	0.43	0.49
S Series	S15	0.15	0.13	0.17
	S22	0.22	0.19	0.25
	S32	0.32	0.29	0.35
	S35	0.35	0.32	0.38
	S38	0.38	0.35	0.41
	S38HS	0.38	0.35	0.41
	S60	0.60	0.57	0.63
	S60HS	0.60	0.57	0.63

Chemical Resistance

In general, the chemical properties of 3M™ Scotchlite™ Glass Bubbles resemble those of a soda-lime borosilicate glass.

Thermal Conductivity

Series	Product	Calculated Thermal Conductivity (W·m-1·K-1) at 70°F (21°C)
K Series	K1	0.047
	K15	0.055
	K20	0.070
	K25	0.085
	K37	0.124
	K46	0.153
S Series	S15	0.055
	S22	0.076
	S32	0.108
	S35	0.117
	S38	0.127
	S38HS	0.127
	S60	0.200
	S60HS	0.200

Conductivity increases with temperature and product density. The thermal conductivity of a composite will depend on the matrix material and volume loading of Scotchlite glass bubbles.

Thermal Stability

Appreciable changes in bubble properties may occur above 1112°F (600°C) depending on temperature and duration of exposure.

Flotation

Series	Product	Floaters (% by bulk volume) Typical	Floaters (% by bulk volume) Minimum
K Series	K1	96%	90%
	K15	96%	90%
	K20	96%	90%
	K25	96%	90%
	K37	94%	90%
	K46	92%	90%
S Series	S15	96%	90%
	S22	96%	90%
	S32	94%	90%
	S35	96%	90%
	S38	94%	90%
	S38HS	96%	90%
	S60	92%	90%
	S60HS	92%	90%

Packing Factor (Ratio of bulk density to true particle density.)

Averages about 60%.

Oil Absorption

0.2-0.6 g oil/cc of Scotchlite glass bubbles, per ASTM D281-84.

Volatile Content

Maximum of 0.5 percent by weight.

Alkalinity

Maximum of 0.5 milliequivalents per gram

pH

Because 3M™ Scotchlite™ Glass Bubbles are a dry powder, pH is not defined. The pH effect will be determined by the alkalinity as indicated above. When Scotchlite glass bubbles are mixed with deionized water at 5 volume percent loading, the resulting pH of the slurry is typically 9.1 to 9.9, as measured by a pH meter.

Dielectric Constant

K Series: 1.2 to 1.7 @ 100 MHz, based on theoretical calculations.

S Series: 1.2 to 2.0 @ 100 MHz, based on theoretical calculations.

The dielectric constant of a composite will depend on the matrix material and volume loading of Scotchlite glass bubbles.

Particle Size

	Product	Particle Size (microns, by volume) 3M QCM 193.0 Distribution 10th%	50th%	90th%	Effective Top Size
K Series	K1	30	65	115	120
	K15	30	60	105	115
	K20	25	55	95	120
	K25	25	55	90	105
	K37	20	45	80	85
	K46	15	40	70	80
S Series	S15	25	55	90	95
	S22	20	35	65	75
	S32	20	40	70	80
	S35	10	40	75	85
	S38	15	40	75	85
	S38HS	15	40	75	85
	S60	15	30	55	65
	S60HS	11	30	50	60

Particle Size *(continued)*

Hard Particles (3M QCM 93.4.3)
No hard particles (e.g. glass slag, flow agent, etc.) greater than U.S. number 40 (420 microns) standard sieve will exist.

Oversize Particles (3M QCM 93.4.4)
For *K1, K15, K20* and *K25* glass bubbles:
Using a 10 gram sample on a U.S. number 80 standard sieve (177 microns), a maximum of five (5) percent by weight glass bubbles will be retained on the sieve.

For *K37 and K46* glass bubbles:
Using a 10 gram sample on U.S. number 100 standard sieve (149 microns), a maximum of one (1) percent by weight glass bubbles will be retained on the sieve.

For *S15, S32, S35, S38, S38HS, S60 and S60HS* glass bubbles:
Using a 10 gram sample on a U.S. number 140 standard sieve (105 microns), a maximum of three (3) percent by weight glass bubbles will be retained on the sieve.

For *S22* glass bubbles:
Using a 10 gram sample on a U.S. number 200 standard sieve (74 microns), a maximum of five (5) percent by weight glass bubbles will be retained on the sieve.

Appearance (3M QCM 22.85)

White to the unaided eye.

Flow (3M QCM 22.83)

3M™ Scotchlite™ Glass Bubbles remain free flowing for at least one year from the date of shipment if stored in the original, unopened container in the minimum storage conditions of an unheated warehouse.

Labeling

Scotchlite glass bubbles will be packaged in suitable containers to help prevent damage during normal handling and shipping. Each container will be labeled with:

1. Name of manufacturer
2. Type of Scotchlite glass bubbles
3. Lot number
4. Quantity in pounds

To help ensure ease of storage and handling while maintaining free flowing properties, 3M™ Scotchlite™ Glass Bubbles have been made from a chemically stable glass and are packaged in a heavy-duty polyethylene bag within a cardboard container.

Minimum storage conditions should be unopened cartons in an unheated warehouse.

Under high humidity conditions with an ambient temperature cycling over a wide range, moisture can be drawn into the bag as the temperature drops and the air contracts. The result may be moisture condensation within the bag. Extended exposure to these conditions may result in "caking" of the Scotchlite glass bubbles to various degrees. To minimize the potential for "caking" and prolong the storage life, the following suggestions are made:

1. Carefully re-tie open bags after use.
2. If the polyethylene bag is punctured during shipping or handling, use this bag as soon as possible, patch the hole, or insert the contents into an undamaged bag.
3. During humid summer months, store in the driest, coolest space available.
4. If good storage conditions are unavailable, carry a minimum inventory, and process on a first in/first out basis.

Dusting problems that may occur while handling and processing can be minimized by the following procedures:

1. For eye protection wear chemical safety goggles. For respiratory system protection wear an appropriate NIOSH/MSHA approved respirator. (For additional information about personal protective equipment, refer to Material Safety Data Sheet.)
2. Use appropriate ventilation in the work area.
3. Pneumatic conveyor systems have been used successfully to transport Scotchlite glass bubbles without dusting from shipping containers to batch mixing equipment. Static eliminators should be used to help prevent static charges.

   Diaphragm pumps have been used to successfully convey Scotchlite glass bubbles. Vendors should be consulted for specific recommendations.

Scotchlite glass bubble breakage may occur if the product is improperly processed. To minimize breakage, avoid high shear processes such as high speed Cowles Dissolvers, point contact shear such as gear pumps or 3-roll mills, and processing pressures above the strength test pressure for each product.

3M™ Scotchlite™ Glass Bubbles Health and Safety Information

For product Health and Safety Information, refer to product label and Material Safety Data Sheet (MSDS) before using product.

Packaging Information

Small Box (10 Cubic ft.)

A single corrugated box with a plastic liner. All boxes are banded together and to the wooden pallet. 4 boxes per pallet.

Each box inside diameter is 22 in. x 19 in. x 39 in.
Pallet size is 42 in. x 48 in.

Large Box (50 Cubic ft.)*

A single corrugated box with a plastic liner. Top enclosed with interlocking double cover banded. Bottom is normal box closure, entire box banded to wooden pallet.

Each box inside diameter is 48 in. x 42 in. x 44 in. Overall load size is 48 3/4 in. x 42 3/4 in. x 50 in. including pallet. Pallet size is 42 in. x 48 in.

*S60 and S60HS large boxes are a 38 cubic ft.

Box Weights

	Product	Small Box	Large Box*	Truckload Large Box* 44 Pallets
K Series	K1	40 lb.	210 lb.	9,240 lb.
	K15	50 lb.	265 lb.	11,660 lb.
	K20	60 lb.	350 lb.	15,400 lb.
	K25	80 lb.	430 lb.	18,920 lb.
	K37	100 lb.	660 lb.	29,040 lb.
	K46	125 lb.	815 lb.	35,860 lb.
S Series	S15	50 lb.	265 lb.	11,660 lb.
	S22	60 lb.	385 lb.	16,940 lb.
	S32	100 lb.	525 lb.	23,100 lb.
	S35	100 lb.	630 lb.	27,720 lb.
	S38	100 lb.	680 lb.	29,920 lb.
	S38HS	100 lb.	680 lb.	29,920 lb.
	S60	125 lb.	850 lb.	37,400 lb.
	S60HS	125 lb.	850 lb.	37,400 lb

*Box weights may vary due to manufacturing tolerances on each product.

3M™ Scotchlite™ Glass Bubbles are supported by global sales, technical and customer service resources, with fully-staffed technical service laboratories in the U.S., Europe, Japan, Latin America and Southeast Asia. Users benefit from 3M's broad technology base and continuing attention to product development, performance, safety and environmental issues.

For additional technical information on Scotchlite glass bubbles in the United States, call 3M Performance Materials Division, **800 367 8905**.

For other 3M global offices, and information on additional 3M products, visit our web site at: **www.3m.com/microspheres**

United States
3M Performance Materials Division
3M Center, Building 223-6S-04
St. Paul, MN 55144-1000
800 367 8905
800 810 8514 (Fax)

Europe
3M Specialty Materials
3M Belgium N. V.
Haven 1005, Canadastraat 11
B-2070 Zwijndrecht
32 3 250 7874

Canada
3M Canada Company
Specialty Materials
P.O. Box 5757
London, Ontario
N6A 4T1
800 364 3577

Japan
Sumitomo 3M Limited
33-1, Tamagawadai 2-chome
Setagaya-ku, Tokyo
158-8583 Japan
813 3709 8250

Asia Pacific and Latin America
Call (U.S.) **651 736 7123**

3M Performance Materials Division

3M Center, Building 223-6S-04
St. Paul, MN 55144-1000
www.3m.com/microspheres

Issued: 12/03

4689 (HB)
98-0212-3710-6

True Lite Lightweight Aggregate
Block Blend #444
Water–Cooled Expanded Blast Furnace Slag for Concrete Masonry Units

Sieve Analysis – ASTM C136

Sieve Metric	Sieve Alternative	Lafarge Specification	Typical Gradation
9.5 mm	3/8”	100%	100%
6.3 mm	1/4”	100%	98%
4.75 mm	4 mesh	92% - 100%	95%
2.36 mm	8 mesh	55% - 70%	65-70%
1.18 mm	16 mesh		38%
600 um	30 mesh		21%
300 um	50 mesh	10% - 15%	12%
150 um	100 mesh	8% - 12%	10%
75um	200 mesh	2% - 4%	3%

Statistical Control
Plus/Minus 10% on all Sieves from Target Mean

DOT Equivalent

Illinois DOT	QC/QA	FA2 or FA20
Indiana DOT	QA	#23 or #24

Physical Properties

Moisture Content (ASTM C566)	10% - 14%
Unit Weight (Loose-Wet) (ASTM C29)	56 lbs/ft3 – 61 lbs/ft3 (Depending on Moisture)
Absorption (ASTM C127)	10% - 16%
Specific Gravity (ASTM C127)	2.140
Specific Gravity (SSD) (ASTM C127)	2.244
Fineness Modulus	3.4
Sodium Sulphate Soundness (AASHTO T104)	2.4% Loss
Organic Impurities (ASTM C40)	Less than Plate No. 1
Staining (ASTM C641)	Very Slight
Loss on Ignition	1.33%
Pop-Outs	No Surface Pop-Outs
Los-Angeles Abrasion (ASTM C131)	32.6% Loss
Shrinkage (28 day)	0.014%
Freeze-Thaw Resistance (ASTM C666)	96.2%

ASTM D3987 & EPA 1311

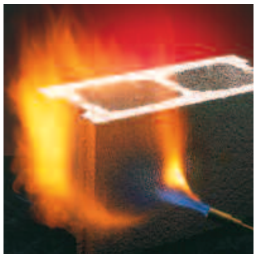
Analyte	RCRA TCLP max conc. (mg/L)	Block Mix #444
Antimony (Sb)	1	<0.01
Arsenic (As)	5	<0.02
Barium (Ba)	100	0.463
Beryllium (Be)	0.007	<0.0001
Cadmium (Cd)	1	<0.001
Chromium (Cr)	5	<0.001
Lead (Pb)	5	<0.006
Mercury (Hg)	0.2	<0.001
Nickel (Ni)	70	<0.002
Selenium (Se)	1	<0.04
Silver (Ag)	5	<0.0003
Thallium (Tl)	7	<0.02
pH (TCLP)		7.9
Solids content (g/g)		0.9
pH (Extract of solid waste with water)		10.37

True *LITE* Lightweight Aggregate™

The Future in Concrete and Masonry

Lafarge Slag has been in the business of processing blast furnace slag since 1953. With operations in East Chicago, Indiana and Hamilton, Ontario, Lafarge processes over two million tons of blast furnace slag annually. With access to water, rail and trucks at both facilities, Lafarge Slag can service virtually any market in North America. **Lafarge True Lite Lightweight Aggregate™** brand aggregate is another example of Lafarge's commitment to be the world leader in building materials.

True Lite Lightweight Aggregate™ is a product that supports the concept of "green building." The production of **True Lite Lightweight Aggregate™** does not deplete our non-renewable natural resources. In fact, it is a "value added" means of recycling. **True Lite Lightweight Aggregate™** is a 100% recycled product that conforms to the US and Canadian government environmentally preferable purchasing programs and **LEED™** (Leadership in Energy & Environmental Design) certification programs.



The insulating properties of **True Lite Lightweight Aggregate™** and its stability at high temperatures result in lightweight masonry units possessing up to 35% improved fire ratings as compared to normal weight concrete of equal thickness. The fire resistance performance of this expanded slag aggregate even outperforms other lightweight aggregates such as expanded clay, shale and slate.

Increase Productivity

Using **True Lite Lightweight Aggregate™** in your lightweight and medium weight block can increase productivity for masonry contractors by 10% to 18%*. **True Lite Lightweight Aggregate™** blocks can be used for structural applications and conform to the same ASTM requirements as standard weight blocks. Since **True Lite Lightweight Aggregate™** blocks are substantially lighter and easier to place, they can contribute to reducing back injuries and thus workman compensation claims.

* Based on NCMA study "Research Investigation of Mason Productivity - NCMA Library TF03654

Lightweight blocks produced with **True Lite Lightweight Aggregate™** have the highest thermal insulating capacity in comparison to concrete blocks of equal volume. Products manufactured using **True Lite Lightweight Aggregate™** can help reduce structural framing and foundation loads. Heating and air conditioning costs can also be reduced due to the capillary nature of the aggregate, which aids in the dispersion of heat and cold.

The countless minute voids on unpainted **True Lite Lightweight Aggregate™** concrete masonry surfaces provide a texture that traps and dissipates up to 45% of incident noise. Comparable weight block surfaces can stop only 27% of incident noise.

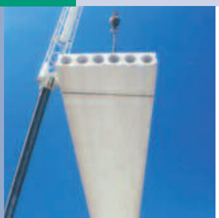
Lafarge Slag

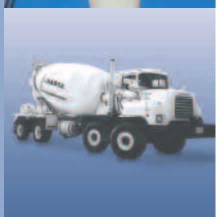
3210 Watling Street
East Chicago, IN 46312
Tel.: (219) 378-1193

139 Windermere Road
Hamilton, ON L8H 3Y2
Tel.: (905) 547-2133

LAFARGE

Achieve LEED™ points by using True Lite Lightweight Aggregate™ in concrete and masonry products





True Lite Lightweight Aggregate™ is a co-product of iron production and qualifies as a recycled product. For **LEED™** (Leadership in Energy & Environmental Design) designated projects, concrete products manufactured with **True Lite Lightweight Aggregate™** qualify for points under Materials and Resources for Local/Regional Materials, Recycled Content and potentially Innovation and Design.

U.S. GREEN BUILDING COUNCIL MEMBER

CANADA GREEN BUILDING COUNCIL · CONSEIL DU BÂTIMENT DURABLE DU CANADA
MEMBER / MEMBRE

True Lite Lightweight Aggregate™ Contribution to Green Building LEED Rating Summary – LEED-NC (version 2.1)

LEED Checklist Item	Total Available Points	True Lite Lightweight Aggregate™ Point Contribution
Sustainable Sites	14	3
Water Efficiency	5	3
Energy & Atmosphere	17	Minimum 1*
Materials & Resources	13	7
Indoor Environmental Quality	15	1
Innovation & Design Process	5	1
Total Points	**69**	**16+**

*Reducing design energy costs below regulated values can earn from 1-10 points for reductions of 15% (minimum) to 60%

Elements for achieving success

True Lite Lightweight Aggregate™ is an innovative example of the commitment by Lafarge to be the world leader in the construction materials industry. **True Lite Lightweight Aggregate™** meets **ASTM C 330** and **C 331**, and supports the concept of "green building" by preserving our non-renewable natural resources. Whether for masonry, ready-mixed or precast concrete, **True Lite Lightweight Aggregate™** can add value to any project while helping to preserve the environment.

Lafarge NewCem® Slag Cement is a co-product of the iron-making process at steel mills. NewCem provides flexibility in concrete proportioning to achieve low permeability, resistance to chlorides, high sulfate resistance, resistance to alkali silica reaction, greater strength potential, lower temperatures for mass concrete and improved workability.

Fly Ash is a co-product of electric utility plants and is used as a key mineral admixture for many high performance concretes. The many performance enhancing properties and the typically lower cost have made fly ash one of the key ingredients in modern concrete production. Fly ash may also be used as an alternate raw material in cement production, helping in the same way as slag cement, to preserve other natural resources.

Limited Warranty

Lafarge warrants that Lafarge True Lite Lightweight Aggregate meets ASTM and CSA requirements. Lafarge makes no other warranty, whether of merchantability or fitness for a particular purpose with respect to this product. Having no control over its use, Lafarge will not guarantee finished work in which Lafarge True Lite Lightweight Aggregate is used.

LAFARGE NORTH AMERICA

NYCON

Nycon, Inc.
101 Cross Street
Westerly
Rhode Island
02891 USA
Phones
800 456 9266
401 596 3955
Fax
401 596 4242
Web
www.nycon.com
E-mail
nycon@nycon.com

March 24, 2010

To Whom it May Concern,

We hereby confirm the PVA-fiber product, Kuralon RF4000x30, meets the requirement of ASTM C1116, coming from past technical test data and papers.

The standard specification of this product is as follows:

Material:	Polyvinyl Alcohol
Configuration:	Chopped fiber
Color:	Yellowish White
Specific Gravity:	1.3
Length:	30 mm (1.18")
Tensile Strength:	900 MPa (130,500psi)
Chemical Stability:	Stable
Absorption:	Minimal

Best Regards,

Bob Cruso
Manager
New Nycon, Inc.
Tel 800 456 9266
bcruso@nycon.com

NYCON®

Product Information

KURALON™ RF4000	PVA Fibers for Structural Concrete Reinforcement

Kuralon RF4000 PVA fibers are designed to provide structural reinforcement in concrete applications as a replacement for wire mesh. The unmatched molecular bond strength of PVA fibers with concrete makes Kuralon RF4000 ideal for reinforcement or cracking control. This high bond strength eliminates the need for longer fibers, making mixing easier with less impact on slump. Kuralon RF4000 fibers are suitable for precast, ready mix or shotcrete applications.

Description:

Material:	Polyvinyl alcohol
Configuration:	Chopped fiber
Color:	Yellowish white
Specific Gravity:	1.3
Length:	1.18" (30mm)
Tensile Strength:	130,500 psi (0.9GPa)
Chemical Stability:	Stable
Absorption:	Minimal

Dosage:

Dosage rates for Kuralon RF4000 vary depending on the results desired. Structural benefits begin to accrue at a dosage of approximately seven pounds per cubic yard, typically for slabs, spalling prevention or precast applications. At more than 10 pounds per cubic yard, Kuralon RF4000 can replace or reduce wire mesh in shotcrete and other applications.

Benefits of Kuralon RF4000 Fibers in Concrete:

- Replacement or reduction of wire mesh providing a rust-free solution that is easier on users and equipment and reduces labor and material costs.
- Compared to steel, there are no sharp fiber protrusions.
- They are a more efficient reinforcement system than other conventional synthetic systems.

Applications:

- Industrial and warehouse floor slabs, Pavements, etc.
- Slope stabilization, tunnel linings, etc.
- New construction and repair airport aprons and taxiways
- Seismic and security safeguard in new structures, and upgrades to existing structures
- Septic tanks, vaults, and other specialty precast

Note:

Complete CSI manu-spec format specification and a material data safety sheet are available from your Nycon representative.

Support Services:

Nycon engineers are available for assistance in selecting the appropriate Nycon synthetic fiber product and dosage level for specific applications and for field support.

Nycon, Inc.
101 Cross Street
Westerly, RI 02891
Fax
401 596 4242
Web
www.nycon.com
E-mail
nycon@nycon.com
Phones
800 456 9266
401 596 3955

NYCON®

Helping You Build Smarter and Better.™

Nycon, Inc.
101 Cross Street
Westerly
Rhode Island
02891 USA
Phones
800 456 9266
401 596 3955
Fax
401 596 4242
Web
www.nycon.com
E-mail
nycon@nycon.com

March 24, 2010

To Whom it May Concern,

We hereby confirm the PVA-fiber product Kuralon RECS15x8 meets the requirement of ASTM C1116 coming from past technical test data and papers.

The standard specification of this product is as follows:

Material:	Polyvinyl alcohol
Configuration:	Chopped fiber
Color:	Yellowish White
Specific Gravity:	1.3
Length:	8mm (0.375”)
Tensile Strength:	1600MPa (232,000psi)
Chemical Stability:	Stable
Absorption:	Minimal

Best Regards,

Bob Cruso
Manager
New Nycon, Inc.
Tel 800 456 9266
bcruso@nycon.com

NYCON®

Product Information

KURALON™ RECS15	PVA Fibers for Structural Reinforcement

Kuralon RECS15 PVA fibers are designed to provide structural performance in a wide array of mortar applications. PVA-ECC (engineered cementitious composite), a customized mix design using inexpensive materials and Kuralon RECS15 PVA fibers, provides more than 200 times tensile strain capacity than other mixes with synthetic fibers. This new class of materials produces a mortar that behaves like aluminum in flexural and tensile deformation.

First developed at the University of Michigan, PVA-ECC with Kuralon RECS15 PVA fibers has characteristics that provide rich opportunity for many applications worldwide. Repair mortars, cement boards, high-rise curtain walls, seismic remediation, ductile pipes, etc., are but a few of the many applications for this innovative material . The unmatched molecular bond strength of PVA fibers with matrix makes Kuralon RECS15 fibers ideal for producing structural mortars like PVA-ECC. This high bond strength eliminates the need for longer fibers, making mixing easier with less impact on slump.

Description:

Material:	Polyvinyl alcohol
Configuration:	Resin-bundled chopped fiber
Color:	White or yellowish white
Specific Gravity:	1.3
Length:	1/3" (8mm)
Tensile Strength:	232,000 psi (1600 MPa)
Chemical Stability:	Stable
Absorption:	Minimal

Dosage:

The optimum fiber dosage of PVA-ECC at up to 44 lbs per cubic yard offers the possibility of reduced-steel and even steel-free reinforcement. This mix design was developed utilizing micromechanics to deliver tensile strain capacity more than 200 times greater than other synthetic fiber-reinforced mortars. PVA-ECC actually becomes stronger after the first crack is formed. In tensile or flexural deformation, the material more closely resembles the ductility of aluminum.

Dosages of 11-22 lbs per cubic yard of mix can be used to enhance the structural value of steel reinforcement. The use of PVA-ECC combined with steel reinforcement retards the yielding deformation and reduces hoop reinforcement. In addition, PVA-ECC typically produces multiple micro-cracks. Since these are too small for water to permeate, structural durability is enhanced.

Benefits of Kuralon RECS15 in Mortar:

Kuralon RECS15 eliminates the need for conventional steel reinforcement, as well as its attendant labor, time, and costs.

Applications:

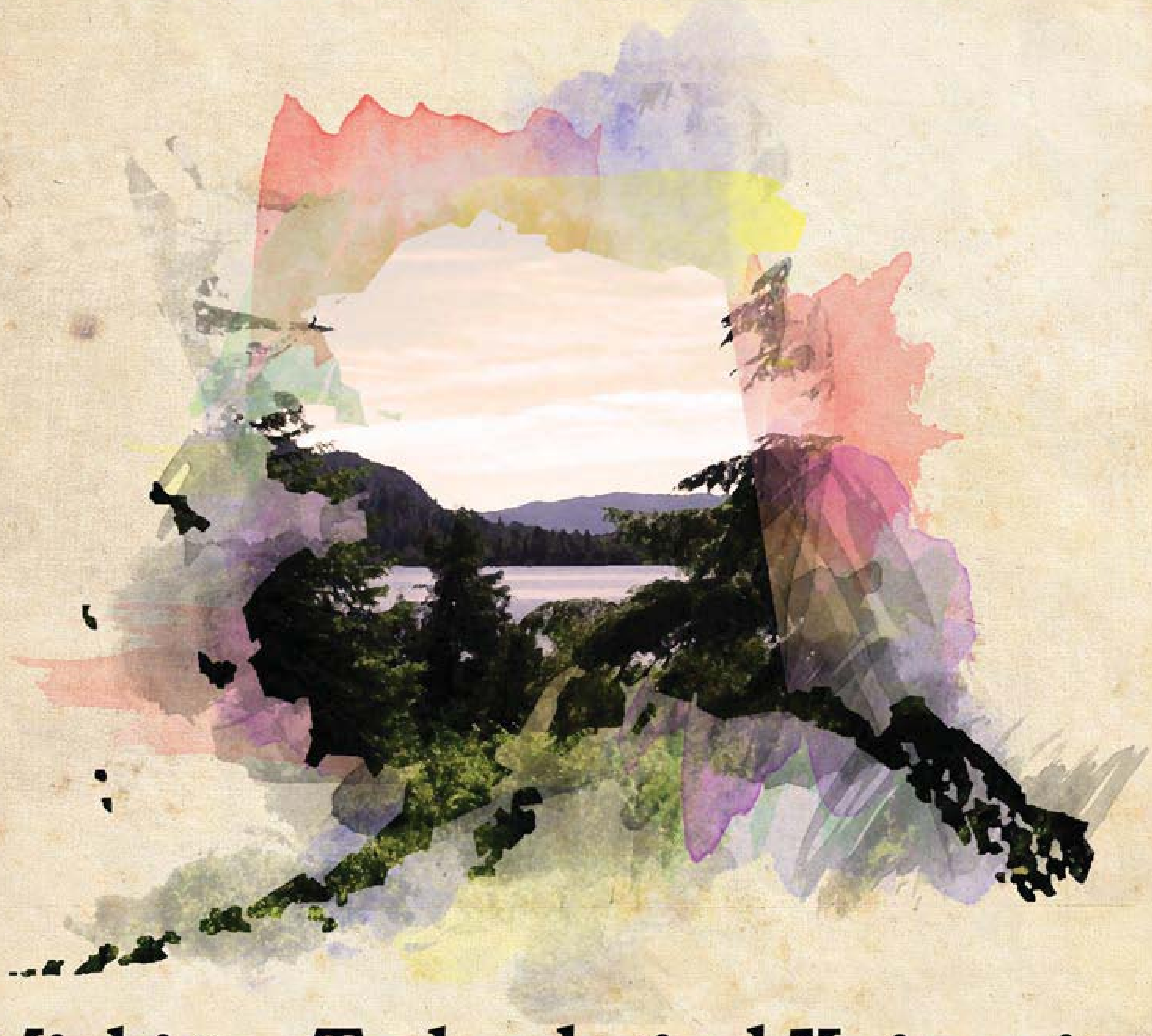
- New construction and repair of airport aprons and taxiways
- Security and seismic safeguards in new structures and upgrades to existing structures
- Industrial and warehouse slabs
- Tunnel linings
- Architectural and specialty precast shapes
- Repair mortars
- Replacement for glass fiber reinforced cement

Nycon, Inc.
101 Cross Street
Westerly, RI 02891
Fax
401 596 4242
Web
www.nycon.com
E-mail
nycon@nycon.com
Phones
800 456 9266
401 596 3955

NYCON®

Helping You Build Smarter and Better.™

FRONTIER



Michigan Technological University
Concrete Canoe
2010-2011 Design Paper

Table of Contents

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 has 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	164 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	60.2 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™ (NCCC) debating the accuracy of the team's Finite Element Analysis (FEA) and what the critical loading scenario actually was. Before the 2011 NCCC rules were released the team had cast a prototype canoe and created a detailed plan to empirically answer these questions.

Michigan Tech's prototype canoe, *Ursula*, was designed to test the possibility of using minimal reinforcement. The team theorized that the tensile strength of the concrete alone would be 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 just 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. Cutting *Ursula* into six-inch wide cross sections revealed that certain areas had been cast too thin. The second flaw was within the team's FEA, since it overlooked the concerns of punching shear stress. The loading area of the paddlers' weight was too large skewing the punching shear results.

After *Ursula* broke, the team shifted its focus to determine 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. Applying this rule, the Young's modulus of **POLARIS**'s three-fifths of an 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 creates 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 found the male sprint to be the critical loading case. To confirm this, 73 strain gages were placed at key locations on **POLARIS**. After many hours of testing, it was confirmed that the greatest tensile stress (85 psi) occurred on the outside gunwale 10 feet, 2 inches from the bow during the men's sprint buoy turn as seen in Figure 1 on page 2.

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 very close to the same for all of the team's canoes. Thus, the team assumed that the second moment of inertia and the strain gages distance from the neutral axis are the basis of the factor needed to convert stress from **POLARIS** to any other canoe of a similar hull shape. The team was then able to calculate a maximum gunwale 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 (see Figure 2).

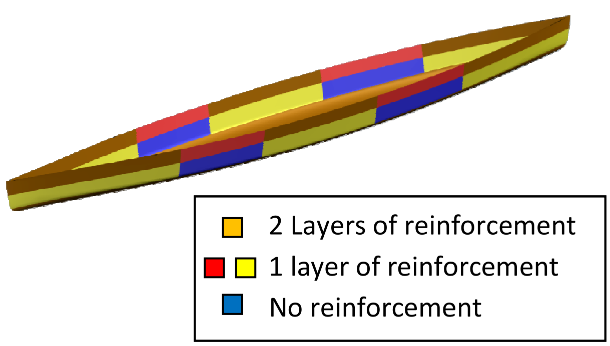


Figure 2: **FRONTIER**'s reinforcement scheme as viewed from above. The bow of the canoe is to the left.

Post Analysis

At the 2011 North Central Conference, a crack formed on **FRONTIER**'s port side 13 feet, 8 inches from the bow during the men's sprint preliminary races (see Figure 3). During the first strokes of the men's sprint race, the paddlers heard a cracking sound. However, the paddlers finished the race. Upon returning to shore, the team reviewed the extent of the damage and concluded that the concrete had failed structurally. The team believed that the four-and-a-half inch strip of reinforcement along the gunwale cap would be sufficient to hold the canoe together and continued racing. For the rest of the races, the team placed the stern paddler directly in line with the crack to avoid creating a larger moment about the fracture.

After competition an extensive visual inspection was done on **FRONTIER**. The team discovered that fine cracks formed on the starboard side of the canoe in both locations where there is no reinforcement. From the visual inspection the team concluded that the cause of the structural crack may be due to poor quality control that amplified a stress concentration created by the reinforcement scheme. In addition the team realized that when comparing the stresses of two canoes, both the bending moment equation and the torsion equation must be used. These equations depend on holding moment and torque values the same in both canoes. Using this combined-loading approach the team calculated a new maximum gunwale stress of 147 psi 10 feet, 2 inches from the bow. This stress was determined assuming that the paddlers could create a torque of 214 ft-lbs on the canoe during a buoy turn. The fine cracks were determined to have formed after the initial failure; when the stress normally held on the port side of the canoe was redistributed to go through the port side's reinforcement as well as the starboard side's reinforced concrete.

Figure 3: The structural crack on **FRONTIER**'s port side.

To ensure that **FRONTIER** withstands the national competition, the team tested reinforcement samples and ran additional empirical tests on **POLARIS**. The first test on **POLARIS** was used to determine whether the team overlooked a much larger stress in the areas where no reinforcement was placed during initial testing. These new tests proved however, that the team had previously determined the correct max stresses.

The team then tested **POLARIS** to see if moving the stern paddlers to the crack location would decrease the stresses the canoe would experience in that area. The move yielded an average stress reduction of 35%, resulting in a maximum tensile stress of 75 psi. After the move the team determined that the reinforcement produced a factor of safety of 3.28 through the structural crack. From the post-analysis testing the team is confident in **FRONTIER**'s ability to survive the NCCC.

Development and Testing

Due to matching hull designs, similar aesthetic demands, low unit weight, and ample strength, the team used the 2009-2010 mix, Kippis, as a baseline for this year's mix. Upon receiving this year's rules, the team began material research and testing. During testing, one aspect of each batch was changed while all other variables were held constant. The team used a five-tier system to adjust binders, aggregates, fibers, water to cementitious materials (w/c) ratio, and admixtures. These tiers are referred to as I, II, III, IV, and V, respectively.

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). Binders were that were dark in color were eliminated 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 to 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.

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 mix workability while retaining the w/c ratio and consequently, the strength of the mix. To achieve the necessary workability, the HRWR manufacturer's recommended 3-8 fl oz/cwt dosage was exceeded.

Six 2x4-inch cylinders were made for each batch tested. Compressive and split-tensile tests were completed in accordance with ASTM standards. After numerous weeks of mixing and testing, the team found this year's mix, Kodiak, to have ideal strength and unit weight properties, producing 1,026 psi in compression, 389 psi in tensile, and a unit weight of 60.2 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 chose Chromarat C-Grid® CT275 Carbon Fiber Grid as its primary reinforcement based on prior knowledge. 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.

As a paddler exerts pressure on the bottom of the canoe it will bow outward, increasing the potential for the concrete to crack. If this were to happen, water would seep 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 overestimating the normal in-plane stress while the punching shear stress was vastly underestimated. A 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, 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.

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 both a safety and compliance chair. 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 testing and construction tasks. 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 to account for travel costs for the 30 member team. Donated materials were estimated to be $12,000, while the team has had to spend $3,000 on remaining necessary materials. The Bill of Materials for FRONTIER can be found in Appendix C.

To meet analysis and design demands, 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 residual 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 3. 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 3: 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 – 3/30/11
Finishes Complete – 3/27/11
North Central Conference Competition – 4/3/11
Design Paper Submittal – 5/7/11
National Concrete Canoe 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 4 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.

Table 4: 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

The team ordered 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 to provide a stiff surface for concrete placement as well as create a barrier to prevent water loss through the foam.

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. Water-based stains were then used to enhance the overall aesthetic appeal. The canoe and school names were added using an inlay/outlay technique. A high-gloss sealer was applied completing the construction process.

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 actual stresses and determined the critical loading scenario of a canoe. These design uncertainties have perplexed competitors in the past.

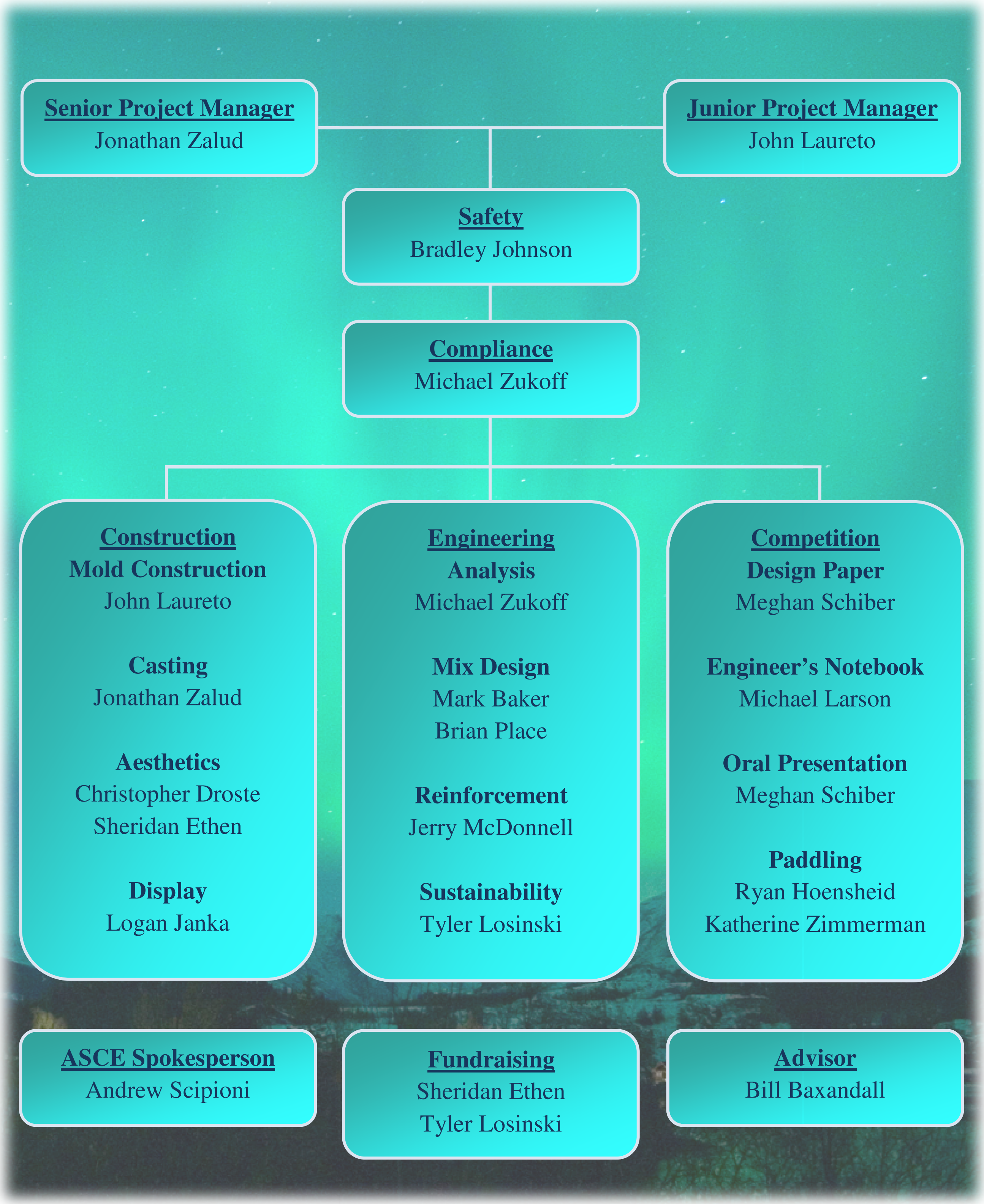
The team used 73 strain gages placed at key locations along POLARIS to disprove the coinciding FEA scheme and determine the most critical loading scenario. To capture data from full scale races, the strain gages were connected to Narada transmitters. These transmitters, created by a professor at Michigan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

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.

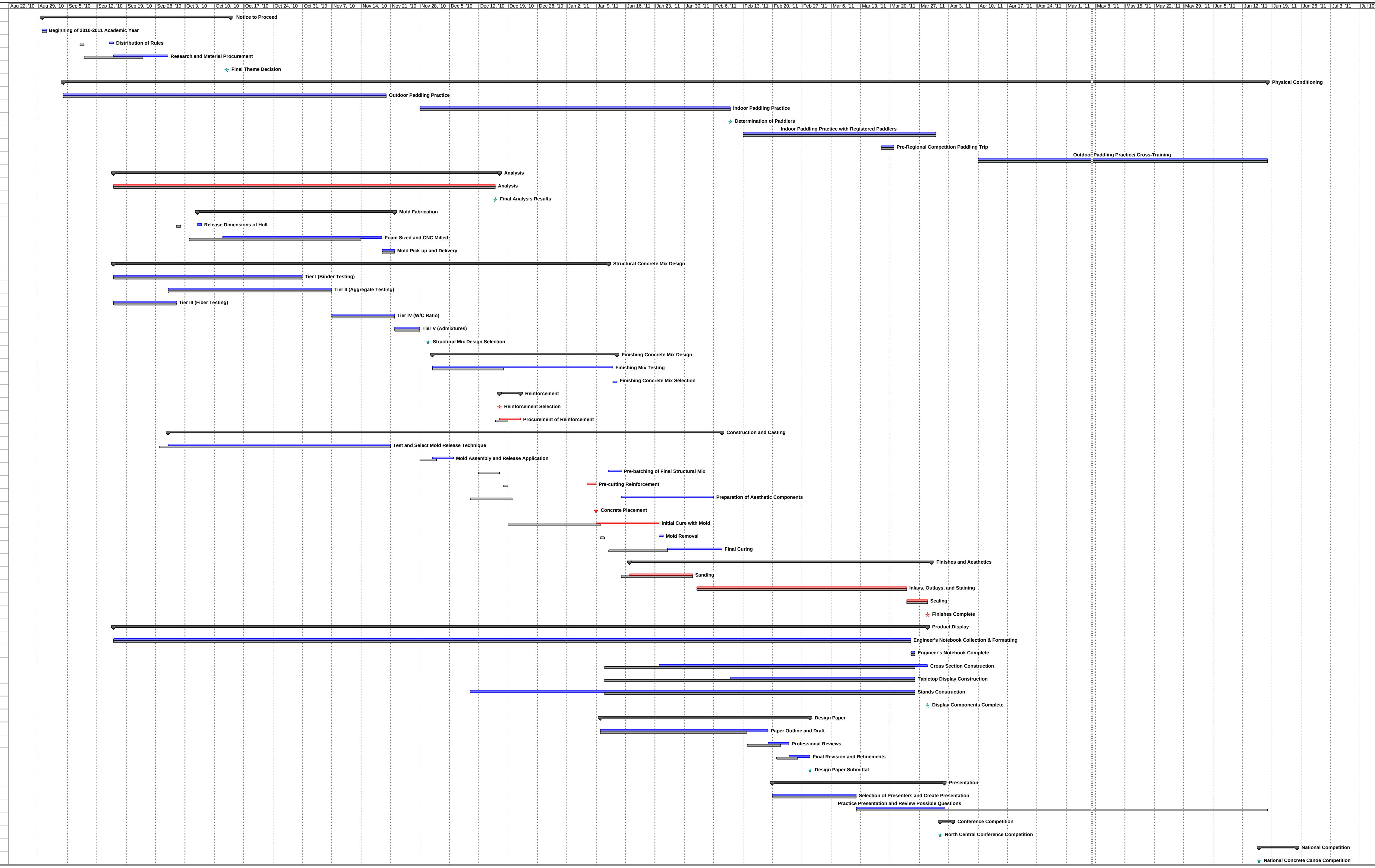
Another sustainable practice was the use of a release aid that was designed to separate concrete from an epoxy surface. This not only allowed for an easy de-molding of the canoe, but also caused no major damage to the mold, enabling the team to reuse the mold in the future.

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 aesthetically-appealing yet structurally-sound mix all combined to make FRONTIER the most engineered canoe ever produced by Michigan Tech.

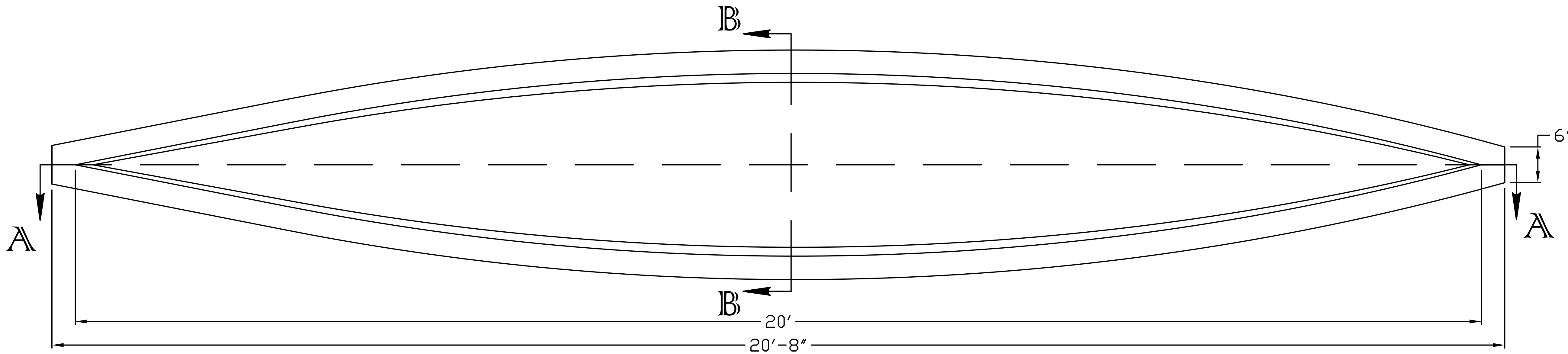
Organization Chart

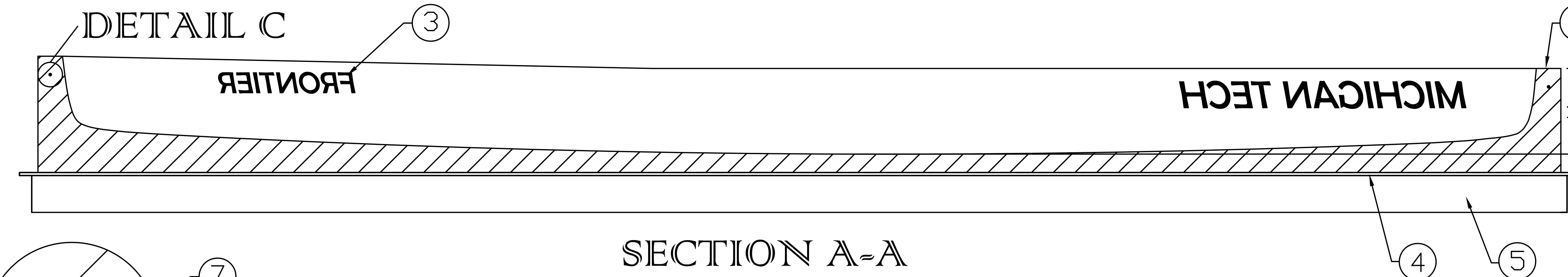


ID	Task Name	Baseline Start	Baseline Finish	~Actual Start~	~Actual Finish~
1	**Notice to Proceed**	**Mon 8/30/10**	**Wed 10/13/10**	**8/30/10**	**10/13/10**
2	Beginning of 2010-2011 Academic Year	Mon 8/30/10	Mon 8/30/10	8/30/10	8/30/10
3	Distribution of Rules	Wed 9/8/10	Wed 9/8/10	9/15/10	9/15/10
4	Research and Material Procurement	Thu 9/9/10	Wed 9/22/10	9/16/10	9/28/10
5	Final Theme Decision	Wed 10/13/10	Wed 10/13/10	10/13/10	10/13/10
6	**Physical Conditioning**	**Sat 9/4/10**	**Wed 3/30/11**	**9/4/10**	**On Track**
7	Outdoor Paddling Practice	Sat 9/4/10	Fri 11/19/10	9/4/10	11/19/10
8	Indoor Paddling Practice	Sun 11/28/10	Wed 2/9/11	11/28/10	2/9/11
9	Determination of Paddlers	Thu 2/10/11	Thu 2/10/11	2/10/11	2/10/11
10	Indoor Paddling Practice with Registered Paddlers	Sun 2/13/11	Wed 3/30/11	2/13/11	4/9/11
11	Pre-Regional Competition Paddling Trip	Fri 3/18/11	Sun 3/20/11	3/18/11	3/20/11
12	Outdoor Paddling Practice/ Cross-Training	Sun 4/10/11	Fri 6/17/11	4/10/11	On Track
13	**Analysis**	**Thu 9/16/10**	**Thu 12/16/10**	**9/16/10**	**12/16/10**
14	Analysis	Thu 9/16/10	Wed 12/15/10	9/16/10	12/15/10
15	Final Analysis Results	Thu 12/16/10	Thu 12/16/10	12/16/10	12/16/10
16	**Mold Fabrication**	**Fri 10/1/10**	**Sun 11/21/10**	**10/6/10**	**11/21/10**
17	Release Dimensions of Hull	Fri 10/1/10	Fri 10/1/10	10/6/10	10/6/10
18	Foam Sized and CNC Milled	Mon 10/4/10	Sat 11/13/10	10/12/10	11/18/10
19	Mold Pick-up and Delivery	Fri 11/19/10	Sun 11/21/10	11/19/10	11/21/10
20	**Structural Concrete Mix Design**	**Thu 9/16/10**	**Tue 11/30/10**	**9/16/10**	**11/30/10**
21	Tier I (Binder Testing)	Thu 9/16/10	Sat 10/30/10	9/16/10	10/30/10
22	Tier II (Aggregate Testing)	Wed 9/29/10	Sat 11/6/10	9/29/10	11/6/10
23	Tier III (Fiber Testing)	Thu 9/16/10	Thu 9/30/10	9/16/10	9/30/10
24	Tier IV (W/C Ratio)	Sun 11/7/10	Sun 11/21/10	11/7/10	11/21/10
25	Tier V (Admixtures)	Mon 11/22/10	Sat 11/27/10	11/22/10	11/27/10
26	Structural Mix Design Selection	Tue 11/30/10	Tue 11/30/10	11/30/10	11/30/10
27	**Finishing Concrete Mix Design**	**Wed 12/1/10**	**Thu 1/13/11**	**12/1/10**	**1/13/11**
28	Finishing Mix Testing	Wed 12/1/10	Fri 12/17/10	12/1/10	1/12/11
29	Finishing Concrete Mix Selection	Thu 1/13/11	Thu 1/13/11	1/13/11	1/13/11
30	**Reinforcement**	**Thu 12/16/10**	**Sat 12/18/10**	**12/16/10**	**12/21/10**
31	Reinforcement Selection	Thu 12/16/10	Thu 12/16/10	12/16/10	12/16/10
32	Procurement of Reinforcement	Thu 12/16/10	Sat 12/18/10	12/17/10	12/21/10
33	**Construction and Casting**	**Mon 9/27/10**	**Tue 1/25/11**	**9/29/10**	**2/7/11**
34	Test and Select Mold Release Technique	Mon 9/27/10	Sat 11/20/10	9/29/10	11/20/10
35	Mold Assembly and Release Application	Sun 11/28/10	Wed 12/1/10	12/1/10	12/5/10
36	Pre-batching of Final Structural Mix	Sun 12/12/10	Thu 12/16/10	12/16/10	12/18/10
37	Pre-cutting Reinforcement	Sat 12/18/10	Sat 12/18/10	1/7/11	1/8/11
38	Preparation of Aesthetic Components	Fri 12/10/10	Sun 12/19/10	12/19/10	1/9/11
39	Concrete Placement	Sun 12/19/10	Sun 12/19/10	1/9/11	1/9/11
40	Initial Cure with Mold	Sun 12/19/10	Sun 1/9/11	1/9/11	1/23/11
41	Mold Removal	Mon 1/10/11	Mon 1/10/11	1/24/11	1/24/11
42	Final Curing	Wed 1/12/11	Tue 1/25/11	1/25/11	2/7/11
43	**Finishes and Aesthetics**	**Sat 1/15/11**	**Tue 3/29/11**	**1/17/11**	**3/27/11**
44	Sanding	Sat 1/15/11	Mon 1/31/11	1/17/11	1/31/11
45	Inlays, Outlays, and Staining	Wed 2/2/11	Wed 3/23/11	2/2/11	3/21/11
46	Sealing	Thu 3/24/11	Mon 3/28/11	3/23/11	3/26/11
47	Finishes Complete	Tue 3/29/11	Tue 3/29/11	3/27/11	3/27/11
48	**Product Display**	**Thu 9/16/10**	**Sun 3/27/11**	**9/16/10**	**3/30/11**
49	Engineer's Notebook Collection & Formatting	Thu 9/16/10	Thu 3/24/11	9/16/10	3/29/11
50	Engineer's Notebook Complete	Fri 3/25/11	Fri 3/25/11	3/30/11	3/30/11
51	Cross Section Construction	Tue 1/11/11	Fri 3/25/11	1/21/11	3/25/11
52	Tabletop Display Construction	Tue 1/11/11	Fri 3/25/11	2/10/11	3/25/11
53	Stands Construction	Tue 1/11/11	Fri 3/25/11	12/10/10	3/17/11
54	Display Components Complete	Sun 3/27/11	Sun 3/27/11	On Track	3/30/11
55	**Design Paper**	**Mon 1/10/11**	**Fri 2/25/11**	**1/10/11**	**2/28/11**
56	Paper Outline and Draft	Mon 1/10/11	Sun 2/13/11	1/10/11	2/18/11
57	Professional Reviews	Mon 2/14/11	Mon 2/21/11	2/19/11	2/23/11
58	Final Revision and Refinements	Mon 2/21/11	Fri 2/25/11	2/24/11	2/28/11
59	Design Paper Submittal	Fri 2/25/11	Fri 2/25/11	2/28/11	2/28/11
60	**Presentation**	**Sun 2/20/11**	**Sat 4/2/11**	**2/20/11**	**On Track**
61	Selection of Presenters and Create Presentation	Sun 2/20/11	Fri 3/11/11	2/20/11	3/14/11
62	Practice Presentation and Review Possible Questions	Sat 3/12/11	Fri 6/17/11	3/15/11	On Track
63	**Conference Competition**	**Fri 4/1/11**	**Sun 4/3/11**	**4/1/11**	**4/3/11**
64	North Central Conference Competition	Fri 4/1/11	Sun 4/3/11	4/1/11	4/3/11
65	**National Competition**	**Thu 6/16/11**	**Sun 6/19/11**	**On Track**	**On Track**
66	National Concrete Canoe Competition	Thu 6/16/11	Sun 6/19/11	On Track	On Track

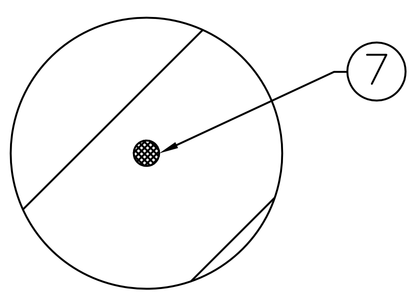


Critical Task Baseline Milestone Summary



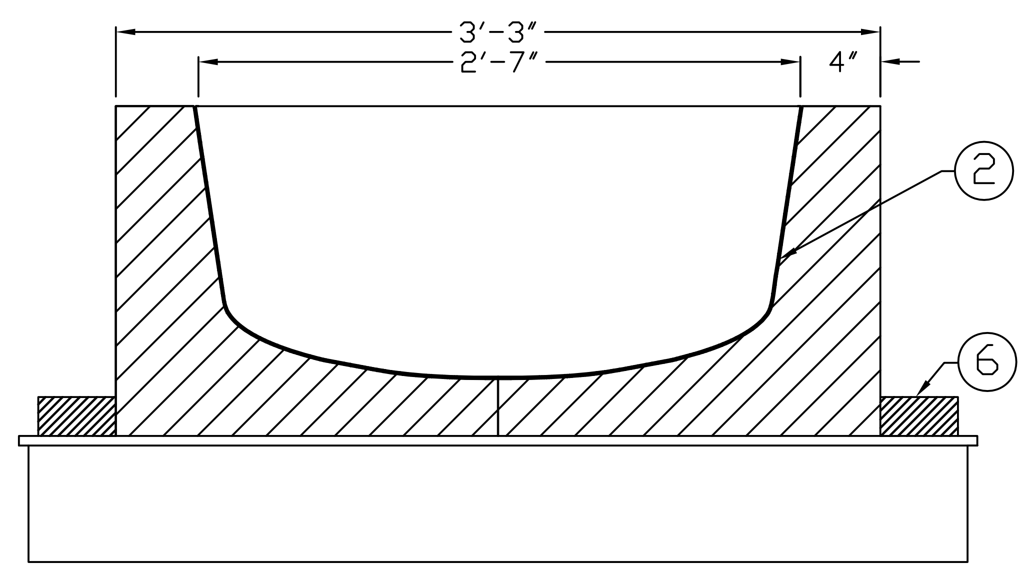


SECTION A-A



DETAIL C

SCALE 4:1



SECTION B-B

SCALE 2:1

BILL OF MATERIALS

NO.	DESCRIPTION	QTY.	UNIT COST	SUBTOTAL
1	POLYSTYRENE FOAM MOLD	2 PIECES	$800/PIECE	$1,600
2	EPOXY	1 GAL	$42.20/GAL	$42.20
3	VINYL INLAY	83 SQ IN	$0.12/SQ IN	$9.96
4	1/2″ OSB	48 SQ FT	$0.42/SQ FT	$20.16
5	2″X6″ LUMBER	56 LN FT	$0.48/LN FT	$26.88
6	2″X4″ LUMBER	4 LN FT	$0.35/LN FT	$1.40
7	3/8″ X 8″ BOLT ASSEMBLY	2 EA.	$0.75 EA.	$1.50
			TOTAL	$1,702.10

MichiganTech

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

DRAWING NAME: MOLD DESIGN	DATE: 2/24/2011
BOAT NAME: FRONTIER	
DRAWN BY: ANDREW SCIPIONI	SCALE: 1:20
CHECKED BY: JON ZALUD	SHEET: 9

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	326.04	1.659	0.68	0.003	332.40	1.691
CM2	Lafarge NewCem® GGBFS		2	157.80	1.264	0.33	0.003	160.88	1.289
CM3	VCAS™ 8		2.60	157.80	0.973	0.33	0.002	160.88	0.992
CM4	VCAS™ 160		2.60	157.80	0.973	0.33	0.002	160.88	0.992
	Total Cementitious Materials:			**799.45**	**4.868**	**1.67**	**0.010**	**815.04**	**4.963**
Fibers									
F1	Nycon Kuralon™ RF4000 30mm		1.30	10.53	0.130	0.02	0.000	10.74	0.132
F2	Nycon Kuralon™ RECS15 8mm		1.30	5.27	0.065	0.01	0.000	5.37	0.066
	Total Fibers:			**15.80**	**0.195**	**0.03**	**0.000**	**16.11**	**0.199**
Aggregates									
A1	Poraver® 1.0-2.0mm	Abs: 2.0	0.53	78.48	2.373	0.16	0.005	80.01	2.419
A2	Poraver® 0.5-1.0mm	Abs: 2.0	0.71	78.48	1.771	0.16	0.004	80.01	1.806
A3	Poraver® 0.25-0.5mm	Abs: 2.0	0.88	82.59	1.504	0.17	0.003	84.20	1.533
A4	3M™ K-1	Abs: 0.0	0.14	85.64	9.804	0.18	0.020	87.31	9.995
A5	Lafarge True Lite Aggregate™	Abs: 2.0	3.00	108.82	0.581	0.23	0.001	110.94	0.593
	Total Aggregates:			**434.01**	**16.033**	**0.91**	**0.033**	**442.48**	**16.346**
Water									
W1	Water for CM Hydration (W1a+W1b)		1.00	239.83	3.844	0.50	0.008	244.51	3.918
	W1a. Water from Admixtures^			94.93		0.002		96.78	
	W2b. Additional Water			144.91		0.50		147.73	
W2	Water for Aggregates, SSD		1.00	6.97		0.01		7.10	
	Total Water *(W1 +W2)*:			**246.80**	**3.844**	**0.52**	**0.008**	**251.62**	**3.918**
Solids Content of Latex Admixtures and Dyes									
S1	Xypex Xycrilic-Admix		1.05	112.19	1.712	0.23	0.004	114.38	1.746
	Total Solids of Admixtures:			**112.19**	**1.712**	**0.23**	**0.004**	**114.38**	**1.746**

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	215.24	84.77	3.43	0.002	219.44	86.42
Ad2	BASF Glenium 3030® NS HRWR	9.18	*lb/gal*	20.27	22.23	10.16	0.01	0.000	22.67	10.36
	Water from Admixtures (W1a) :					**94.93**		**0.002**		**96.78**

			Design Proportions	Actual Batch Proportions	Yielded Proportions
	Cement-Cementitious Materials Ratio		0.41	0.41	0.41
	Water-Cementitious Materials Ratio		0.3	0.3	0.3
	Slump, Slump Flow, *in.*		1.00 +/ 0.50	0.50	0.50
M	Mass of Concrete, *lbs*		1608.26	3.37	1639.62
V	Absolute Volume of Concrete, ft^3		26.652	0.055	27.172
T	Theoretical Density, lb/ft^3	= (M/V)	60.34	61.17	60.34
D	Design Density, lb/ft^3	= (M/27)	59.57		
D	Measured Density, lb/ft^3			60.20	60.20
A	Air Content, %	= [(T-D)/T x 100%]	1.29	1.58	0.24
Y	Yield, ft^3	= (M/D)	27	0.056	27
R_y	Relative Yield	= (Y/YD)		0.981	

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 End Cap								
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	318.09	1.618	0.68	0.003	327.43	1.666
CM2	Lafarge NewCem® GGBFS		2	153.96	1.234	0.33	0.003	158.48	1.270
CM3	VCAS™ 8		2.60	153.96	0.949	0.33	0.002	158.48	0.977
CM4	VCAS™ 160		2.60	153.96	0.949	0.33	0.002	158.48	0.977
	Total Cementitious Materials:			**779.95**	**4.750**	**1.67**	**0.010**	**802.86**	**4.889**
Aggregates									
A1	Poraver® 1.0-2.0mm	Abs: 2.0	0.53	68.34	2.067	0.15	0.004	70.35	2.127
A2	Poraver® 0.5-1.0mm	Abs: 2.0	0.71	68.34	1.543	0.15	0.003	70.35	1.588
A3	Poraver® 0.25-0.5mm	Abs: 2.0	0.88	71.63	1.305	0.15	0.003	73.74	1.343
A4	3M™ K-1	Abs: 0.0	0.12	77.39	10.002	0.17	0.021	79.66	10.295
A5	Lafarge True Lite Aggregate™	Abs: 2.0	3.00	96.20	0.514	0.21	0.001	99.02	0.529
	Total Aggregates:			**381.91**	**15.429**	**0.82**	**0.033**	**393.13**	**15.882**
Water									
W1	Water for CM Hydration (W1a+W1b)		1.00	233.99	3.750	0.50	0.008	240.86	3.860
	W1a. Water from Admixtures^			92.61		0.00		95.33	
	W2b. Additional Water			141.37		0.50		145.52	
W2	Water for Aggregates, SSD		1.00	6.09		0.01		6.27	
	Total Water *(W1 +W2)* **:**			**240.08**	**3.750**	**0.51**	**0.008**	**247.13**	**3.860**
Solids Content of Latex Admixtures and Dyes									
S1	Xypex Xycrilic-Admix		1.05	109.45	1.671	0.23	0.004	112.67	1.720
	Total Solids of Admixtures:			**109.45**	**1.671**	**0.23**	**0.004**	**112.67**	**1.720**
Admixtures (including Pigments in Liquid Form)			% Solids	Dosage (fl oz/cw t)	Water‡ in Admixture (lb/yd^3)	Amount (fl oz)	Water‡ in Admixture (lb)	Dosage (fl oz/cw t)	Water‡ in Admixture (lb)
Ad1	Xypex Xycrilic-Admix	8.76 *lb/gal*	28.02	215.24	82.70	3.43	0.002	221.57	85.13
Ad2	BASF Glenium 3030® NS HRWR	9.18 *lb/gal*	20.27	22.23	9.91	0.01	0.000	22.88	10.21
	Water from Admixtures (W1a) **:**				**92.61**		**0.002**		**95.33**
	Cement-Cementitious Materials Ratio			0.41		0.41		0.41	
	Water-Cementitious Materials Ratio			0.3		0.3		0.3	
	Slump, Slump Flow, *in.*			2.00 +/ 0.50		1.50		1.50	
M	Mass of Concrete, *lbs*			1511.39		3.24		1555.79	
V	Absolute Volume of Concrete, ft^3			25.599		0.055		26.351	
T	Theoretical Density, lb/ft^3	= (M/V)		59.04		59.04		59.04	
D	Design Density, lb/ft^3	= (M/27)		55.98					
D	Measured Density, lb/ft^3					58.55		58.55	
A	Air Content, %	= [(T-D)/T x 100%]		5.19		0.83		0.83	
Y	Yield, ft^3	= (M/D)		27		0.055		27	
R_y	Relative Yield	= (Y/YD)				0.971			

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	298.34	1.518	0.64	0.003	290.67	1.479
CM2	Lafarge NewCem® GGBFS		2	150.71	1.208	0.32	0.003	146.84	1.177
CM3	VCAS™ 8		2.60	152.76	0.942	0.33	0.002	148.83	0.917
CM4	VCAS™ 160		2.60	100.47	0.619	0.22	0.001	97.89	0.603
	Total Cementitious Materials:			**702.29**	**4.286**	**1.51**	**0.009**	**684.23**	**4.176**
Aggregates									
A1	Poraver® 0.25-0.5mm	Abs: 2.0	0.88	252.21	4.593	0.54	0.010	245.72	4.475
A2	3M™ K-1	Abs: 0.0	0.14	98.42	11.266	0.21	0.024	95.89	10.977
A3	Lafarge True Lite Aggregate™	Abs: 2.0	3.00	133.28	0.712	0.29	0.002	129.85	0.694
	Total Aggregates:			**483.91**	**16.571**	**1.04**	**0.036**	**471.47**	**16.145**
Water									
W1	Water for CM Hydration (W1a+W1b)		1.00	210.69	3.376	0.45	0.007	205.27	3.290
	W1a. Water from Admixtures^			144.42		0.00		140.71	
	W2b. Additional Water			66.27		0.45		64.56	
W2	Water for Aggregates, SSD		1.00	7.71		0.02		7.51	
	Total Water *(W1 +W2)* **:**			**218.40**	**3.376**	**0.47**	**0.007**	**212.78**	**3.290**
Solids Content of Latex Admixtures and Dyes									
S1	Xypex Xycrilic-Admix		1.05	164.96	2.518	0.35	0.005	160.72	2.453
	Total Solids of Admixtures:			**164.96**	**2.518**	**0.35**	**0.005**	**160.72**	**2.453**
Admixtures (including Pigments in Liquid Form)			% Solids	Dosage (fl oz/cw t)	Water‡ in Admixture (lb/yd^3)	Amount (fl oz)	Water‡ in Admixture (lb)	Dosage (fl oz/cw t)	Water‡ in Admixture (lb)
Ad1	Xypex Xycrilic-Admix	8.76 *lb/gal*	28.02	360.27	124.64	5.18	0.003	351.01	121.43
Ad2	BASF Glenium 3030® NS HRWR	9.18 *lb/gal*	20.27	49.26	19.78	0.02	0.000	47.99	19.27
	Water from Admixtures (W1a) **:**				**144.42**		**0.004**		**140.71**
Cement-Cementitious Materials Ratio				0.42		0.42		0.42	
Water-Cementitious Materials Ratio				0.3		0.3		0.3	
Slump, Slump Flow, *in.*				4.50 +/ 0.50		5.00		5.00	
M	Mass of Concrete, *lbs*			1569.56		3.38		1529.21	
V	Absolute Volume of Concrete, ft^3			26.752		0.058		26.064	
T	Theoretical Density, lb/ft^3	= (M/V)		58.67		58.67		58.67	
D	Design Density, lb/ft^3	= (M/27)		58.13					
D	Measured Density, lb/ft^3					57.69		57.69	
A	Air Content, %	= [(T-D)/T x 100%]		0.92		1.67		1.67	
Y	Yield, ft^3	= (M/D)		27		0.059		27	
R_y	Relative Yield	= (Y/YD)				1.026			

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/cw t)	Water‡ in Admixture (lb/yd^3)	Amount (fl oz)	Water‡ in Admixture (lb)	Dosage (fl oz/cw t)	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

					Design Proportions (Non SSD)		Actual Batch Proportions		Yielded Proportions	
Mixture: Kodiak Blue 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	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/cw t)	Water‡ in Admixture (lb/yd^3)	Amount (fl oz)	Water‡ in Admixture (lb)	Dosage (fl oz/cw t)	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* *ǂ 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/cw t)	Water‡ in Admixture (lb/yd^3)	Amount (fl oz)	Water‡ in Admixture (lb)	Dosage (fl oz/cw t)	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

Lafarge NewCem® GGBFS	lb	28.5	$ 0.0054	$ 0.15
VCAS™ 8	lb	28.5	$ 0.35	$ 9.98
VCAS™ 160	lb	28.5	$ 0.35	$ 9.98
Poraver® 1.0-2.0mm	lb	11.8	$ 0.85	$ 10.03
Poraver® 0.5-1.0mm	lb	8.83	$ 0.85	$ 7.51
Poraver® 0.25-0.5mm	lb	11.8	$ 0.85	$ 10.03
Lafarge True Lite Lightweight Aggregate™	lb	14.7	$ 0.003	$ 0.04
3M™ K-1	lb	11.8	$ 11.03	$ 130.15
Nycon Kuralon™ RECS15 (8mm) PVA	lb	0.99	$ 6.60	$ 6.53
Nycon Kuralon™ RF4000 (30mm) PVA	lb	1.98	$ 6.90	$ 13.66
Xypex Xycrylic-Admix	lb	14.1	$ 5.10	$ 71.95
BASF Glenium® 3030 NS	gal	0.16	$ 15.00	$ 2.40
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	0.20	$ 68.95	$ 13.79
Ameripolish Water-Based Concrete Dye Blue	gal	0.10	$ 68.95	$ 6.90
Ameripolish Water-Based Concrete Dye Green	gal	0.05	$ 68.95	$ 3.45
Ameripolish Water-Based Concrete Dye Red	gal	0.10	$ 68.95	$ 6.90
Ameripolish Water-Based Concrete Dye Yellow	gal	0.05	$ 68.95	$ 3.45
ChemMasters Crystal Clear-A	gal	1.00	$ 22.00	$ 22.00
Huron Technologies Release Coating 7572	gal	0.25	$ 22.50	$ 5.63
Mold	LS	1	$ 1,702.10	$ 1,702.10
Total Production Cost				**$ 2,253.64**