

Construction of a Concrete Canoe for the 2012 ASCE Student Conference



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We would also like to thank Mark Mackenzie, the Quality Control Plant Manager at Erie Haven, for his knowledge and guidance regarding materials to be used in the concrete mix designs, as well as providing contacts for various companies. There are also several students that assisted in the concrete canoe casting, and de-molding of the canoe: Ryan Prince, Zach Estes, Nicholas Fenton, and Dustin Lambert. Also, a concrete canoe team was established to race the canoe at competition. The canoe team consisted of: Jacob Allen, Nicholas Fenton, Ethan Hess, Dustin Lambert, Ryan Prince, Amanda Bade, Alee Carlsgaard, Cristy Gimbel, Emily Hauter, and Jessica Sample. The design team is so grateful for the help and assistance of these individuals.

There were also several companies that donated materials or monetary values this semester that were essential to completing the mold construction, canoe construction, transportation of the canoe, and competing in the 2012 Great Lakes Conference. The companies that donated materials or monetary values were Lafarge, GRACE Construction Products, Haydite, Speedway Redi Mix, Direct Colors, American Structurepoint, I-69 Trailer, Engineering Resources, and Three Rivers Running Company. The full list of companies and the material(s) they donated can be found in Appendix A.

Without the help, assistance, guidance, and/or donation from these individuals and companies, the concrete canoe would have been much more challenging, if possible at all.

Abstract

As the Indiana-Purdue University Fort Wayne (IPFW) student chapter of American Society of Civil Engineers (ASCE) continues to grow, so does the desire to participate in civil engineering conferences. This year, the IPFW ASCE student chapter proposed that the senior civil engineering students design, test, and build a concrete canoe for the Concrete Canoe competition at the Regional ASCE Student Chapter Conference. This conference allows the civil engineering students at IPFW to be recognized for their engineering abilities compared to the other engineering schools around the nation. The 2012 concrete canoe was chosen as a senior design project to establish a strong foundation for future civil engineering students to design, build, and compete successfully in ASCE competitions.

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The first semester of the year (Fall 2011) was dedicated to the analysis and design of the concrete canoe, and establishing the schedule and budget to create a successful canoe in the time required. The second semester of the year (Spring 2012) was devoted to executing the canoe design to produce the final product to compete in the ASCE Student Chapter Conference. To create the final product, various steps were involved: building the wood interior and exterior mold, casting the canoe, finishing, establishing a transportation plan, and preparing for all the competition requirements. The canoe competition involved a final product display, racing the canoe, a design paper, and an oral presentation. IPFW competed successfully on April 20, 2012 against other engineering schools in the Midwest area and achieved impressive results in all of the canoe competitions.

Introduction

Problem Statement

Since the early 1970's the student organizations of American Society of Civil Engineers (ASCE) have conducted the concrete canoe competition. In the fall of 2010, the IPFW student chapter of ASCE decided to enter their first concrete canoe competition in the spring of 2011. This school year, the senior design team will tackle designing and building the canoe for the competition in the spring of 2012.

In order to design and produce a successful concrete canoe for competition, the senior design team had to review and interpret the rules and regulations as stated in the 2012 ASCE National Concrete Canoe Competition Rules and Regulations. According to the rules and regulations of the competition, the development of the canoe can be broken down into these four categories: analysis, development and testing, project management and construction, and innovation and sustainability. In the first semester, the canoe design was analyzed for buoyancy and strength. The concrete mix designs were tested to meet the specifications according to the competition. Team members explored new options in sustainable materials required for the concrete mix design.

In the spring semester, senior design team learned leadership skills, along with practical experience in project management and construction. The newest technologies and innovative ideas were implemented in the construction of the canoe whenever possible, and the design team explored various alternatives and developed a transportation plan for the canoe.

The completion of the concrete canoe included various aspects of civil engineering and involved a combination of management, construction, concrete design, environmental topics, communication, and transportation of the final product.

Background

For years, universities from around the world have competed in designing, building and racing concrete canoes. The first ASCE national canoe competition occurred in 1988, and 22 years later, the IPFW ASCE student chapter participated in their first competition at the University of Wisconsin-Milwaukee in Spring of 2011.

Each year ASCE comes out with new rules and regulations to make the competition more challenging and to ensure previous canoe designs are altered. Dimensions, concrete mix design variables and percentage of sustainable materials are some of the factors that can be varied from year to year.

Despite some complications with the 2010-2011 concrete canoe, the experience provided a good foundation for the 2011-2012 IPFW concrete canoe design. Considering this is a competition, the design team analyzed the winning aspects from the top performing canoes from previous years.

Scope

As defined in the “Design of a Concrete Canoe for the 2012 ASCE Student Conference,” the scope of the entire project was as follows:

1. The canoe will be delivered to the host’s place of competition in April of 2012.
2. Funding will be provided by IPFW ASCE, not by the canoe build and design team.
3. Finite Element Analysis (FEA) and hand calculations will be done before mold design can be finalized.
4. FEA will determine stress and displacements on canoe.
5. Mold design will meet required dimensions as specified in the rules.
6. Mold will be designed and built for ease of casting and de-molding.
7. Mold will be created in such a way that it is transportable to competition.
8. Concrete mix design will meet all criteria as set out in the rules.
9. Several mix designs will be tested before construction of canoe to find the optimal design.
10. Concrete mix designs will use sustainable materials when possible.
11. Transport canoe to competition without compromising the integrity of the canoe.

Spring Semester Goals

To construct the canoe for the 2012 ASCE Great Lakes Conference, the design team had to establish a list of goals to be completed in the 2012 Spring Semester. The goals for this semester were as follows:

1. Build the concrete canoe according to the design established in the Fall Semester, as defined in “Design of a Concrete Canoe for the 2012 ASCE Student Conference.”
2. Transport the canoe safely from Fort Wayne, Indiana to the 2012 Great Lakes Conference held at Bradley University in Peoria, Illinois.
3. Compete successfully at the 2012 Great Lakes Conference.

Project Breakdown

Since the 2011 Fall Semester was dedicated to the design of the concrete canoe, the 2012 Spring Semester was devoted to constructing the canoe according to the design. The design of the canoe was divided into four main tasks: finite element analysis (FEA), concrete mix design, mold design, and construction management. To achieve the Spring Semester goals as stated above, a parametric study was done to optimize the thickness of the canoe before construction. The construction of the canoe involved various tasks: mold construction, casting the canoe, removing the mold, finishing the canoe, preparing for competition, transporting the canoe, and competing in the 2012 ASCE Great Lakes Conference. Each member of the senior design team was actively involved in completing these tasks.

Constraints and Limitations

Rules and Regulations

The 2012 Rules and Regulations contain over sixty pages of competition parameters, with thirteen sections specifically outlining each significant segment of the competition. The thirteen sections are defined as follows:

1. General Rules and Regulations: provides a summary of what each school must do to be qualified and general information about the competition.
2. Canoe: provides the specification for the canoe to be built, such as dimensions, structural materials that can be used, and defining which canoes will be allowed to race.
3. Concrete: provides specification for the concrete mix design. This section was used in developing the concrete mix design.
4. Reinforcement: provides specifications for the various materials that be used as reinforcement, as well as the percent open-area allowed for the reinforcement.
5. Finishing: provides the specifications for the various materials that may be used to finish the surface of the canoe.

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6. Design Paper: determines the topics that must be covered in the design paper, such as concrete and composite development and testing, project management, innovations and sustainable aspects of the design.
7. Engineer's Notebook: intended to serve as a technical document, which contains the supportive information for the design and construction of the canoe.
8. Oral Presentation: contains the details for presentation to be given at the host school during the conference.
9. Final Product (Canoe and Cutaway Section): describes the various aspects of the Final Product judging and to provide guidance to the judges on the criteria for the assessment.
10. Product Display: provides the details as to limitations on how to set up the display featuring the tabletop display, concrete cylinder(s), sample(s) of concrete aggregate(s), seat and/or mats, and the Engineer's Notebook.
11. Race Rules and Regulations: this provides a guideline as to how the races will be conducted, including the rules of the races.
12. National Qualifying Rules: allows for teams that would like to be eligible to participate at the national level to follow the nation rules.
13. Overall Scoring: provides the scoring breakdown and how the scoring will take place.

For the full set of the 2012 ASCE National Concrete Canoe Competition Rules and Regulations, please visit: <http://www.concretecanoe.org/2012Trivia/2012NCCCRulesRegulations.pdf>.

Parametric Study

Additional finite element analysis was conducted to determine the most optimal and economical thickness for the canoe. Finite element analysis to determine the stress within the canoe can be found in the Fall Semester senior design team's paper: "Design of a Concrete Canoe for the 2012 ASCE Student Conference." From that analysis, case 2 was found to be the most critical case because it had the highest tensile stresses. This case consisted of 4 people in the canoe, weighing 200 pounds each, and the water pressure up to the rim of the canoe. It was found that the maximum principle tensile stress was 51 psi. To determine the most optimal and economical thickness for the canoe; a parametric study was conducted. The parametric study used the same forces as in case 2, but increased the thickness from 1" to 2" and decreased the thickness from 1" to ½". All the forces remained constant throughout the parametric study. The maximum principle tensile stress was recorded for each thickness analyzed. The maximum tensile stress is the most critical stress because concrete is weakest under tension so the maximum tensile stress was controlling. The results can be seen in Figure 1.

Tensile Stress versus Canoe Thickness

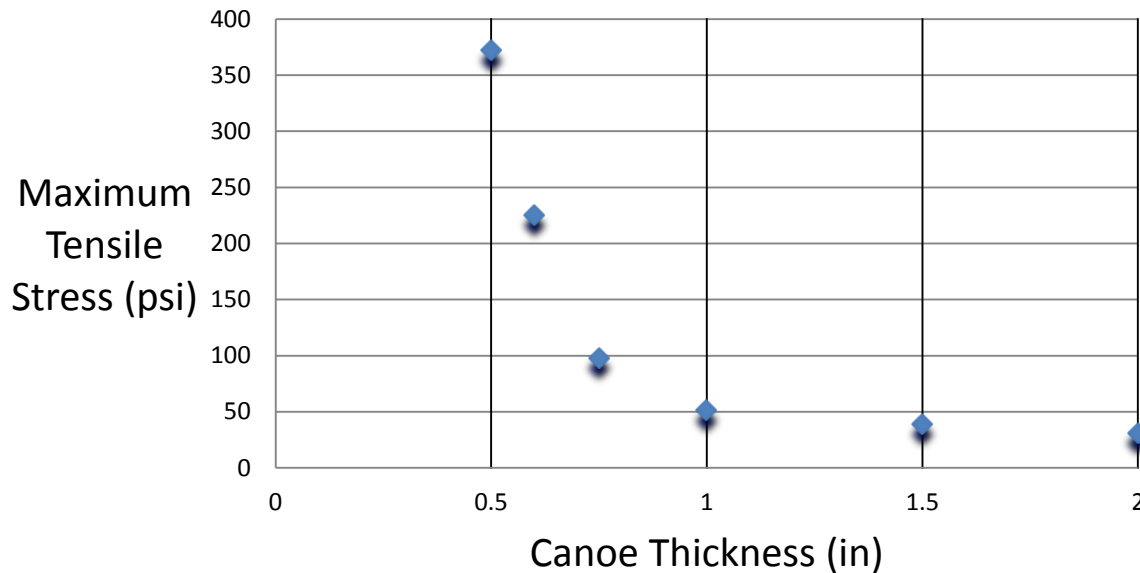


Figure 1: Parametric Study.

The results found that the 1" thickness was both optimal and economical for the concrete canoe. If the thickness was increased the maximum principle tensile stress would not decrease by very much (change in stress from 1" to 2" was a 20 psi decrease). When the thickness decreased, the maximum principle tensile stress would increase exponentially (change in stress from 1" to ½" was a 320 psi increase). The 1" thickness was the most optimal and economical because it is using the least amount of concrete, and has a low maximum tensile principle stress.

Mold Construction

The mold construction for the spring 2012 concrete canoe began as soon as finals were over during the Fall 2011 semester. Since the design was finalized, the materials would need to be estimated and then purchased. The primary materials used in the construction of the mold were medium density fiberboard (MDF), dimensional lumber (2x4), 5mm hardwood plywood. The mold construction was broken down into six phases: 1) Drawing AutoCAD patterns 2) Base Construction 3) Skeleton construction 4) creating the surface of the mold 5) surface finishing and 6) creating the graphics.

Phase 1: AutoCAD Patterns

The first phase of the mold construction was to draw the interior and exterior cross sections using AutoCAD in order to create patterns to be printed off and cut out. These patterns were drawn at one foot increment cross sections using AutoCAD and then they were printed off at a 1:1 scale. The exterior cross sections used from last year's specifications were easy to

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manipulate, creating the necessary patterns. The interior mold cross sections were simply the dimensions of the exterior that have been offset by one inch for the thickness of the hull plus 5mm for the thickness of the plywood. After each pattern was printed and cut out of the paper, the corresponding interior and exterior cross section patterns were compared to each other to ensure correct hull thickness at each respected one foot increment along the length of the skeleton. Once this process was complete, the second phase of the mold construction could begin. This process can be seen below in Figure 2.

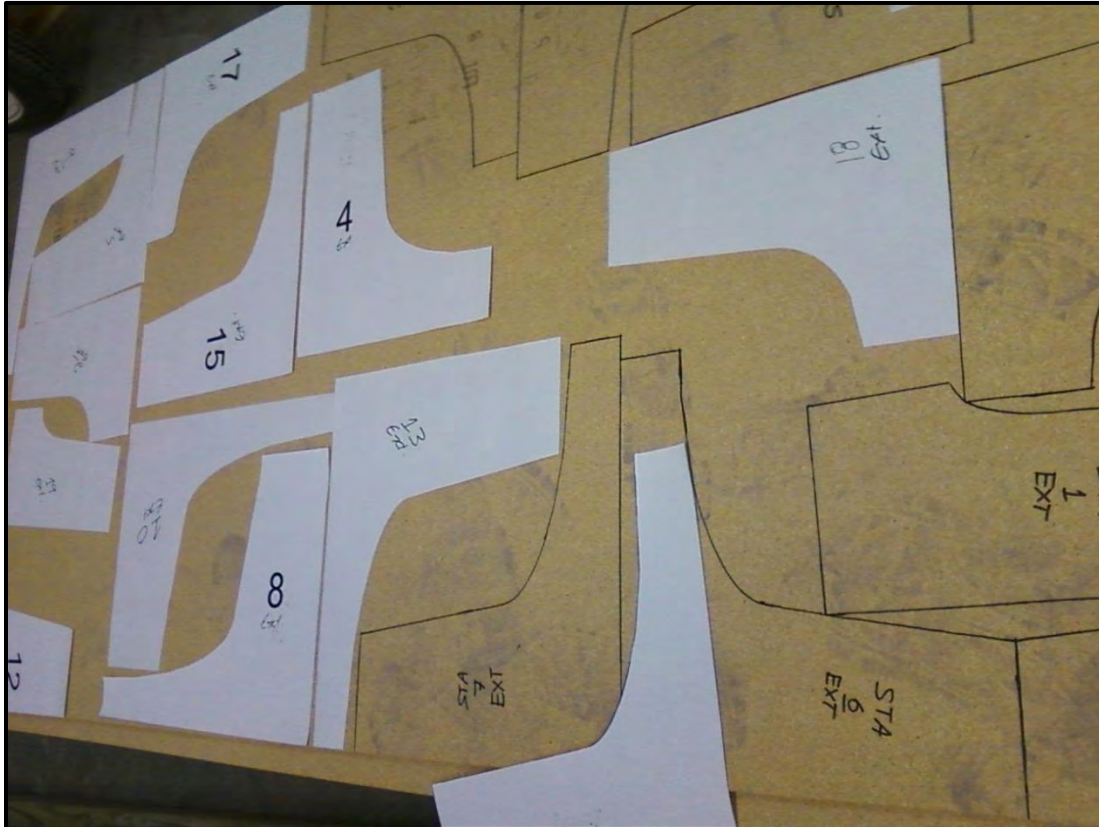


Figure 2: Patterns drawn in AutoCAD.

Phase 2: Base Construction

A strong base to support both the mold and the canoe during casting and/or curing would need to be constructed to ensure the mold does not flex much and the complete structure can be moved around if needed since other people will be using the laboratory space during our canoe construction phase. The base was divided into four sections along the length that correspond to the length of each section that the mold will be divided into. The middle two base sections are each six feet long while the two end sections are five feet long. The overall width of the base is four feet and the base top sits approximately 22 inches from the floor. Each of the sections was created in the same manor. The four legs of the section were made out of 4x4 dimensional lumbers. 2x4's connected each of the legs at both the top and bottom of each leg for lateral stability. Four inch wheels were purchased to allow each base section to roll. These wheels were mounted to the bottom of each leg. MDF was used as the base top and was

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simply cut to fit the top. During casting, the mold will be joined together with mechanical fasteners through the 2x4's that face each other of each section. As base sections are completed, the sections of the exterior mold could begin fabrication to reduce time and to maximize labor usage. The base can be seen in Figure 3, along with the skeleton of the canoe.

Phase 3: Skeleton Construction

Exterior mold

The patterns created on AutoCAD were arranged onto the MDF for the purposes of maximizing the wood usage, reducing the waste and minimizing the cost. All of the patterns for both the interior and exterior were labeled to reduce the confusion as to which side of the canoe hull each section belongs. Each pattern was then traced onto the MDF and then each pattern was cut out of the MDF. All of the pieces cut out of the MDF had specific dimensions and belonged to a specific part of the mold. The combination of all of the MDF pieces would make up the "skeleton" of the mold. Each section of the base would be a platform for two of the mold section since the mold (base on the design) would be able to separate down its length. Therefore, two pieces of MDF was cut so that when combined, they would be the same size as each base section. Each of the skeleton pieces would be arranged to their respected position and place onto each respected mold section.

Each of the skeleton pieces would be fixed to each mold section with drywall screws, glue and reinforces with more pieces of MDF in each corner of each skeleton piece. There was a piece of MDF that would be cut (created on AutoCAD, pattern cut out) to fit the top, leading exterior edge of the canoe. Every single exterior mold section was created in the same manor. Throughout this process, all of the sections must be checked to ensure that the entire structure is in alignment.

Interior Mold

After the patterns were cut out of the MDF, they were arranged in order by their respected position. Since the interior mold was separated into six, equally-spaced section of three feet, each skeleton piece was fixed to a three feet long, six inch wide piece of MDF. Lateral supports were cut and fixed to each skeleton section. 2x4's were cut approximately three feet in length and mounted to the MDF three foot lengths and will be used as handles or lifting points for each section. All of the sections must be checked to ensure that the entire structure is in alignment.



Figure 3: Skeleton of canoe being constructed on top of base.

Phase 4: Mold Surface

Exterior Mold

Applying the plywood surface was the most difficult part of this construction process. All of the 5mm plywood was cut to two feet wide sections, and then soaked in water for a minimum of 24 hours. After the wood was saturated, the wood was measured as to where the wood would begin to bend as it is pressed into the curvature of the skeleton. Once the measurements were taken, the wood was scored using a carpenter's knife approximately half the depth of the thickness. Each plywood section was then pressed into place, and then nailed down with pneumatic brad gun. Each piece of plywood was then trimmed to the edge of the mold. Some sections may need to be patched with more plywood due to the effects of trying to bend a two dimensional surface into a three dimensional shape. Once each section is completed and all patches have been made, the final phase is ready to begin. Throughout this process, all of the sections must be checked to ensure that the entire structure is in alignment.

Interior Mold

Through trial and error, it was determined that the best way to wrap each interior mold section with the plywood is do it in three pieces. Two of these pieces would start at the top edge of each interior mold section and be wrapped to the curvature of the mold section. The third

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piece would be cut to join each side of the mold section from the curved surfaces. Each of the three pieces should be reinforced from the inside to ensure these pieces do not separate or shift during casting. This process is repeated for all interior mold sections. The applying of the plywood can be seen in Figure 4.



Figure 4: Applying the soaked plywood to the canoe skeleton.

Phase 5: Surface Finishing

Finishing the surface of the mold was the same for all of the interior and exterior sections. This process began by aligning all of the sections together for both the interior mold and the exterior mold. All of the mold sections were fastened together and then marked to show how each section lines up to each other. Joint compound was applied to the plywood of both the interior mold and exterior mold, filling in any gaps, cracks, nail holes or any other imperfections. All of the surfaces were sanded until the desired quality had been achieved, as seen in Figure 5. Finally, the plywood was coated with spray adhesive and be allowed to become tacky. A thin layer of plastic (saran wrap) was applied to the surface to give a final, finished surface to the exterior of the canoe as well as ease the de-molding process, and can be seen in Figure 6.



Figure 4: Sanding the wood with the joint compound applied.



Figure 5: Thin layer of plastic applied to the exterior mold.

Phase 6: Creating the Graphics

The graphics were created by mounting vinyl inlays to either the interior mold or the exterior mold depending on the specified location of the graphic. The graphics included with this year's canoe design are 1) large blue eyes at the bow 2) the name of our school spelled out completely 3) the name of this year's canoe (Water Strider) and 4) a water strider on the inside floor of the canoe. After each graphic was cut out of the vinyl, it was nailed to the mold using a pneumatic nail gun. Figures 7 and 8 show the vinyl inlays process.

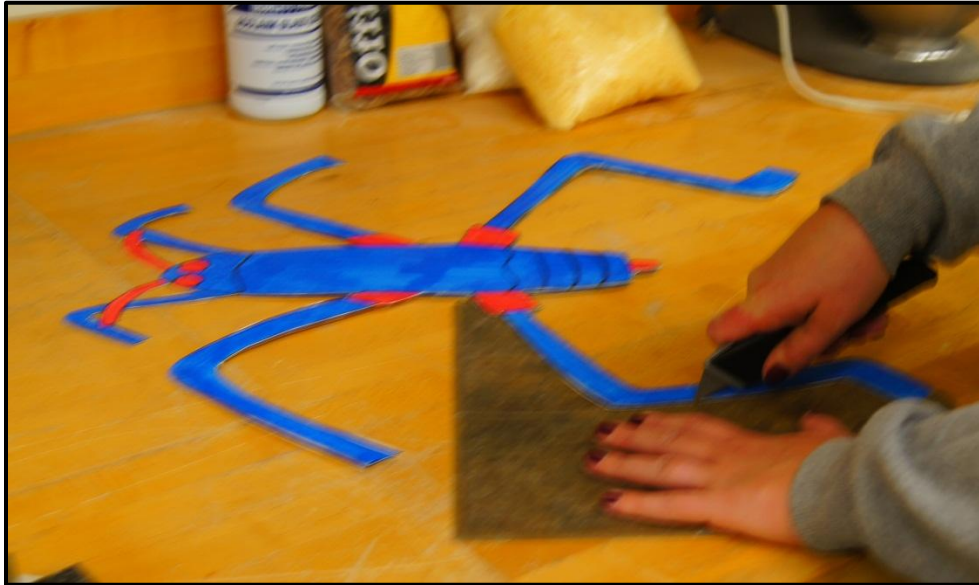


Figure 7: The water strider inlay being cut out of vinyl.



Figure 8: The vinyl inlays for the school name and canoe name being attached.

Casting Canoe

Preparation

In preparation for casting the canoe, both the interior and exterior mold sections were inspected to ensure that all sections were mechanically fastened together so that each mold (interior and exterior) functioned as one unit. The interior mold needed to be reinforced from the top by connecting all sections with 2x4's that ran the length. The exterior mold sections were screwed to each other, then to the base so the mold would not move. All of the seams between each mold section (both exterior and interior molds) were filled in with joint compound or putty then covered with plastic so concrete would not leak out between sections. To finalize the mold preparation, the interior and the exterior mold sections were wiped down with a vegetable oil to ensure the concrete would not bond to the mold.

All of the reinforcing was pre-cut prior to casting so the time that it took for placement of the reinforcing was minimized. For this year's canoe design, two layers of fiberglass reinforcing mesh were used along with five rows of longitudinal steel reinforcing rods (1/8 inch thick). The reinforcing mesh was dropped in perpendicular to the length of the canoe and cut so that a few inches of the mesh was exposed, so that the mesh could be pulled up during pouring after the interior mold had been bolted into place. Each of the reinforcing mesh sections overlapped six inches in any direction. The steel reinforcing rods were measured, trimmed and wire-tied together so that placement would be quick and easy. To ensure there was at least a 1/8 inch amount of concrete covering the reinforcing mesh and steel rods, some steel "chairs" were crafted out of the steel ties and bent so that when the reinforcing mesh is placed on the chairs, the mesh will sit a minimum of 1/8 inch from the surface of the exterior mold, as seen in Figure 9.

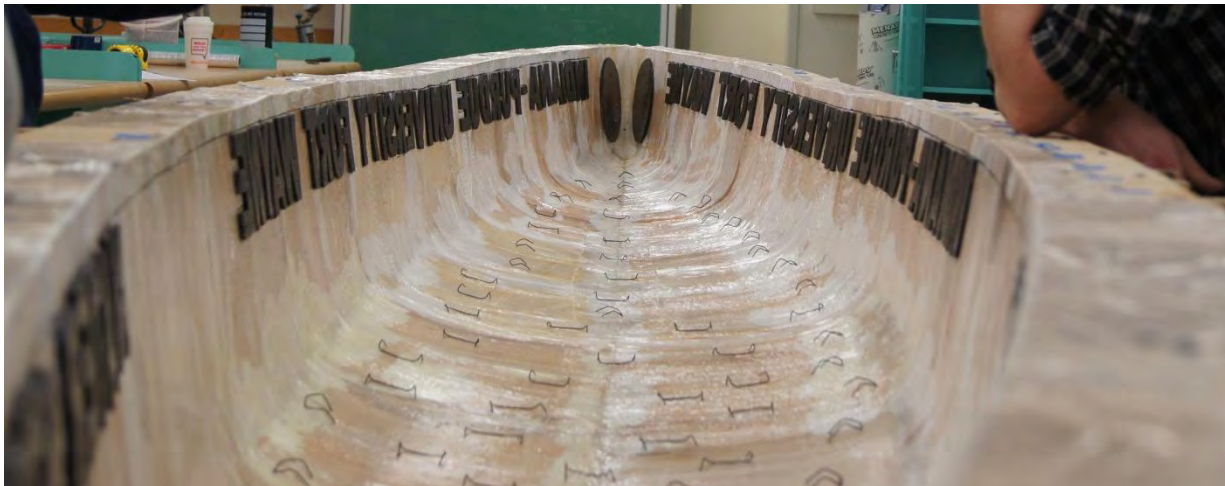


Figure 9: Steel chairs placed in mold.

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The interior mold section was 18 feet long while the exterior mold section was 20 feet long, leaving a one foot solid hull at both the bow and stern. There needed to be some extra concrete in these two areas of the hull, but this amount was too much. To reduce the amount of concrete needed for these two sections of the hull, each end was filled in with rigid foam that was cut in a way to maintain a one inch concrete cover. This foam was to be inserted after the interior mold section was fitted into place during casting and while the concrete was being poured up the sides, between the interior and exterior molds.

Casting

After each of the concrete batches was mixed, test cylinders, beams and unit weight measurements were taken for quality assurance. At one and a quarter cubic feet per batch, the number of batches required was estimated to be five which was to include the concrete for the test cylinders and beams as well as the entire canoe. The amount of concrete estimated to finish the canoe was around five cubic feet with an average of around 60 pounds per cubic foot unit weight which means that the canoe was estimated to weigh around 300 pounds.

After the tests were completed for each batch, the concrete was poured into the exterior mold until the concrete covered the reinforcing “chairs” completely at which point the first layer of reinforcing mesh was placed and then pressed down so that concrete seeped through the holes of the mesh. Then, more concrete was poured into the mold until another 1.8 inch of concrete covered the first layer of reinforcing mesh. The reinforcing rods were then placed into the concrete on top of the mesh. The reinforcing rods were basically “sandwiched” between the two layers of the reinforcing mesh. After the steel rods were dropped into place, the final layer of reinforcing mesh was placed. Concrete was then spread over the mesh while working the concrete through the holes of the mesh to ensure that there would not be any voids around the reinforcing layers. Figures 10 and 11 show this process.



Figure 10: First layer of concrete being placed.



Figure 11: Reinforcing fiberglass mesh being added, along with steel bars.

After all of the reinforcing was placed, concrete was continuously poured into the mold until the depth of the concrete at the bottom of the mold achieved a minimum of one inch but not more than 1-1/8 inch. Concrete was casted up each side of the exterior mold until the concrete began to settle. The interior mold was then lifted and set into place. The alignment of the interior mold relative to the exterior mold was checked to be sure it was in position from the side and down the length. When the interior mold was verified that it was correctly aligned, the interior mold should be bolted to the exterior mold so that the interior mold would not shift during the remainder of the casting process.

After the interior and exterior molds were joined, the casting continued by pouring the concrete in between the mold sections. To aid in consolidation, a concrete vibrator was placed on top of the interior mold structure. Tapping the sides of the exterior mold and “churning” the concrete also helped to consolidate the concrete. Regardless of the efforts, some voids in the canoe hull were expected due to the design of the mold. The concrete was poured into the mold until the concrete reached the top of both of the molds (the top of the mold was used as a reference point which was the actual top edge of the canoe). As the bow and stern ends were filled up with concrete, the foam pieces that were pre-cut were simply pushed into place and then concrete was filled around them. After the concrete was poured to the top edge of the canoe, the concrete was smoothed out with a trowel. This concludes the casting of the canoe, but other steps were taken to ensure proper curing of the canoe. Figures 12, 13, and 14 explain this process.



Figure 12: The interior mold being attached to the exterior mold.

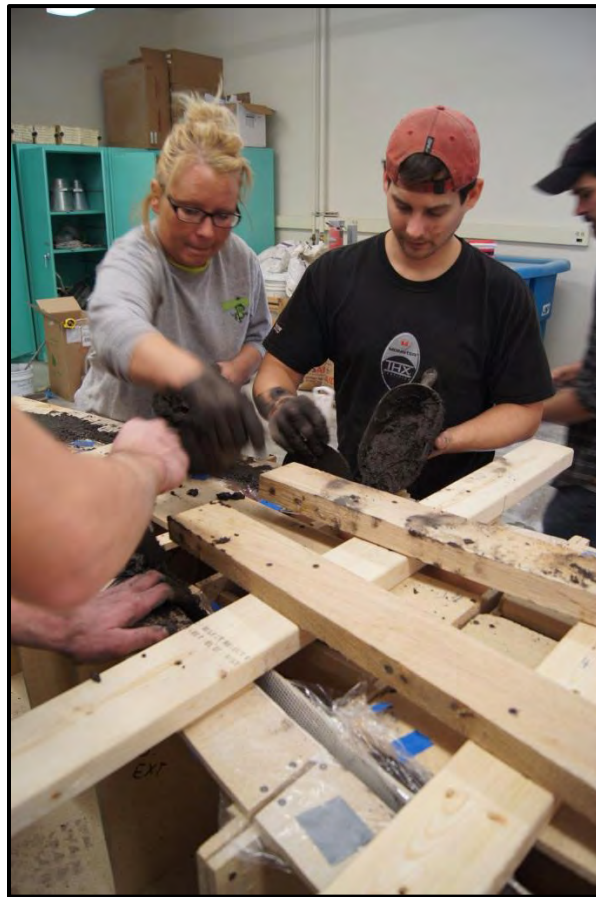


Figure 13: Pouring concrete down the sides of the molds.



Figure 14: Rigid foam wedge being placed in the bow.

Curing

While the concrete cured inside the mold, wet burlap was placed on any exposed surface (to the air) and plastic was laid over the burlap. The concrete was cured for a minimum of 14 days before the removal of the interior mold to ensure proper strength. After the interior mold was removed, wet burlap was again placed on any exposed surface with plastic on top of the burlap. The canoe was cured for a minimum of 28 days before the canoe was removed from the mold completely since concrete typically achieves the majority of its strength after this amount of curing time has lapsed. After the canoe was completely removed from the mold, further curing was not deemed necessary.

Mold Removal

As previously stated, the interior mold was removed fourteen days after the pour. The stern portion of the mold was disassembled in an effort to allow for easy removal of the five other interior mold sections. The sections were pulled vertically out after the handles were cut into the sections. Once the entire interior mold was removed, wetted burlap and plastic were once again placed back over the canoe to continue in the curing process.

Twenty-eight days after the pour, the exterior mold sections were removed with the help of our faculty advisors and a few ASCE student chapter members. Despite covering the mold in a layer of vegetable oil, the canoe seemed to be stuck to the walls of the mold. A crow bar was needed in order to separate the mold sections and the canoe enough that people could pull them apart with their hands. The two bow sections were removed first without any damaged to the mold

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pieces or the canoe. The problem was discovered that the inlays were not pulling out of the walls of the canoe. Since the inlays had been nailed to the wall of the mold the team had to separate the mold from the nails and inlays. The team used the crow bar once again to start the careful separation of canoe from mold. The base pieces of the mold broke due to the lack of strength of the wood used in the construction. It was determined in order to safely de-mold the canoe the mold would need to be disassembled. The skeleton pieces were removed to allow for the wood skin to be peeled back from the canoe.

During the whole mold removal, the team was careful to not put any forces on the canoe, that would cause it to crack or break. The canoe was placed on two mattresses with the bow and stern supported by blocks of high density foam. Figures 15 and 16 display the mold removal.



Figure 15: Starting to de-mold with crow bar.



Figure 16: Removing the exterior mold from the canoe.

Finishing

The first step in finishing the canoe was to fill in any voids that were present on the interior of the canoe with a patch mix. Once the patch mix had cured for 7 days the team rough sanded the interior of the canoe with 80 grit sand paper. The canoe was flipped to expose the whole exterior and the process was repeated. The vinyl inlays were carefully removed from the canoe. The edges of the inlays were cleaned up using a dremel tool. A white concrete inlay mix was placed into all of the inlays. After 7 days, the canoe was rough sanded a second time, with 150 grit sand paper, to even out the new inlays with the rest of the canoe. The team then spread a black slurry mix all over the canoe to fill in any small voids that presented themselves during the rough sanding step. The team wet sanded with 220 grit sand paper over the entire canoe to give the surface a very smooth feel. The eyes and the water strider were painted with a blue concrete stain. The letters for the school and canoe name were first painted black and then outlined in white using epoxy concrete paint. The canoe had the black concrete stain painted on it to allow for a uniform black color. Finally, the design team applied a clear coat on the canoe to give the concrete canoe a shiny, finished look. Figures 17 through 23 display the different finishing stages.



Figure 17: The design team with the unfinished canoe.



Figure 18: The patch mix being applied where needed.



Figure 19: The design team starting to rough sand the canoe.



Figure 20: The design team wet-sanding the canoe.



Figure 21: Applying the blue stain to the water strider graphic.



Figure 22: Applying the concrete paint to the lettering.



Figure 23: The final canoe product with two coats of the clear sealer applied.

Other Project Deliverables

The concrete canoe competition involved not only designing and building a concrete canoe, but various other aspects. The competition was judged on four main categories: a design report, an oral presentation, final product display, and the races. The senior design team also presented the concrete canoe design at the 2012 ASCE State Section Meeting.

Concrete Canoe Design Report

As explained previously, the design report was one of the four main categories that the competition was judged upon. It was worth 25% of the overall competition, and therefore it was imperative to complete this design report according to the specifications as laid out in the 2012 ASCE NCCC Rules and Regulations. The design report was to cover various areas related to the design and construction of the concrete canoe such as the concrete and composite development and testing, project management, innovations and sustainable aspects. The design report had to be mailed and received by the judges no later than March 1, 2012. The design team worked on the paper collectively to complete the report requirements, as well as send it to the judges by the deadline. The design report had an extremely stringent format to follow, and had to contain the following sections: report cover, table of contents, executive summary, hull design, structural analysis, development and testing, construction, project management, sustainability, organization chart, project schedule, design drawing, references, mixture proportions, and a bill of materials. The final 2012 IPFW Design Report is attached to Appendix B.

Oral Presentation

The oral presentation was the second category in the overall canoe competition, and was also worth 25% of the scoring. The oral presentation was a live, five minute technical presentation highlighting the various aspects of the project followed by a seven minute question and answer period with the judges. The oral presentation gave the design team the opportunity to explain to the judges, in person, the design concept and construction process. The final 2012 IPFW Oral Presentation is attached in Appendix C. Figure 24 shows Amanda and Jacob giving the oral presentation at Conference.



Figure 24: Amanda Bade and Jacob Allen giving the oral presentation at Conference.

Final Product Display

The final product display contained various parts, and also contributed to 25% of the overall scoring. It involved not only the displaying the final concrete canoe product, but also setting up a tabletop display, creating a cutaway section to explain the construction process, and completing an Engineer's Notebook that contained pictures of the construction process, and standards for the materials used in the concrete canoe.

At competition, the judges base part of the final product display scoring on aesthetics. The concrete canoes were all assembled in a common area, and placed on display stands. The senior design team asked IPFW ASCE student members to take the lead on building the display stand for the canoe. Nicholas Fenton, the ASCE student chapter president built the canoe display based on this year's canoe theme: Water Striders. Figure 25 below, shows the final canoe product display, to look like a Water Strider.



Figure 25: Final Product Display.

The product display also included a tabletop display which was to include concrete cylinders of the different mixes used in the canoe construction, samples of the concrete aggregates, samples of the reinforcement used in the canoe, a poster display conveying information in the design paper such as photographs and charts, a cutaway section of the canoe, and the Engineer's Notebook. Figure 26 shows the tabletop display, and Figure 27 shows the cutaway section. The cutaway section of the canoe was a three-foot section serving as a representative of both the raw and finished canoe. It was created to show concrete placement, finishing of the canoe at various stages, and display how the interior and exterior mold created the desired shape of the bow and also achieve the consistent one-inch thickness.



Figure 26: Tabletop display.



Figure 27: Cutaway section.

The Engineer's Notebook, as displayed in Figure 26 on the tabletop display, was a technical document which contained supportive information related to the design and construction of the canoe. It also included a compliance certificate to ensure the registered participants of the canoe team met all eligibility requirements. The Engineer's Notebook also followed a strict format, and contained the following sections: Table of Contents, Compliance Certificate, Construction Photographs including mold construction, canoe construction and finishing the canoe, Hull Thickness/Reinforcement and Percent Open Area Calculations, and Material Technical Data Sheets of all the materials used in the concrete canoe final product. The final 2012 IPFW Engineer's Notebook is attached in Appendix D.

The Races

The final 25% of the canoe competition scoring came from racing the canoe. The races involved five different competitions: a men's endurance, a women's endurance, a men's sprint, a women's sprint, and finally, a coed sprint. The IPFW canoe racing team consisted of ten of the IPFW ASCE Student Chapter members, including three from the senior design team: Amanda Bade, Jacob Allen, and Jessica Sample. The canoe racing team started practicing for the races in early February right up until the week before Conference. Practices involved either working at out the IPFW Student Athletic Center, or taking canoe up to Blue Lake, in Churubusco, Indiana, as seen in Figure 28.



Figure 28: Practicing rowing at Blue Lake.

The endurance races at the competition consisted of either two men or two women and a 600 meter course. The men's sprint and women's sprint involved either two men or two women and a 200 meter course. The coed sprint race included two men and two women and a 400 meter course. The races were competed against other schools in the conference. Figure 29 below shows the coed race.



Figure 29: The coed race at Conference.

ASCE State Section Meeting

As previously discussed, the concrete canoe design was presented at the annual ASCE State Section meeting held in Carmel, Indiana. Every year, the ASCE holds a meeting for all the ASCE members in Indiana, and the meeting includes lunch, awards, and presentations by senior design teams from various Indiana Engineering Schools. As a way to prepare for the Concrete Canoe Competition, two members of the senior design team, Jacob Allen and Jessica Sample, participated in the senior design competition. Every senior design team that presented received a one hundred dollar check for their ASCE Student Chapter Organization, while the winning senior design team won a plaque. Although the IPFW senior design team did not win the competition, the canoe design presentation was complimented and the hard work of the team was acknowledged. The presentation given was the same presentation given at Conference, and is attached in Appendix C. A handout was passed around to explain the four different the categories the competition was judged on, and is attached in Appendix E.

Mobilization

The team also had to develop a way to transport the canoe safely to the conference. The canoe was transported in a trailer. The team decided to create a box with padding that the canoe could sit in. The padding was essential because it had to absorb any vibrations caused by the vehicle or imperfections in the roads, during transit. Any vibrations would cause stress in the canoe and if the stress became too great it would crack the canoe. The box was designed to both hold the canoe in the trailer, and to make it easy to move the canoe. The box was constructed out of particle board, 2" x 4" boards, 2" x 6" boards, and screws. Particle board was used as the base of the box and the 2" x 4" boards were used as reinforcement under the particle board. Then the 2" x 6" boards were placed around the perimeter on the top to create a lip so the canoe doesn't slide off. It was constructed in three 7' section, giving a total length for the box to be 21'. This allowed for a 4" clearance at either end, because the canoe is 20' in length. The width of the box was 42", giving a 3" clearance on either side of the canoe because the canoe is 36". Six handles were placed on both sides of the box in order to create an easy way to lift the box to move the box with the canoe in it. These handles were made out of nylon rope and securely tied to prevent the rope from breaking loose. For the comfort of the people caring the box and canoe, the nylon rope was also thread through $\frac{3}{4}$ " PVC pipe. A picture of the final transportation box can be found in Figure 30.



Figure 30: The canoe in the transportation box.

Three different materials were used to help cushion the canoe in transit. Within the box, two materials were used. First, the box was lined with two layers of bubble wrap. Second, the box was lined with two layers of 9¼" fiberglass attic insulation. This was above the 6" lip from the 2" x 6" boards, but once the canoe was placed in the box, the canoe compressed the two layers of fiberglass attic insulation to 5". The canoe was set into the box upside down, as seen in Figure 30. The canoe was upside down because this will prevent the canoe from rocking from side to side, and the canoe would be stronger because the walls will form an arc. Most stress within an arc are compressive stress and concrete is much stronger in compression than tension. This will help prevent cracking during transit. The canoe in the box can be seen above in figure something. Two bed mattresses were placed under the box, in the trailer. Additional fiberglass attic insulation was added to areas around the box to insure the canoe would not move. Finally, the canoe was strapped down to the box in order to prevent the canoe from bouncing. This method provided much success. The canoe arrived at conference with no damage.

Product Performance

Once the canoe was transported to the Conference location, the concrete canoe team (as listed in the Acknowledgements) set up the final product display. The judges passed back the scores for the design papers. The design team received a perfect score, with no deductions. After the judges assessed the final product display, the race portion of the competition began. A "swamp test" was first conducted to be sure every school's concrete canoe floated. The "swamp test" consisted of putting the canoe in the lake, filling it with water, and allowing the judges to

Concrete Canoe Design 2012

observe the canoe float to the top. Following the “swamp test,” came the races in the following order: women’s endurance, men’s endurance, women’s sprint, men’s sprint, and coed sprint. The results from the races are as follows:

- 5th in the Women’s Endurance Race
- 5th in the Men’s Endurance Race
- 8th in the Women’s Sprint Race
- 6th in the Men’s Sprint Race
- 3rd in the Coed Sprint Race

The results of the canoe competition were not revealed until the Awards Ceremony of the Conference. The IPFW design team and concrete canoe team received the following:

- 3rd Best Design Paper (with no deductions)
- 5th Overall for the Concrete Canoe
- 3rd Overall for the ASCE Conference

The IPFW ASCE Student Chapter Members who attended the Great Lakes Conference were very proud of these accomplishments. The design and construction of the concrete canoe was an overall success, and the product performed as the senior design team expected.

Conclusions on Final Design

In conclusion, the team designed and created a successful final product for the 2012 ASCE National Concrete Canoe Competition Regional Conference held at Bradley University. The team built the mold according to the Fall 2011 design. The mold functioned as designed until it was to be removed. There were graphics stapled to the top of the mold that was not part of the design that when combined with the frictional force from the weight of the canoe, resulted in the team having to destroy the mold to remove it from the canoe. The casting of the canoe went smoothly and as planned. The finishing was reduced considerably from the previous year. The design paper was a complete success with zero deductions. The oral presentation successfully conveyed all the design team’s design concepts to the judges. The final product display was impressive to say the least with a minor deduction from the table display. The outcome of the races was respectable for the first year racing in this competition. The design and construction of the concrete canoe was an overall success, and the product performed as the senior design team expected. Overall, this project was a success and this project set the bar high for future ASCE concrete canoe competitions for IPFW to participate in.

To follow up on the concrete canoe as to how it was designed please refer to the Design Report of this project that was posted in December 2011 on the IPFW engineering website.

Appendix A

Table A.1: Companies and Donations.

Company	Donation(s)
Lafarge	Portland Cement
GRACE Construction Products	Reinforcing fibers, silica fume
Haydite	Lightweight aggregate-expanded shale
Speedway Redi Mix	Concrete Color Dye
Directs Colors	Concrete Stain
American Structurepoint	Monetary
I-69 Trailer	Trailer for Transport
Engineering Resources	Monetary
Three Rivers Running Company	Wetsuits

Appendix B

2012

**Concrete Canoe
Design Report**



Water Striders

The illustration shows a water strider insect on a dark blue background with a splash of lighter blue water. The insect is depicted with its legs extended, as if it is walking on the water's surface. The splash is composed of several droplets and bubbles, with some light reflecting off them. The overall aesthetic is clean and modern, with a focus on the natural theme of the report.

INDIANA PURDUE FORT WAYNE



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EXECUTIVE SUMMARY

Indiana-Purdue University Fort Wayne (IPFW) is located in the second largest city in Indiana: Fort Wayne. The university is a joint campus, combining two exceptional schools: Purdue University (West Lafayette) and Indiana University (Bloomington). The IPFW campus was established in 1964 with approximately 3,100 students, and has expanded into the largest university in Northeast Indiana, with over 200 programs offered and almost 15,000 students currently enrolled. While IPFW offers four engineering degrees, the civil engineering program is the newest of the programs, with its first graduates in 2009. Despite the program’s young existence, the American Society of Civil Engineers (ASCE) student chapter at IPFW is one of the most active and developed student organizations on campus.

The ASCE Student Chapter at IPFW has attended the ASCE Conference Competitions for six years, competed for the past three years in various events, and is entering the National Concrete Canoe Competition (NCCC) for the second year. While last year’s Concrete Canoe Team was made up of nearly twenty members, this year’s team consisted of four senior students who selected the concrete canoe competition as the 2011-2012 civil engineering senior design project. All of the tasks concerning the concrete canoe, from design, to structural analysis, to construction, to project management, were accomplished by a concrete canoe team of the four senior design students. These limitations made this year’s concrete canoe a particularly challenging and time-consuming task. However, IPFW’s Concrete Canoe Team is confident and enthusiastic to present the 2011-2012 concrete canoe: **WATER STRIDERS**.

When in water, animals and humans alike will either learn to swim or sink like a rock. However, there is one type of species that is capable of skimming across the water effortlessly: **WATER STRIDERS**. This particular kind of spider uses surface tension, along with little hairs on its legs that trap tiny air bubbles to gracefully skim across the water. As IPFW enters the Conference Concrete Canoe Competition for the second year, the team aspires to design and create a successful canoe that would achieve the same attribute as **WATER STRIDERS**.

This year’s canoe design most significant new features included punching shear analysis, interior mold in addition to the exterior mold for a consistent thickness, and a lightweight concrete mix design. After a year of analyzing, designing, testing, and constructing, the IPFW Concrete Canoe Team is proud to present the 2011-2012 canoe: **WATER STRIDERS**.

WATER STRIDERS SPECIFICATIONS

Name	WATER STRIDERS
Length	20 feet
Maximum Width	31 inches
Depth	14 inches
Average Thickness	1 inch
Total Weight	300 pounds
Colors	Black and blue
Reinforcement	Fiberglass grid, steel rods

CONCRETE PROPERTIES

Structural Mix	
Unit Weight	60.5 pcf
24-day Compressive Strength	1135 psi
24-day Tensile Strength	389 psi
Patch Mix*	
Unit Weight	66.0 pcf
Finishing Mix*	
Unit Weight	64.5 pcf

* Compressive and tensile strengths were unable to be determined before submission of design paper.

HULL DESIGN

Since the 2012 ASCE National Concrete Canoe Competition™ Rules and Regulations added some leniency to the rules regarding the hull design dimensions, the design team had to determine whether the previous hull design developed by the Committee on the National Concrete Canoe Competition (CNCCC) and used in the 2009-2011 ASCE National Concrete Canoe Competitions would continue to be used for this year's design, or whether a new hull design and dimensions should be created. After considering a variety of creative options and innovative ideas, it was decided to continue to use the standard hull design used in last year's **THE ROOKIE**. In order to create a mold that would be used for years to come, which will be discussed in more detail in the Construction and Sustainability portion of this paper, it was important to use these standard dimensions in case future competitions' rules and regulations return to the more exact hull design dimensions.

One of the main design goals for the **WATER STRIDERS** was to reduce the overall weight of **THE ROOKIE** design while designing a hull with a low probability of cracking and improve stability. Since **THE ROOKIE** had an average thickness of two inches, one way to reduce the weight of the canoe for this year's design was to control the thickness of the hull. A uniform hull thickness would also improve stability by providing a more uniformly distributed weight of the concrete. Another idea to reduce the weight was to decrease the amount of concrete fill needed as a collar tie at the bow and stern. **THE ROOKIE** had two feet of concrete fill which was determined to be excessive for the lateral stresses at the collar tie. The **WATER STRIDERS** concrete fill for the collar tie was decreased to one foot of the bow and stern allowing adequate strength while decreasing the local weight by nearly three times as that of **THE ROOKIE**. Rigid foam was trimmed to the

shape of the bow and stern collar ties allowing for a one inch concrete cover. These foam inserts will potentially reduce the weight of the concrete fill collar ties by another 25%.

The final dimensions regarding the length of the canoe, the maximum width of the canoe, and the maximum depth of the canoe that were chosen for this year's canoe is a direct copy of the previous year's dimensions as outlined by the 2011 ASCE National Concrete Canoe Competition™ Rules and Regulations. The length of the canoe is 20 feet measured at the gunwale from the bow to the stern. The beam is 31 inches measured at the gunwale, and 10 feet-2 inches from the bow. The rocker and chine dimensions were not modified in any way. The overall height of the canoe is 16 inches at the bow and 14 inches at the stern, and the maximum width of the canoe is 31 inches at the widest part of the canoe.

A hull thickness of one inch was used to exceed the stresses as calculated in the Finite Element Analysis. This uniform thickness simplified the mold design and construction process while providing sufficient cover for the 2 layers of reinforcing grid and the longitudinal steel rods. The hull design of the **WATER STRIDERS** played a key role in reducing the weight of the canoe, as well as producing a mold design that can potentially be used for future Concrete Canoe Competitions. Figure 1 below displays the overall shape and concept of the **WATER STRIDERS** hull design.

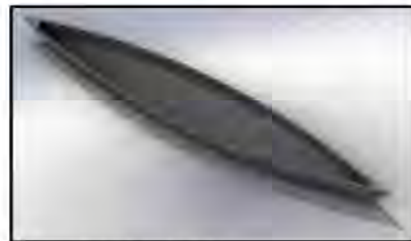


Figure 1: Solid Model.

STRUCTURAL ANALYSIS

This year, to ensure a successful and competitive canoe would be created; the IPFW concrete canoe team performed its canoe analysis in ANSYS Workbench™ to establish the maximum stresses, the required concrete tensile and compressive strengths, as well as an adequate canoe thickness. Hand calculations were performed to determine the depth of water the canoe would sit in, and to verify the ANSYS Workbench™ results.

As seen in Figure 1, the concrete canoe was modeled in SolidWorks™ and then imported into ANSYS Workbench™ to analyze the stresses on the canoe. The analysis was divided into four main cases: the canoe sitting in a depth of 5 inches of water, 1) with four people in the canoe and 2) without people in the canoe, and the water level up to the rim of the canoe, 3) with four people in the canoe and 4) without people in the canoe. The water pressure was computed using Equation 1 below, and was determined to be 0.1807 psi an assumed to be uniformed.

$$P = \rho * g * h \quad (\text{Equation 1})$$

Where: ρ is the density of water
 g is the gravitational constant
 h is the depth in the water

Case 1 was analyzed at a water depth of 5 inches, and with four people in the canoe, with an assumed weight of 200 pounds per person. The second case was analyzed with four people again, but this time with the water depth at the top of the walls of the canoe. Case 3 simulated the canoe with a depth of 5 inches of water, and no one in the canoe. Case 4 was analyzed with nobody in the canoe, and the water depth at the top of the walls of the canoe. This final case was important to analyze for the “swamp test” portion of the competition, and to determine if the canoe would rise to surface once submerged. The maximum stresses for each case can be found in Table 1.

Table 1: Max Stress Results.

	Case 1	Case 2	Case 3	Case 4
Max Compressive Stress (psi)	10	23	317	290
Max Tensile Stress (psi)	45	51	24	14

Case 3 gave the maximum compressive stress of 317 psi, and Case 2 gave the maximum tensile stress of 51 psi. Figures 2 and 3 show cases 2 and 3 respectively, as analyzed in ANSYS Workbench™.

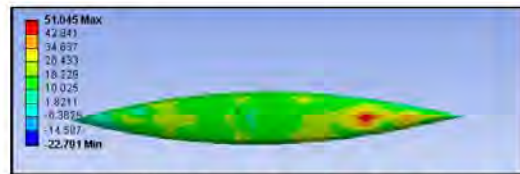


Figure 2: ANSYS™ Tensile Stress Results for Case 2.

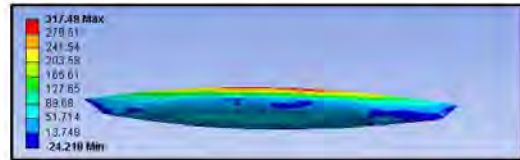


Figure 3: ANSYS™ Compressive Stress Results for Case 3.

It was concluded that the maximum tensile stress occurred in Case 2 due to punching shear, which happens in concrete when highly concentrated forces are applied. The ANSYS™ results determined the design goals for the strengths of the concrete mixes were to be greater than 51 psi for tensile strength and 317 psi for the compressive strength and determined a 1 inch hull thickness was more than adequate for the canoe design. It was also concluded that the stresses on the canoe were low enough that only minimal reinforcement would be required to account for temperature and shrinkage.

DEVELOPMENT & TESTING

The main goals for this year's concrete mix design were to create a lightweight concrete with a low unit weight, and able to withstand the stresses applied to the canoe as analyzed in ANSYS™. Although the rule regarding percentage of sustainable aggregates required for the canoe was eliminated this year, it remained an important personal goal for this year's concrete canoe team that the canoe would incorporate sustainable materials and concepts. To achieve these goals, the unit weight for the final concrete mix design was desired to be lower than that of water (62.4 pcf), and the tensile and compressive strengths of the mix design were to be higher than 51 psi and 317 psi, respectively, based on the structural analysis results found in ANSYS™. The sustainable aggregates used in last year's **THE ROOKIE** would continue to be used for the **WATER STRIDERS** concrete mix design.

This year's baseline mix design included some of the materials and mix proportions from **THE ROOKIE'S** mix design: a 0.4 water to cementitious materials ratio, expanded shale, glass beads, fibers, air entrainer, water reducer, and silica fume. However, some proportions, quantities and materials were altered to identify the optimal mix design to be used for the **WATER STRIDERS**. The concrete canoe team came up with a list of design variables that would be altered throughout the mixing and testing, and they are as follows:

- Cementitious Materials
- Cement to Cementitious Materials Ratio
- Aggregate Materials
- Ratio of Aggregate Materials
- Amount of Fiber Reinforcement Added

Before calculating the mix designs, the specific gravity of all the cementitious materials and aggregates, as well as the absorption of aggregates had to be determined. While most of the

WATER STRIDERS 2012

manufacturers provide these specifications, the expanded shale had to be tested using ASTM C127-Specific Gravity and Absorption of Coarse Aggregate. The team created a total of 10 different mixes throughout the design process altering these design variables, and tested each mix for unit weight (ASTM C138/C138M-01a), and compressive (ASTM C39/C39M-05) and tensile strengths (ASTM C293-02, ASTM C78-10). Four of the mixes were tested for shrinkage using the ASTM C157/C157M standards, to determine whether or not the shrinkage reducing cementitious material would be added.

The total amount of cementitious materials was altered from 700 lb/yd³ to 800 lb/yd³ in some of the mixes to assess the benefits and downfalls of increasing cementitious materials. For cementitious materials, the design team used Portland Cement as required by the rules, silica fume for high strength and durability, and a cementitious material called Komponent, to help reduce shrinking. The cement to cementitious materials ratio was varied in two ways: using 80% Portland Cement, and 20% silica fume; and also 64% Portland Cement, 20% silica fume, and 16% Komponent. The amount of Komponent was added to the concrete mix design according to the manufacturer's recommendations.

As briefly explained, glass beads and expanded shale were used as the aggregate materials in the mix designs. In order to achieve a well-graded aggregate mixture, four different sizes of the glass beads were used: beads with a 0.1-0.3 mm diameter, 0.25-0.50 mm diameter, 0.5-1.0 mm diameter, and 1.0-2.0 mm diameter. Although glass beads added to the sustainability of the canoe, as well as reducing the weight, they were quite expensive. The expanded shale is a fine and lightweight aggregate that was donated to the design team, thus by adding this aggregate it would lessen the cost of the canoe. The ratio of the aggregate materials would be varied in three different ways: 100% glass beads with no expanded

WATER STRIDERS 2012

shale; 75% glass beads with 25% expanded shale; and 50% glass beads with 50% expanded shale. Each of the four different grades of glass beads was calculated to be equal in volume for each mix design. The amount of fiber reinforcement that was added was altered from 3 lb/yd³ (manufacturer’s recommendations) to 6 lb/yd³ once it was discovered that the mixes with 3 lb/yd³ of fiber reinforcement did not contain the ideal distribution of fiber reinforcement throughout the batch. By doubling the amount of fiber reinforcement added to the mixes, uniform distribution was achieved, as well as improving the flexural strength of the concrete mix.

The admixtures and their quantities stayed consistent with each mix, and was added based on the manufacturers’ recommended dosages as well as experience. The water reducer that was used had a broad range of 3-18oz/100 pounds of cement. This range depended on the mixture, so it was determined from experience to add 8.4 oz/100 pounds of cementitious materials for the design mixes. The air entrainer that was used had no standard recommended dosages, but the company had done trial mixes using 1.5 oz/100 pounds of cement, and noted that the dosage would be dependent on a number of factors. Based on experience, and understanding that the desired concrete mix was to have a high air content to produce a low unit weight, the canoe team determined a dosage of 3.8 oz/100 pounds of cementitious materials to provide the desired air content in the mix designs.

After all the mixes were completed, the canoe team compared the unit weights and strength results of the concrete mixes to determine the most economical and optimal concrete mix design for the 2012 concrete canoe: **WATER STRIDERS**.

Even though additional reinforcement was not required, as determined by the Structural Analysis results in ANSYS Workbench™, fiberglass grid

and steel bars were added to enhance the flexural strength of the canoe to reduce the probability of failure. The **WATER STRIDERS** team considered using a carbon fiber mesh grid, but due to a limited budget and availability, the fiberglass grid was decided to be comparable alternative. The percent open area of the fiberglass grid was calculated to be 63%, which exceeds the minimum open area of 40% as stated in the *2012 ASCE National Concrete Canoe Competition™ Rules and Regulations*. The final concrete mix design, reinforcement added, and concrete properties are included below in Table 2.

Table 2: Concrete Mix Design.

Water to Cement Ratio:	
0.4	
Cementitious Materials:	
80% Portland Cement (700lb/yd ³)	
20% Silica Fume	
Admixtures:	
Air Entrainer	
Water Reducer	
Black Dye	
Aggregates:	
75% Glass Beads :	
Four grades from 0.1 mm to 2 mm	
25% Expanded Shale	
Reinforcement:	
Fibers (6 lb/yd ³)	
Fiberglass Grid	
Steel Bars	
Concrete Properties:	
Unit Weight	60.5 pcf
24-Day Tensile Strength	1135 psi
24-Day Compressive Strength	389 psi

This final mix was chosen due to its low unit weight, high compressive and tensile strengths. The shrinkage reducing cementitious material, Komponent was not added due to significantly lower compressive and tensile strength results. The final concrete design mix satisfied all of the design goals for the concrete mix as well as produced a workable and effective mix design to be used for the **WATER STRIDERS**.

CONSTRUCTION

In the second year of competing in the Concrete Canoe competition, the construction team set a reasonable goal which was to create a smooth canoe with simple colorful graphics. With a four person team, careful planning and time management would prove to be key for a successful project.

A cost analysis was performed on various types of mold construction concepts to achieve the lowest cost possible given the extremely limited budget and resources. The mold would be constructed in a way as to allow future use of the mold with some modification given dimensional changes and the materials selected would need to be durable to avoid destruction of the mold during removal. In order to control the thickness of the hull design, a mold was created for both the interior and the exterior dimensions of the canoe hull design. With this mold design, the interior section would be divided into 6 equally spaced sections to reduce the efforts of removing the interior section from the canoe. The exterior mold section was divided into eight sections for the same reasons as stated for the interior mold section. A rigid base was built in four independent sections each fixed to 4 inch casters allowing the mold to be moved and broken down for storage.



Figure 4: One Bow Piece of Exterior Mold.

Both interior and exterior sections of the mold were constructed using the same materials for simplicity, ease of construction, and uniformity. The skeleton was constructed using $\frac{1}{2}$ inch Medium Density Fiberboard (MDF) for cost, strength and ease of fabrication. Hardwood plywood with a width of 5 mm was selected for durability to withstand the pressure created by the concrete sandwiched between the molds. The plywood was cut to length, labeled and soaked overnight in water to reduce the probability of the plywood fracturing during application. Each plywood section would then be warped to fit the contour requirements of the hull. A light sanding was needed to remove any surface extrusions while joint compound was applied to fill any voids.

A plastic shrink wrap was applied to the surface of each mold section to provide an impermeable surface, and a releasing agent was applied to the plastic to prevent the plastic bonding to the concrete. Inlays with a $\frac{1}{16}$ inch thickness were created out of recycled vinyl flooring for the graphics and lettering and nailed to the mold sections.

The reinforcement consists of two layers of fiberglass woven fabric and $\frac{1}{8}$ inch steel rods. The fiberglass grid reinforcement was cut to fit the canoe curvature perpendicular to the length with an overlap according to the manufacturer's recommendations. Longitudinal reinforcement was achieved with five equally spaced rows of steel rods ending 3 feet from the bow and stern with three rows continuing to the full length of the canoe. Steel chairs, as shown in Figure 5 on the following page, were placed on the surface of the exterior mold section every 8 inches to ensure the desired cover for the reinforcement grid would be achieved.



Figure 5: Steel Chairs and Inlays.

Casting of the concrete began in the center of the exterior mold section and was spread out in each direction covering all of the reinforcement pins and inlays. The first layer of reinforcement was applied, and followed by another layer of concrete approximately 1/8 inch thick where the second layer of reinforcement grid and the longitudinal rods were placed. The concrete casting continued until concrete covered the rocker at which the interior section of the mold was inserted into the desired position. The interior and exterior mold sections were bolted together to eliminate shifting during the rest of the casting process. Casting the concrete between each mold section involved a funnel and a concrete mix with a relatively high slump for workability. As the concrete was casted, the mold was vibrated to aid in consolidation. The first 12 inches of the bow and stern had a 1 inch concrete thickness surrounding a rigid foam insert to reduce the weight and adding to buoyancy.



Figure 6: Placement of Reinforcement.

After the concrete had cured for twenty eight days, the mold was removed in two steps. The first step was to remove the interior mold. The interior sections were first unanchored from the exterior sections by removing the bolts that connected the interior mold to the exterior mold for curing. The six sections of the interior mold were then unattached from each other. Finally, each section was removed by lifting that section out of the canoe, in a vertical motion, from bow to stern. After the interior mold was removed, patching was completed as needed.

The second step of the mold removal was to detach the exterior mold. The eight sections of the exterior mold were first unbolted from each other and unanchored from the base of the mold. Then the sections were pulled out from the canoe, in a horizontal motion, from bow to stern. Once the exterior mold was removed, patching was completed as needed.

To finish the canoe, a slurry mix was first made to fill in the inlays on the interior and exterior of the canoe. After the inlays had cured for 24 hours, the interior portion of the canoe was sanded down to a smooth surface finish. The top and sides were then also sanded down to a smooth surface finish. Once the inside and sides of the canoe were finished, the canoe was flipped so that the bottom of the canoe could be sanded down to a smooth surface finish.

PROJECT MANAGEMENT

The project management objectives included: a detailed project schedule, delegated project tasks, and optimizing limited funds. The task of designing and building a canoe was divided into four parts: construction management, mold design, concrete mix design and Finite Element Analysis. Each of the team members took a lead in one of the parts and recruited team members as needed.

This is the second year IPFW is competing in the concrete canoe competition. The limited size and youth of IPFW's ASCE student chapter made funding a major issue, and in order to construct the canoe, fundraising had to be done. The design team first contacted donors of materials from the previous year. The design team then contacted other companies, local and national, regarding potential material donations that could be used for this year's canoe. The IPFW's ASCE student chapter helped with fundraising by selling IPFW engineering apparel, selling gift cards to various businesses, and requesting equipment and monetary donations. To limit expenses and track finances, the project manager approved all team purchases. In total, over \$1,200 worth of materials and equipment were acquired.

The design team brainstormed and came up with a list of all of the tasks that would be required for the completion of the **WATER STRIDERS**. Related tasks were grouped together, and the major milestones were determined and placed in order as they would occur. These major milestones were placed into the schedule as the critical path activities, and can be found in Table 3 below.

Table 3: Critical Path Activities.

Major Milestones
Canoe Design
Material Selection
Concrete Mix Design
Mold Design
Mold Construction
Concrete Testing
Canoe Casting
Form Removal
Design Paper

The major milestones were achieved by delegating tasks to members of the design team. Each team leader had specific deadlines for project goals and was held accountable for that goal to be accomplished.

All four members of the senior design team participated in the design, testing, and construction of the canoe, however two members of ASCE student chapter were recruited to assist with the casting of the **WATER STRIDERS**. In total there was an estimated 925 man hours. The distribution of the total man hours can be found in Figure 7.

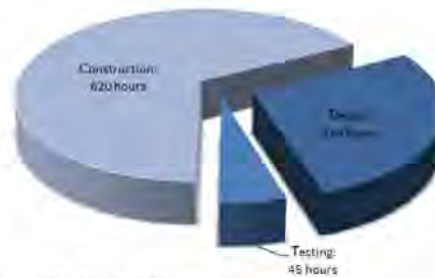


Figure 7: Project Hours.

Quality control and quality assurance were two key factors while creating **WATER STRIDERS**. The 2012 competition rules were referenced frequently to ensure that all of the rules and regulations were followed. Quality control was accomplished throughout the designing, testing, and construction of the **WATER STRIDERS** by measuring the dimensions of the mold and final canoe repeatedly, and mix designs were entered into spreadsheets. With all concrete mix designs, quality assurance tests such as unit weight, air content, and slump, were executed and concrete cylinders and beams were prepared to confirm the mix design properties.

Safety remained a top priority throughout the designing, testing, and construction of the canoe. Team members wore protective gear including gloves, masks, and goggles. The peril associated with hazardous materials and equipment was explained to each team member as well as the precautions necessary to ensure a safe work environment. Each member participated in a safety course to learn how to properly operate the power tools that were used during construction.

SUSTAINABILITY

Although the rule regarding a certain percentage of sustainable materials was eliminated in the *2012 ASCE National Concrete Canoe Competition™ Rules and Regulations*, it remained a primary goal for the canoe design team to incorporate not only sustainable aggregates, but also other sustainable materials and aspects to create an all-around environmentally friendly canoe. Sustainability, as defined by the World Commission on Environment and Development, is the “Development that meets the needs of the present without compromising the ability of future generations to meet their own needs.” These “needs” discussed in this definition are talking about the social, economic and environmental needs. By incorporating sustainability into the design and construction of this year’s concrete canoe, the canoe team is taking into account the needs of future IPFW canoe teams, as well as the future needs of the community.

The mold was created using a variety of materials, all locally purchased. The number of trips to the local hardware store was minimized to reduce excess carbon emissions. A material utilized throughout the wood mold design was fiberboard. Fiberboard is produced by using the sawdust and scrap material from sawmills and wood processing factories, that would otherwise end up in landfills.

Also, the wood mold design was created with the intention of lasting for a minimum of three years of use. By extending the life of the mold, the canoe team has reduced the amount of future waste, consumption of raw materials, energy usage, and air and water pollution created during transit of materials. Instead of creating a mold every year, or producing a foam mold with a one-time usage, the canoe team has incorporated a sustainable concept not only for this year’s canoe, but also for future concrete canoe competitions.

For the concrete mix designs, 100% of the aggregates used in the **WATER STRIDERS** are

sustainable materials. The aggregates are made up of expanded shale, and four different grades of glass beads. The expanded shale is a lightweight aggregate created by expanding select minerals in a rotary kiln at temperatures over 1000°C, and results in a smaller amount of material required compared to the raw material. Also, since expanded shale is a lightweight aggregate and available reasonably locally, the canoe team was able to acquire roughly 1200 pounds of it within one trip. By acquiring this large quantity, it enables future concrete canoe teams to use the expanded shale for many future concrete mix designs either for testing or for future competitions. The four different grades of glass beads are made from recycled glass, adding to the sustainability of the canoe. Again, a larger quantity of glass beads was ordered to reduce the amount of carbon emissions that result from the shipping and transportation of products. The amount of glass beads ordered lasted throughout the entire year of testing and mixing, and is enough for the creation of two canoes.

To produce the school and canoe name lettering and **WATER STRIDERS** design inlay, recycled vinyl flooring was used, that would have otherwise gone to the landfill. By using a recycled product like this, instead of buying new vinyl flooring, the canoe team increased the sustainability of the canoe by reducing pollution required to produce and acquire this material, as well as reducing the amount of waste cast into the landfill.

By maximizing these sustainable materials and sustainable concepts, the concrete canoe team was able to create a more environmentally-friendly canoe, while also lessening the social and economic impact. The goal of integrating sustainability for the **WATER STRIDERS** was achieved, and can be used as an example for future IPFW concrete canoe teams that a successful and sustainable concrete canoe can be accomplished, and to always consider the impact on future generations.

ORGANIZATION CHART

PROJECT MANAGER: Amanda Bade
Team Leader for scheduling, team meetings, and ASCE student chapter coordination.



STRUCTURAL ANALYSIS: Jacob Allen
Team Leader for canoe analysis, canoe dimensions, and reinforcement requirements.



- ALL :**
- Mold Construction
 - Canoe Construction
 - Design Paper
 - Display
 - Engineer's Notebook
 - Cross Section
 - Canoe Finishing
 - Material Acquirement
 - Concrete Testing
 - Product Research
 - Oral Presentation



MIX DESIGN: Jessica Sample
Team Leader for concrete mix designs, testing, and acquiring materials.



MOLD DESIGN: Adam Grabill
Team Leader for design of mold, acquiring materials, and construction of mold.

PADDLING TEAM:
Jessica Sample
Emily Hauter
Amanda Bade
Allee Carlgaard
Cristy Gimbel
Nick Fenton
Dustin Lambert
Ethan Hess
Jacob Allen
Ryan Prince

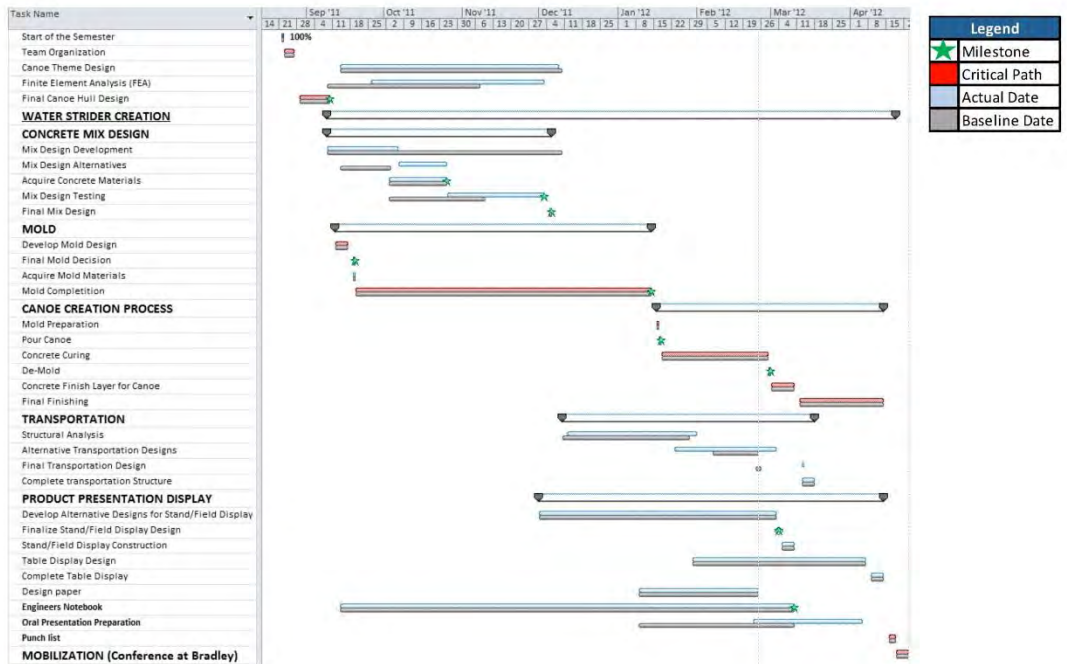
FUNDRAISING:
Nick Fenton
Andrew Hilty
Vanessa Ray

CANOE CONSTRUCTION ASSISTANTS:
Ryan Prince
Zach Estes

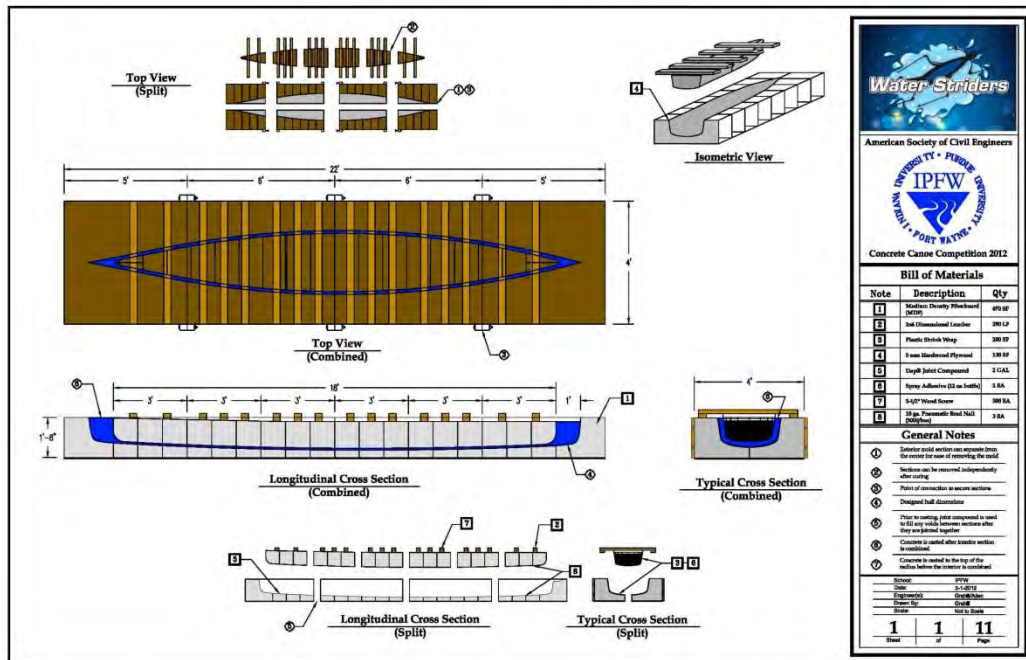
CANOE STAND:
Nick Fenton
Andrew Hilty
Zach Estes
Dustin Lambert
Ethan Hess

ADVISORS:
Mohammad Alhassan
Suleiman Ashur
Mark Mackenzie

PROJECT SCHEDULE



DESIGN DRAWING



APPENDIX A – REFERENCES

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APPENDIX B – MIXTURE PROPORTIONS

Mixture ID: Structural Mix				Design Proportions (Non SSD)		Actual Batched Proportions		Yielded Proportions	
Y _D	Design Batch Size (ft ³):		1.25	Amount (lb/yd ³)	Volume (ft ³)	Amount (lb)	Volume (ft ³)	Amount (lb/yd ³)	Volume (ft ³)
Cementitious Materials			SG						
CM1	Portland Cement		3.15	560.00	2.849	25.93	0.132	523.00	2.661
CM2	Silica Fume		2.20	140.00	1.020	6.48	0.047	130.75	0.952
Total Cementitious Materials:				700.00	3.87	32.41	0.18	653.75	3.61
Fibers									
F1	Fiber		0.91	6.00	0.106	0.28	0.005	5.60	0.099
Total Fibers:				6.00	0.11	0.28	0.005	5.60	0.10
Aggregates									
A1	Haydite	Abs: 8%	1.05	261.20	3.987	12.09	0.185	243.94	3.723
A2	Glass Beads (0.1-0.3mm)	Abs: 32%	0.90	168.30	2.990	7.79	0.138	157.18	2.793
A3	Glass Beads (0.25-0.5mm)	Abs: 26%	0.59	109.90	2.990	5.09	0.138	102.64	2.793
A4	Glass Beads (0.5-1mm)	Abs: 21%	0.47	87.50	2.990	4.05	0.138	81.72	2.792
A5	Glass Beads (1-2mm)	Abs: 18%	0.39	72.60	2.991	3.36	0.138	67.80	2.793
Total Aggregates:				699.50	15.95	32.38	0.74	653.29	14.89
Water									
W1	Water for CM Hydration (W1a + W1b)			283.07	4.536	13.11	0.210	261.74	4.195
	W1a. Water from Admixtures		1.00	3.07		0.73		0.24	
	W1b. Additional Water			280.00		12.96		261.50	
W2	Water for Aggregates, SSD		1.00	119.00		5.51		0.00	
Total Water (W1 + W2):				402.07	4.54	18.61	0.21	261.74	4.19
Solids Content of Dyes									
S1	Black Dye		1.09	60.48	0.969	2.80	0.045	56.48	0.905
S2	Direct Blue Power Pigment		2.69	0.00	0.000	0.00	0.000	0.00	0.000
Total Solids of Admixtures:				60.48	0.97	2.80	0.04	56.48	0.91
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/yd ³)
Ad1	Air Entrainer 8.7 lb/gal		10.20	2.80	0.53	0.91	0.08	2.62	0.04
Ad2	Superplasticizer 8.9 lb/gal		17.10	13.04	2.54	4.23	0.65	12.18	0.20
Water from Admixtures (W1a):					3.07		0.73		0.24
Cement-Cementitious Materials Ratio					0.800		0.800		0.800
Water-Cementitious Materials Ratio					0.400		0.400		0.400
Slump, Slump Flow, in.					5.00		5.000		5.000
M	Mass of Concrete, lbs			1749.05		80.97		1630.87	
V	Absolute Volume of Concrete, ft ³			25.43		1.18		23.71	
T	Theoretical Density, lb/ft ³ = (M/V)			68.79		68.79		68.80	
D	Design Density, lb/ft ³ = (M/27)			64.78					
D	Measured Density, lb/ft ³					60.5		60.5	
A	Air Content, % = [(T - D) / T x 100%]			6%		12%		12%	
Y	Yield, ft ³ = (M/D)			27		1.34		27	
Ry	Relative Yield = (Y/Y _D)					1.071			

Mixture ID: Patch Mix				Design Proportions (Non SSD)		Actual Batched Proportions		Yielded Proportions		
Y _D	Design Batch Size (ft ³):			1.25						
Cementitious Materials				SG	Amount (lb/yd ³)	Volume (ft ³)	Amount (lb)	Volume (ft ³)	Amount (lb/yd ³)	Volume (ft ³)
CM1	Portland Cement			3.15	640.00	3.256	29.63	0.151	599.12	3.048
CM2	Silica Fume			2.20	160.00	1.166	7.41	0.054	149.78	1.091
Total Cementitious Materials:					800.00	4.42	37.04	0.20	748.90	4.14
Fibers										
F1	Fiber			0.91	6.00	0.106	0.28	0.005	5.62	0.099
Total Fibers:					6.00	0.11	0.28	0.005	5.62	0.10
Aggregates										
A1	Haydite	Abs: 8%	1.05	483.20	7.375	22.37	0.341	452.34	6.904	
A2	Glass Beads (0.1-0.3mm)	Abs: 32%	0.90	103.80	1.844	4.81	0.085	97.17	1.726	
A3	Glass Beads (0.25-0.5mm)	Abs: 26%	0.59	67.80	1.845	3.14	0.085	63.47	1.727	
A4	Glass Beads (0.5-1mm)	Abs: 21%	0.47	54.00	1.845	2.50	0.085	50.55	1.727	
A5	Glass Beads (1-2mm)	Abs: 18%	0.39	44.80	1.846	2.07	0.085	41.94	1.728	
Total Aggregates:					753.60	14.75	34.89	0.68	705.46	13.81
Water										
W1	Water for CM Hydration (W1a + W1b)				283.51	4.543	13.13	0.210	262.39	4.205
	W1a. Water from Admixtures			1.00	3.51		0.96		0.28	
	W1b. Additional Water				280.00		12.96		262.12	
W2	Water for Aggregates, SSD			1.00	119.00		5.51		0.00	
Total Water (W1 + W2):					402.51	4.54	18.63	0.21	262.39	4.21
Solids Content of Dyes										
S1	Black Dye			1.09	60.48	0.969	2.80	0.045	56.62	0.907
S2	Direct Blue Power Pigment			2.69	0.00	0.000	0.00	0.000	0.00	0.000
Total Solids of Admixtures:					60.48	0.97	2.80	0.04	56.62	0.91
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/yd ³)
Ad1	Air Entrainer 8.7 lb/gal			10.20	2.80	0.61	1.04	0.11	2.62	0.05
Ad2	Superplasticizer 8.9 lb/gal			17.10	13.04	2.90	4.83	0.85	12.21	0.23
Water from Admixtures (W1a):						3.51		0.96		0.28
Cement-Cementitious Materials Ratio					0.800		0.800		0.800	
Water-Cementitious Materials Ratio					0.400		0.400		0.400	
Slump, Slump Flow, in.					5.00		5.000		5.000	
M	Mass of Concrete, lbs				1903.59		88.13		1778.99	
V	Absolute Volume of Concrete, ft ³				24.79		1.15		23.16	
T	Theoretical Density, lb/ft ³ = (M/V)				76.78		76.78		76.80	
D	Design Density, lb/ft ³ = (M/27)				70.50					
D	Measured Density, lb/ft ³						66.0		66.0	
A	Air Content, % = [(T - D) / T x 100%]				8%		14%		14%	
Y	Yield, ft ³ = (M/D)				27		1.34		27	
Ry	Relative Yield = (Y/Y _D)						1.068			


Mixture ID: Finishing Mix				Design Proportions (Non SSD)		Actual Batched Proportions		Yielded Proportions	
Y _D	Design Batch Size (ft ³):		0.75						
Cementitious Materials			SG	Amount (lb/yd ³)	Volume (ft ³)	Amount (lb)	Volume (ft ³)	Amount (lb/yd ³)	Volume (ft ³)
CM1	Portland Cement		3.15	560.00	2.849	15.56	0.079	538.00	2.737
CM2	Silica Fume		2.20	140.00	1.020	3.89	0.028	134.50	0.980
Total Cementitious Materials:				700.00	3.87	19.44	0.11	672.50	3.72
Fibers									
F1	Fiber		0.91	6.00	0.106	0.17	0.003	5.76	0.102
Total Fibers:				6.00	0.11	0.17	0.003	5.76	0.10
Aggregates									
A1	Haydite	Abs: 8%	1.05	0.00	0.000	0.00	0.000	0.00	0.000
A2	Glass Beads (0.1-0.3mm)	Abs: 32%	0.90	865.80	15.382	24.05	0.427	831.79	14.778
A3	Glass Beads (0.25-0.5mm)	Abs: 26%	0.59	0.00	0.000	0.00	0.000	0.00	0.000
A4	Glass Beads (0.5-1mm)	Abs: 21%	0.47	0.00	0.000	0.00	0.000	0.00	0.000
A5	Glass Beads (1-2mm)	Abs: 18%	0.39	0.00	0.000	0.00	0.000	0.00	0.000
Total Aggregates:				865.80	15.38	24.05	0.43	831.79	14.78
Water									
W1	Water for CM Hydration (W1a + W1b)			283.07	4.536	7.86	0.126	269.26	4.315
	W1a. Water from Admixtures		1.00	3.07		0.26		0.26	
	W1b. Additional Water			280.00		7.78		269.00	
W2	Water for Aggregates, SSD		1.00	119.00		3.31		0.00	
Total Water (W1 + W2):				402.07	4.54	11.17	0.13	269.26	4.31
Solids Content of Dyes									
S1	Black Dye		1.09	0.00	0.000	0.00	0.000	0.00	0.000
S2	Direct Blue Power Pigment		2.69	0.31	0.002	0.01	0.000	0.30	0.002
Total Solids of Admixtures:				0.00	0.00	0.00	0.00	0.00	0.00
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/yd ³)
Ad1	Air Entrainer 8.7 lb/gal		10.20	2.80	0.53	0.54	0.03	2.69	0.05
Ad2	Superplasticizer 8.9 lb/gal		17.10	13.04	2.54	2.54	0.23	12.53	0.21
Water from Admixtures (W1a):					3.07		0.26		0.26
Cement-Cementitious Materials Ratio					0.800		0.800		0.800
Water-Cementitious Materials Ratio					0.400		0.400		0.400
Slump, Slump Flow, in.					5.00		5.000		5.000
M	Mass of Concrete, lbs			1854.87		51.52		1779.30	
V	Absolute Volume of Concrete, ft ³			23.89		0.66		22.91	
T	Theoretical Density, lb/ft ³ = (M/V)			77.63		77.63		77.66	
D	Design Density, lb/ft ³ = (M/27)			68.70					
D	Measured Density, lb/ft ³					66.0		66.0	
A	Air Content, % = [(T - D) / T x 100%]			12%		15%		15%	
Y	Yield, ft ³ = (M/D)			27		0.78		27	
Ry	Relative Yield = (Y/Y _D)					1.041			

APPENDIX C – BILL OF MATERIALS

Material	Quantity	Unit Cost	Total Price
Cementitious Materials:			
Portland Cement	129.5 (lbs.)	\$0.15 (lb)	\$19.43
Silica Fume	32.5 (lbs.)	\$0.38 (lb)	\$12.35
Admixtures:			
BASF Master Builders Micro Air	0.79 (lb.)	\$0.65 (lb.)	\$0.51
BASF Glenium® 3030 NS	0.32 (lb.)	\$0.52 (lb)	\$0.17
Davis Colors Black Dye	14 (lbs.)	\$1.12 (lb)	\$15.68
Aggregates:			
Poraver Glass Beads			
0.1-0.3 mm	39.0 (lbs.)	\$0.70 (lb)	\$27.30
0.25-0.50 mm	25.5(lbs.)	\$0.70 (lb)	\$17.85
0.5-1mm	27.5 (lbs.)	\$0.70 (lb)	\$19.25
1-2 mm	17.0 (lbs.)	\$0.70 (lb)	\$11.90
Haydite Expanded Shale	60.5 (lbs.)	\$0.05 (lb)	\$3.03
Reinforcement:			
PAREX ®Fiberglass Grid	150 (sq. ft.)	\$0.18(sq. ft.)	\$27.00
Grace Fibers-CRB 3/4"	1.5 (lbs.)	\$7.25 (lb.)	\$10.88
Steel Bars	108 (linear feet)	\$0.68 (linear foot)	\$107.32
Wooden Mold:			
Interior	1 (total)	lump sum	\$146.00
Exterior	1 (total)	lump sum	\$345.00
Miscellaneous:			
Direct Colors Blue Powder Pigment	5.0 (oz)	\$0.75	\$3.75
Vinyl Lettering and Design	1(total)	lump sum	\$50.00
Clear Concrete Curing Compound	1 (gal)	\$6.20	\$6.20
Total			\$823.60

Appendix C



Indiana-Purdue University Fort Wayne



Water Striders

ASCE National Concrete Canoe Competition 2012

Group:
Jacob Allen
Amanda Bade
Allen Carlsgaard



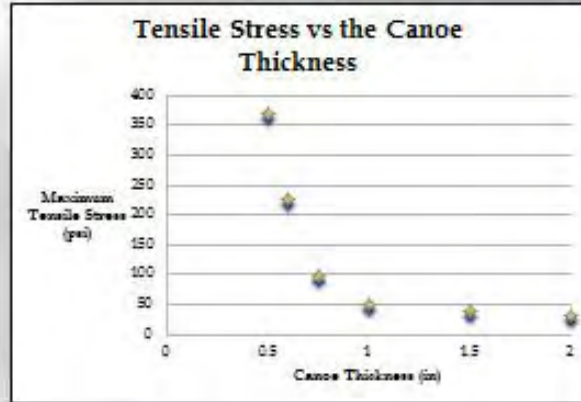
Designing a Concrete Canoe (that floats)



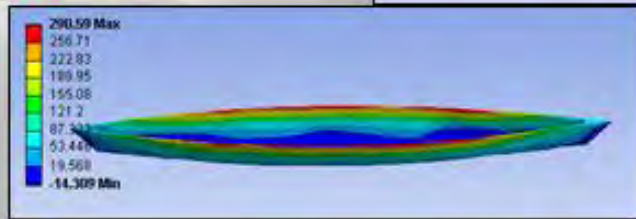
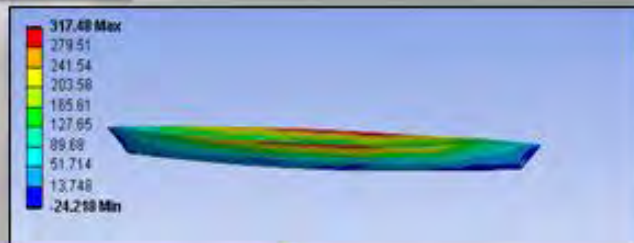
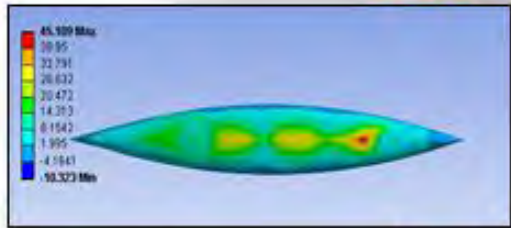
- Analysis
- Mold Design
- Concrete Mix Designs
- Testing
- Construction Management



Analysis



Analysis



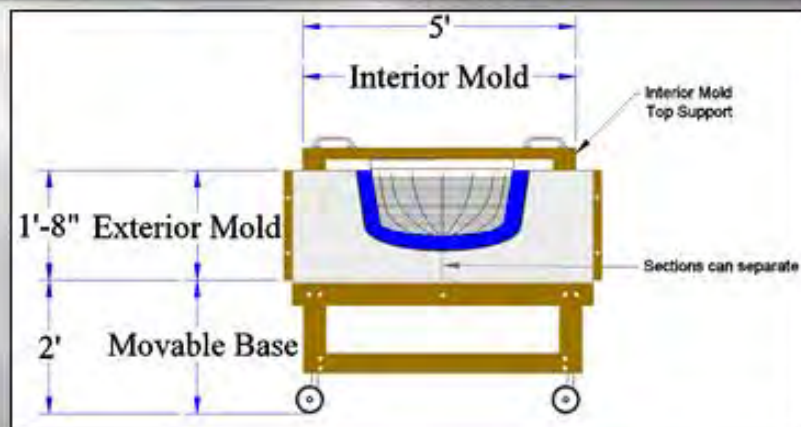
Analysis

FEA: Case 2

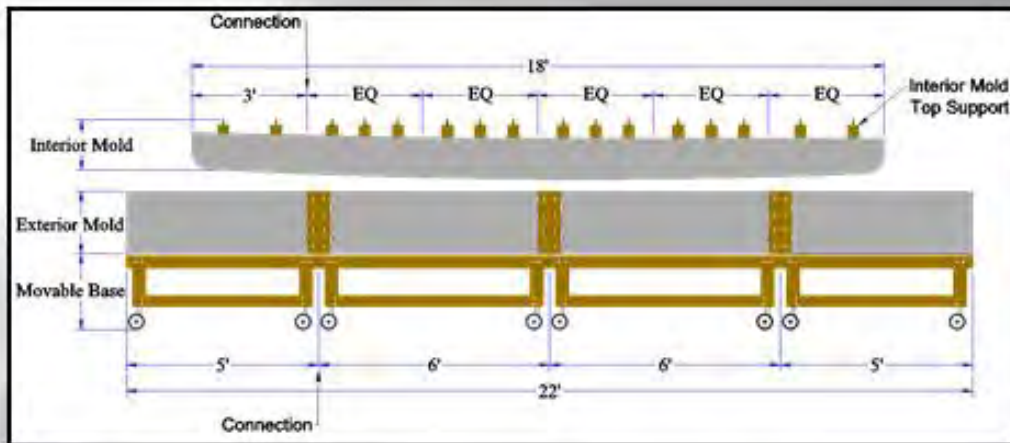
Four people in canoe with water depth at rim of canoe



Mold Design



Mold Design



Testing & Comparing

Mix Number	Casting Date	Mix Designation	Design Unit Weight (lb/ft ³)	Measured Unit Weight (lb/ft ³)	14-Day Break		
					Compressive Strength (psi)	Flexural Strength (psi)	Residual Strength (psi)
1	11/2/2011	100% Beads 700 CM-3 FB	58	51	1,377	300	240
2	11/2/2011	75% Beads 700 CM-3 FB	62	54	1,416	310	250
3	11/14/2011	100% Beads 800 CMK-6 FB	62	62	900	230	160
4	11/14/2011	50% Beads 700 CM-6 FB	67	69	845	320	250
5	11/14/2011	75% Beads 800 CMK-6 FB	65	67	1,337	240	180
6	11/23/2011	100% Beads 700 CMK-6 FB	58	50	845	150	120
7	11/23/2011	75% Beads 700 CMK-6 FB	62	51	881	160	140

Testing & Comparing

Comparing Unit Weight vs. Percentage of Beads



Comparing Flexural Strengths



Percentage of Beads vs. Compressive Strength



Final Mix & Construction Management

Final Mix Design:

Weights for Mix	
Cement	560 lb/yd³
Silica Fume	140 lb/yd³
Haydite	261 lb/yd³
Beads	438 lb/yd³
Water	413 lb/yd³
Fibers	6 lb/yd³
Air Entrainer	600 mL/yd³
Super Plasticizer	2025 mL/yd³

- Total Budget
 - \$5,000
- 1,000 man hours; 4 students

Constructing a Concrete Canoe

- Building a Mold
- Canoe Construction
- Canoe Finishing



Constructing a Concrete Canoe

- Building a Mold
- Canoe Construction
- Canoe Finishing



Constructing a Concrete Canoe

- Building a Mold
- Canoe Construction
- Canoe Finishing



Building a Mold



Building a Mold



Building a Mold



Canoe Construction



Canoe Construction



Canoe Construction



Canoe Finishing



Canoe Finishing



Canoe Finishing



Appendix D

2012
ENGINEER'S
NOTEBOOK

An illustration of a water strider insect on a blue water surface with splashes and bubbles. The insect is dark brown with long, thin legs. The water is depicted with various shades of blue and white highlights, suggesting movement and light reflection.

Water Striders

INDIANA PURDUE FORT WAYNE



Indiana-Purdue University Fort Wayne Water Striders

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TAB A-Compliance Certificate

Indiana University-Purdue University Fort Wayne: Water Striders

All participants and team members involved in the design, mold, construction, design paper, engineer's notebook, and oral presentation, or contributed to Water Striders in any way, certify the following:

- o The construction and finishing of the canoe has been performed in complete compliance with the 2012 rules and regulations of the National Competition.
- o The registered participants at the Great Lakes Conference are qualified student members and National Student Members of ASCE, and meet all of the eligibility requirements as specified in the 2011 rules and regulations of the National Competition.
- o The canoe has been completely built in 2011-2012, the current academic year of the competition.
- o The team acknowledges that all material safety data sheets (MSDS) have been read by the project management team.
- o The team acknowledges receipt of the *Request for Information (RFI) Summary*.

Water Striders' Dimensions	
Maximum Length	20 feet
Maximum Width	31 inches
Average Thickness	1 inch
Overall Weight	300 lbs.
Water Striders' Properties	
Structural Mix:	
Unit Weight	60.5 pcf (969.7 kg/m ³)
24-day Compressive Strength	1135 psi (7825.6 kPa)
24-day Tensile Strength	389 psi (2682.1 kPa)
Air Content	19%
Patch Mix:	
Unit Weight	66.0 pcf (1057.8 kg/m ³)
Finishing Mix:	
Unit Weight	64.5 pcf (1033.8 kg/m ³)

Name	ASCE National Member ID Number
Jacob Allen	1005800
Nicholas Fenton	936428
Ethan Hess	1021109
Dustin Lambert	1007837
Ryan Prince	1021047
Amanda Bade	1021100
Alee Carlsgaard	9126297
Cristy Gimbel	9183964
Emily Hauter	509740
Jessica Sample	488174

X

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 Phone: (260) 437-8127

X

Dr. Suleiman Ashur, Faculty Advisor

Email: ashur@enr.ipfw.edu
 Phone: (260) 804-1391

TAB B-Construction Photographs

MOLD CONSTRUCTION:



Figure 1: Sanding the exterior mold to give a smooth finish for the concrete canoe.



Figure 2: Displaying the ability to separate the mold for future changes in dimensions as well as ease in de-molding.

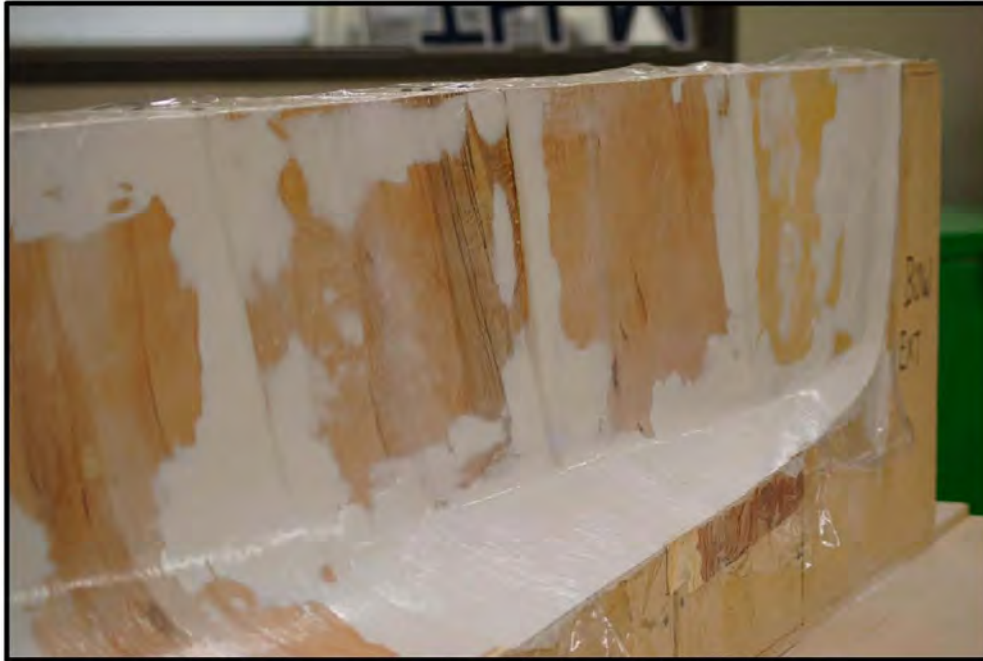


Figure 3: Clear plastic wrap placed on wood mold to ease the de-molding process.



Figure 4: Interior Mold and Exterior mold configuration to obtain consistent 1" thickness.



Figure 5: Vinyl inlays being attached to exterior wood mold to create school name and theme name in concrete canoe.



Figure 6: Water strider vinyl inlay attached to interior mold to create graphic on the interior section of the canoe.

CANOE CONSTRUCTION:

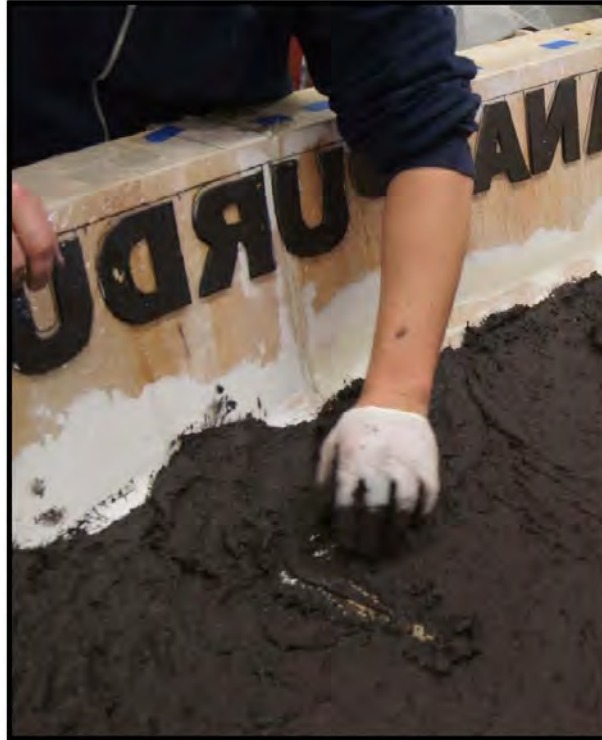


Figure 7: Placing a thin layer on the bottom of the exterior mold before reinforcement installation.



Figure 8: Placing the first layer of fiberglass grid reinforcement and another thin layer of concrete.

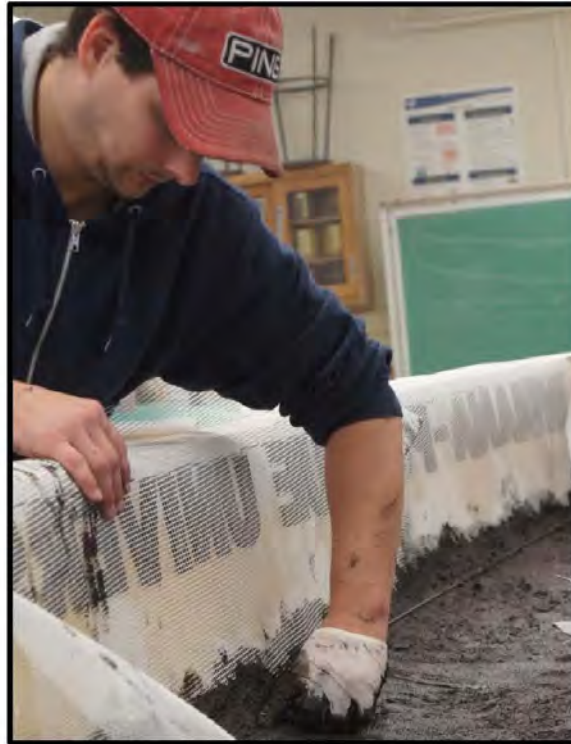


Figure 9: Placing the steel bar reinforcement in the concrete.



Figure 10: Placing the second layer of fiberglass grid reinforcement.



Figure 11: Installing the interior mold onto the exterior mold, then vibrating concrete down the sides to obtain the consistent 1" thickness.



Figure 12: Placement of the solid foam wedge in the bow and stern, and top view of the 1" thickness obtained from attaching interior mold.

FINISHING:



Figure 13: Canoe Team with Canoe after patching, before finishing work.



Figure 14: Sanding and removing the inlays.



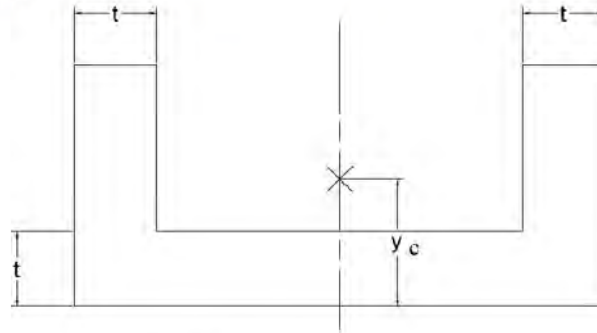
Figure 15: Blue graphic and concrete paint lettering being applied.



Figure 16: Finished canoe with two coats of sealer applied.

TAB C- Hull Thickness and Percent Open Area Calculations
HULL THICKNESS CALCULATIONS:

Cross section of the canoe:



Where: t is the thickness

y_c is the distance from the center of mass to the lower outer fiber

$$y_c = \frac{29 * 1 * \frac{1}{2} + (14 - 1) * 1 * \left(\frac{14 - 1}{2} + 1\right) * 2}{29 * 1 + (14 - 1) * 1 * 2}$$

$$I = \frac{1}{12} * 29 * 1^3 + 29 * 1 * \left(y_c - \frac{t}{2}\right)^2 + 2 * \left(\frac{1}{12} * t * (14 - t)^3 + (14 - t) * t * \left(14 - y_c - \left(\frac{14 - t}{2}\right)\right)^2\right)$$

$$S = \frac{I}{y_c}$$

$$\sigma = \frac{M}{S}$$

Calculations for 1 inch thickness:

$$y_c = \frac{29 * 1 * \frac{1}{2} + (14 - 1) * 1 * \left(\frac{14 - 1}{2} + 1\right) * 2}{29 * 1 + (14 - 1) * 1 * 2}$$

$$y_c = 3.809 \text{ in}$$

$$I = \frac{1}{12} * 29 * 1^3 + 29 * 1 * \left(3.809 - \frac{1}{2}\right)^2 + 2$$

$$* \left(\frac{1}{12} * 1 * (14 - 1)^3 + (14 - 1) * 1 * \left(14 - 3.809 - \left(\frac{14 - 1}{2}\right)\right)^2\right)$$

$$I = 388.82 \text{ in}^4$$

$$S = \frac{388.82}{3.809}$$

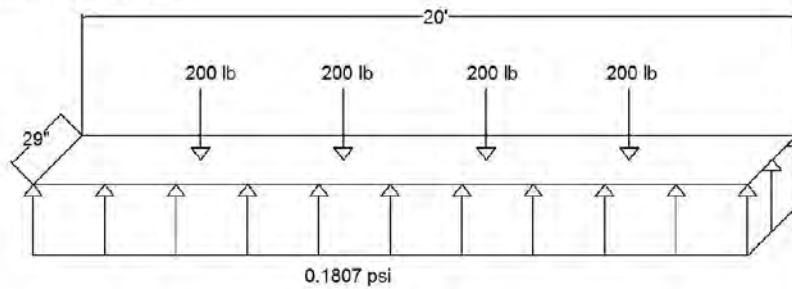
$$S = 102.08 \text{ in}^3$$

Find Moment (M):

$$\text{Water Pressure} = \rho * g * h$$

$$\text{Water Pressure} = (62.4 \text{ lb/ft}^3) * (32.2 \text{ ft/s}^2) * (5 \text{ in})$$

$$\text{Water Pressure} = 0.1807 \text{ psi}$$

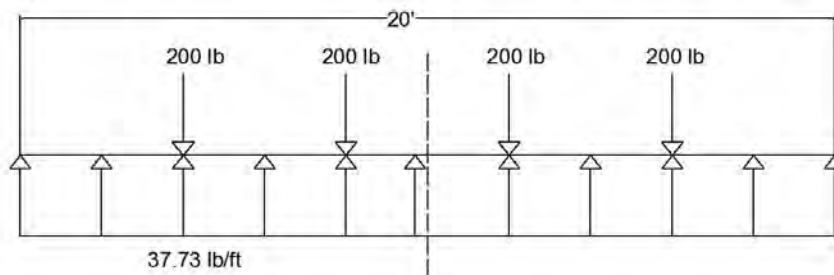


$$w = (\text{Water Pressure}) * (\text{width}) * 60\%$$

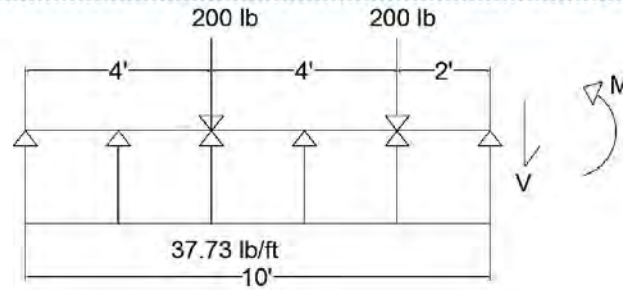
(Multiplied by 60% to account for the shape of the canoe is not a rectangle and reduce the area)

$$w = (0.1807) * (29) * 60\%$$

$$w = 37.73 \text{ lb/ft}$$



Taking a cut in the center of the canoe:



$$\sum M = M + 200 * 2 + 200 * 6 - 37.73 * 10 * 5 = 0$$

$$M = 286.5 \text{ lb} * \text{ft}$$

$$M = 3438 \text{ lb} * \text{in}$$

For 1 inch:

$$\sigma = \frac{3438}{102.08}$$

$$\sigma = 33.68 \text{ psi}$$

FIBERGLASS GRID REINFORCEMENT CALCULATIONS (Percent Open Area):

$$d_1 = 0.1485 + 2 \left(\frac{0.0305}{2} \right) = 0.179 \text{ inches}$$

$$d_2 = 0.1485 + 2 \left(\frac{0.048}{2} \right) = 0.1965 \text{ inches}$$

$$\text{Length}_{\text{sample}} = [(5) * 0.179] = 0.895 \text{ inches}$$

$$\text{Width}_{\text{sample}} = [(5) * 0.1965] = 0.9825 \text{ inches}$$

$$\sum \text{Area}_{\text{open}} = 5 * 5 * 0.1485 * 0.1485 = 0.5513 \text{ in}^2$$

$$\text{Area}_{\text{total}} = 0.895 * 0.9825 = 0.879 \text{ in}^2$$

$$\text{POA} = 0.5513 / 0.879 * 100 = 63\% (> 40\% \text{ min.}) \text{OK!!}$$

TAB D- Material Technical Data Sheets (MTDS)

D-1: LaFarge Type I Portland Cement

PRODUCT DATA SHEET

CEMENT

LAFARGE PORTLAND CEMENT



A versatile, cost-effective
quality building material

Lafarge Portland Cement is a high quality, cost-effective basic building material used in virtually all forms of construction, from hospitals and homes to schools, tunnels and airports. Lafarge Portland Cement meets or exceeds all applicable chemical and physical requirements of ASTM C 150 and CSA A3000-03.

Product Description

Portland Cement

ASTM C 150 Type I, Type IA, Type II, Type III, Type V
CSA A3000-03, GU, GLK, MH, MHL, MS, HE, HEL, LH, LHL, HS

Basic Use: Lafarge Portland Cement is a cost-effective basic building material. It can be used in a wide variety of commercial and architectural concrete construction applications. Uses include cast-in-place, pre-cast, tilt-up, water tanks, drains, bridges, roads, pipes, concrete masonry units, pre-stressed concrete members, masonry mortars and grouts.

Lafarge Portland Cement

U.S.

Type I > This is a general-purpose cement suitable for all uses where the special properties of other types of portland cement are not required.

Type IA > This cement contains an additive that will entrain air to aid in durability when concrete is exposed to freezing temperatures.

Type II > For general use, especially when moderate sulfate resistance or moderate heat of hydration is desired.

Type III > This cement provides high early strength when compared with Type I.

Type V > This is for use when high sulfate resistance is desired. Type V generally gains strength more slowly than Type I.

Canada

GU, GUL* > General use cement, suitable for all applications where the special properties of any other type of portland cement are not required.

MS > Moderate sulphate resistant cement for use in applications requiring moderate levels of sulphate resistance.

MH, MHL* > Moderate heat cement for use in applications requiring moderately low levels of heat generation during the hydration process.

HE, HEL* > High early strength cement for use where high early strengths are required.

LM, LHL* > Low heat cement for use in applications that require significantly low levels of heat generation during the hydration process.

HS > High sulphate resistant cement for use in applications that require high levels of sulphate resistance. HS cement generally gains strength more slowly than the other types.

* NOTE: The suffix "L" indicates a portland-limestone cement.

Options

Select Lafarge manufacturing plants produce air-entrained (Type IA) portland cement that contains an additive that will entrain air to aid in durability when concrete is exposed to freezing temperatures. Certain locations manufacture cements meeting the optional physical and chemical requirements of ASTM and CSA. AASHTO cements are available in certain geographic areas. Contact your Lafarge Cement representative for product use and availability.

Technical data

Lafarge Portland Cement meets or exceeds all applicable chemical and physical requirements of ASTM C 150 and CSA A3000-08.

Use and limitations

Lafarge manufactures all products in accordance with strict QA/QC (quality assurance and quality control) procedures to ensure optimum product performance and uniformity. However, there are many variables that affect concrete performance that are beyond the control of the cement manufacturer. Good concreting practices in accordance with the American Concrete Institute, The National Building Code, Provincial, Municipal and other local building codes are required to achieve desired results. Skilled persons should use these products with special attention given to formwork, batching, mixing, placing, finishing and curing. In most applications, quality aggregates, admixtures and additives should be utilized. For detailed information, contact your Lafarge sales office.

Product Name

Lafarge Portland Cement

Manufacturer

Lafarge North America Inc.
12013 Sunrise Valley Drive
Suite 500
Reston, VA 20191
Lafarge Canada Inc.
334 Avenue Aero
Pointe-Claire, Quebec
H9R 5W5
www.lafarge-na.com

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.

Limited Warranty

Lafarge warrants that Lafarge Portland Cement meets all applicable requirements of ASTM C 150 and CSA A3000-08. Lafarge makes no other warranty, whether of merchantability or fitness for a particular purpose, with respect to Lafarge Portland Cement. Having no control over its use, Lafarge will not guarantee finished work in which Lafarge Portland Cement is used.

Contact your Lafarge Cement office for specific product information, availability and ordering.

Lakes and Seaway Business Unit Bingham Farms, Michigan Phone: 248-694-1991	River Business Unit Leeds Summit, Missouri Phone: 816-251-2103	U.S. East Business Unit Apharotta, Georgia Phone: 678-746-2000	Western Business Unit Calgary, Alberta Phone: 403-271-9110
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FOOTNOTES



D-2: GRACE Silica Fume

Grace Concrete Products



FORCE 10,000® D
High performance concrete admixture
dry densified powder

Product Description

Force 10,000® D is a dry densified microsilica (silica fume) powder designed to increase concrete compressive and flexural strengths, increase durability, reduce permeability and improve hydraulic abrasion-erosion resistance. The specific gravity of Force 10,000 D is 2.20.

Uses

Force 10,000 D can be used to consistently produce concrete with strengths of 6,000 psi (42 MPa) and higher in most instances with locally available materials and existing methods. It may also be used in precast and prestress applications where high early strengths are required.

The addition of Force 10,000 D also produces concrete with increased watertightness and dramatically reduced permeability compared to conventional mixes. Reduced permeability is an important advantage in slowing the intrusion of chloride where corrosion of reinforcing steel is a potential problem. Examples are parking garages, bridge decks and concrete in a marine environment. Force 10,000 D also enhances the durability of concrete against aggressive chemical attack and in hydraulic abrasion-erosion applications.

Preconstruction Trial Mix

It is strongly recommended that trial mixes be made several weeks before construction start up. This will allow the concrete producer an opportunity to determine the proper batching sequence

and amounts of other admixtures needed in order to deliver the required concrete mix to the job site. A trial mix will also help determine whether the combination of concrete materials and construction practices will allow the concrete to meet a specified performance. Grace's broad experience with this product can help the concrete producer deliver a satisfactory product regardless of the mixture proportions. Contact your Grace sales representative for help with trial mixes.

Finishing & Curing

Force 10,000 D concrete can be used in flatwork with little or no modification to the recommended practices outlined in ACI 302, *Guide for Concrete Floor and Slab Construction*.

Force 10,000 D will reduce the surface bleed water of concrete in large applications. ACI 308, *Standard Practice for Curing Concrete*, must be followed to assure that any problems that can occur due to decreased bleeding are minimized. Your Grace representative is available to review your particular job needs.

Performance

Force 10,000 D improves concrete through two mechanisms. The extremely fine microsilica particles are able to fill the microscopic voids between

Product Advantages

- Increases concrete compressive and flexural strength
- Increases and improves durability
- Reduces permeability significantly
- Improves hydraulic abrasion-erosion resistances



the cement particles, creating a less permeable structure. In addition, the microsilica reacts with the free calcium hydroxide within the concrete to form additional calcium silicate hydrate (gel), producing a tighter paste-to-aggregate bond. Force 10,000 D does not affect concrete set times.

Force 10,000 D will improve the mechanical properties of concrete. In order to meet specified concrete performance levels, however, many variables are involved. These include, but are not limited to; concrete materials, weather conditions, testing techniques and mixing, transporting, placing and finishing practices. ACI and ASTM guidelines must be strictly adhered to.

Addition Rates

Force 10,000 D dosage rates will vary based on the requirements of the application. Dosage rates should be calculated on percent microsilica by weight of cement, or on lb/yd^3 (kg/m^3) of concrete, as appropriate. Dosage rates will be as specified. If not specified, consult your Grace representative for your particular job needs.

Compatibility with Other Admixtures and Batch Sequencing

Force 10,000 D is compatible with all conventional water reducers, superplasticizers, set retarders and DCl* corrosion inhibitor. Any air-entraining agent which works effectively with superplasticizers and microsilica, particularly vinylsil resins such as DuraSil* by Grace Construction Products, are recommended. Only non-chloride set accelerators, such as PolarSet*, may be used with Force 10,000 D concrete. All admixtures must be added separately to assure their prescribed performance. Trial mixer and pretesting of concrete are recommended to optimize dosage rates, and ensure ultimate performance.

Force 10,000 D can be used in either central or transit mix concrete production. Force 10,000 D may be used in conjunction with water-reducing admixtures (both normal and high-range as approved by ASTM) to assure workability of the mix.

Packaging & Handling

Force 10,000 D is available in bulk, and 25 lbs (11.4 kg) Concrete Ready Bags™.

Dispensing Equipment

Bulk Force 10,000 D may be stored in already existing cement silos. The silos must be completely clean with no foreign residue remaining which may cause contamination. Up-pipes to the silo for unloading bulk tankers should also be clean and clear of obstructions. Small diameter 4 in. (100 mm) rigid metal pipes with several angles (especially right angles) will cause longer unloading times. Large diameter 6 in. (150 mm) flat lined, flexible rubber pipes will allow for the least unloading time. Dispensing bulk Force 10,000 D will take place in the same manner as that used for cement. Augering or dropping from the silo to the weigh hopper is the usual practice.

Storage

Bagged Force 10,000 D should be stored in a dry, protected area. Manual dispensing by tearing the bags is the normal method. A dust mask should be used when dispensing the bagged product, consult the product MSDS for more complete instructions. Force 10,000 D is not considered a health hazard.

www.graceconstruction.com

North American Customer Service: 1-877-4AD-MIX1 (1-877-423-6491)

Force 10,000 DCl, Densitec, PolarSet and Densocem are trademarks of W. R. Grace & Co.-Conn. registered in the United States and in other countries.

We hope the information here will be helpful. It is based on data and knowledge considered to be true and accurate and is offered for the user's consideration, investigation and verification, but we do not warrant the results to be obtained. Please read all statements, recommendations or suggestions in conjunction with our conditions of sale, which apply to all goods supplied by us. No statement, recommendation or suggestion is intended for any use which would infringe any patent or copyright. W. R. Grace & Co.-Conn., 62 Whitehouse Avenue, Cambridge, MA 02140. In Canada, Grace Canada, Inc., 294 Clements Road, West Ajax, Ontario, Canada L5C 3C6.

This product may be covered by patents or patents pending.
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PAP02

GRACE

**Concrete Products
Technical Guide Specification
Microsilica Concrete**

SECTION 03320

PART 1 - GENERAL

1.01 SUMMARY

- A. This section specifies microsilica (silica fume) admixture for the reduction of concrete permeability to protect against intrusion by chlorides and other aggressive chemicals, and for the production of high-strength concrete.
- B. Related Sections: Other specification sections which directly relate to the work of this Section include, but are not limited to, the following:
 - 1. Section 03300 - Cast-In-Place Concrete.
 - 2. Section 03365 - Post-Tensioned Concrete.
 - 3. Section 03400 - Precast Concrete.

1.02 SUBMITTALS

- A. Product Data: Submit manufacturer's product data, installation instructions, use limitations and recommendations for each material.
- B. Test and Performance Data: Submit independent test data substantiating the product's ability to reduce concrete permeability by chlorides and other aggressive chemicals.

1.03 QUALITY ASSURANCE

- A. Manufacturer: Concrete admixture shall be manufactured by a firm with a minimum of 5 years experience in the production of similar products. Manufacturers proposed for use but not named in these specifications shall submit evidence of ability to meet all requirements specified, and include a list of projects of similar design and complexity completed within the past five years.
- B. Materials: For each type of material required for the work of this Section, provide primary materials which are the products of one manufacturer.
- C. Pre-Construction Conference: A pre-construction conference shall be held two weeks prior to commencement of field operations to install the specified product in order to establish procedures to maintain optimum working conditions and to coordinate this work with related and adjacent work. Agenda for meeting shall include concrete and admixture handling, placing, finishing, and curing.
- D. Manufacturer's Representative: A representative of the manufacturer shall be present for project start-up during initial concrete placement. Engineer may waive requirement for manufacturer's representative if Contractor provides sufficient evidence that producer and finisher have adequate experience with admixtures required.
- E. Trial Mix: Provide a minimum 4 cubic yard (3 m³) trial mix containing proposed concrete design mix placed at the job site in location acceptable to the Engineer. Engineer may waive requirement for trial mix if Contractor provides sufficient evidence that producer and finisher have adequate experience with low water cement ratio mixes.

1.04 PROJECT CONDITIONS

- A. Perform work only when existing and forecasted weather conditions are within the limits established by the manufacturer of the materials and products used.

PART 2 - PRODUCTS

2.01 MANUFACTURER

- A. Provide Force 10,000® microsilica concrete admixtures by Grace Construction Products meeting specified requirements. For customer service in North America:

Call toll free:	877-4AD-MIX1	(877-423-6491)
Fax toll free:	877-4AD-MIX2	(877-423-6492)

2.02 MATERIALS

- A. **Microsilica Admixture:** Provide Force 10,000 concrete admixture by Grace Construction Products complying with ASTM C 1240.

2.03 CONCRETE MIXES

- A. Application Rate:

NTS This section may be used for concrete permeability requirements or high-strength concrete. Application rate (dosage rate) of microsilica may vary depending on individual project requirements. Application rates may be stated in dry pounds per cubic yard, percent of weight of cement, or as required to meet a performance criteria. Typical application rates for low permeability concrete varies from 30 to 60 lbs/cy. Specifier should use only one of the three sections which follow for A. Application Rate.

NTS Force 10,000 Sample Specification For Permeability Requirements

This sample specification may be used by the design engineer when specifying Force 10,000 microsilica for the reduction of concrete permeability to protect against intrusion by chlorides or other aggressive chemicals. Force 10,000 is a microsilica-based admixture manufactured by Grace Construction Products of W. R. Grace & Co.-Conn.

The high silicon dioxide content of microsilica combines with the excess calcium hydroxide in the concrete to form more calcium silicate hydrate "glue." This chemical reaction plus its fine particle size allows Force 10,000 to fill in the voids between the cement grains and aggregate to deliver less permeable concrete. When chlorides migrate through the concrete and attack the steel reinforcing, corrosion occurs. By reducing the permeability of the concrete, chlorides take much longer to reach the steel which extends the service life of the structure considerably. Chlorides are typically present from deicing salts or from a marine environment. Structure applications of Force 10,000 include parking garages, bridge decks and overlays, reinforced pavements, and all structures in a marine environment. Structural concrete design criteria shall follow ACI 318, 357 and 201 guidelines. Parameters used in this sample specification, such as water/cementitious ratio and concrete cover over reinforcing steel, are taken from these guidelines and are conservative values.

There are two ways to specify microsilica concrete for permeability requirements: by prescription or by performance. The prescription method mandates the number of pounds of microsilica per cubic yard to be used while the performance method uses ASTM C 1202 test method to measure "coulombs." Please use one method (prescription or performance) but not both. If the "performance method" is the preferred choice, use ASTM C1202 for mix design purposes only, not as a mix acceptance or rejection criteria during the construction phase. Since the chloride's loading rate and final concrete quality are unknown factors, W. R. Grace cannot guarantee the longevity of the protection offered by Force 10,000. Quality concrete as recommended by ACI and the addition of Force 10,000 will slow the ingress of chlorides into the concrete. Neither quality concrete nor Force 10,000 will stop corrosion forever, but both will retard the onset of corrosion.

Prescription Method

1. Provide microsilica admixture Force 10,000 as manufactured by Grace Construction Products.
2. Microsilica shall be added at a rate of (50) pounds dry weight of microsilica per cubic yard [(30) kg/m³] of concrete.
3. Compressive strength shall be a minimum of (5,000) psi [35 MPa] at 28 days as measured using (4" x 8") (100 mm x 200 mm) cylinder specimens.
4. A maximum water-to-cementitious ratio of 0.40 is required.
5. Microsilica may be counted as cementitious material in calculations.
6. Add microsilica as a liquid slurry or in dry densified form in 25 lb (11.4 kg) Concrete Ready Bags[®] packaging.
7. Blended cements with interground microsilica will not be allowed.

Performance Method

1. Provide microsilica admixture Force 10,000 as manufactured by Grace Construction Products.
2. Microsilica shall have a minimum of (5,000) psi [35 MPa] at 28 days as measured using (4" x 8") (100 mm x 200 mm) cylinders.
3. Permeability of microsilica concrete shall be tested by ASTM C 1202. Results of tests shall be expressed in electrical units of coulombs. Coulomb tests shall be made on two (4" x 8") (100 mm x 200 mm) representative samples, moist cured for 56 days. Test cylinders shall be made according to ASTM C 31. Coulomb requirement shall be () coulombs or less at 56 days. ASTM C 1202 testing shall be used as an indicator of concrete permeability at mix design submittal only.
4. A maximum water-to-cementitious ratio of 0.40 is required.
5. Microsilica may be counted as cementitious material in calculations.
6. Add microsilica as a liquid slurry or in dry densified form in 25 lb (11.4 kg) Concrete Ready Bags[®] packaging.
7. Blended cements with interground microsilica will not be allowed.

NTS: Force 10,000 Sample Specification For High-Strength Concrete Requirements

This sample specification may be used by the design engineer when specifying Force 10,000 microsilica for the production of high-strength concrete. The design engineer should fill in the compressive strength required. Force 10,000 is a microsilica-based admixture manufactured by Grace Construction Products of W. R. Grace & Co.-Conn. The high silicon dioxide content of microsilica combines with the excess calcium hydroxide in the concrete to form more calcium silicate hydrate "glue." This produces a stronger, tighter bonding paste structure. Additionally, the extreme fineness of the microsilica enables it to fill in voids between cement grains and aggregate, creating a less permeable paste. These two factors contribute to providing higher strength, more durable concrete.

Structural applications for high strength Force 10,000 concrete are broad, but include usage in structural columns, beams and girders. Structural concrete design criteria shall follow ACI 318, 357 and 201 guidelines. Parameters used in this sample specification, such as water-to-cementitious ratio are taken from these guidelines and are conservative values. This sample specification is based on the performance method, whereby the compressive strength of the concrete is mandated by the design engineer.

High-Strength Concrete Requirements

1. Provide microsilica admixture Force 10,000 as manufactured by Grace Construction Products.
 2. Microsilica high-strength concrete shall have a minimum of () psi [() MPa] at 28 days.
 3. Test cylinders shall be 4" x 8" (100 mm x 200 mm).
 4. A maximum water-to-cementitious ratio of 0.40 is required.
 5. Microsilica may be counted as cementitious material in calculations.
 6. Add microsilica as a liquid slurry or in dry densified form in 25 lb. (11.4 kg) Concrete Ready Bags packaging.
 7. Blended cements with interground microsilica will not be allowed.
- B. Concrete Cover Over Reinforcement: Minimum concrete cover over reinforcement shall be () inches [() mm].

NTS: Follow ACI 318 recommendations for concrete cover over reinforcement. For deicing salt and marine environments, ACI 318-89, section R7.7.5, requires 2 inches (50 mm) for walls and slabs and 2-1/2 inches (64 mm) for other members. For marine environments, ACI 357 recommends 2-1/2 inches (64 mm).

- C. Air Entrainment: For freeze-thaw durability comply with ACI 318 freezing and thawing exposure requirements, as determined by ASTM C 173 or ASTM C 281.
- D. Water-to-Cementitious Ratio: Provide 0.40 maximum. Microsilica, fly ash, blast furnace slag and cement are considered cementitious materials. The water content of Force 10,000 slurry shall be included as mix design water.
- E. Recommended Cementitious Content for Workability:

Maximum Aggregate	Minimum Cementitious
3/8" (10 mm)	700 pounds/cu.yd. (415 kg/m ³)
1/2" (13 mm)	680 pounds/cu.yd. (400 kg/m ³)
3/4" (20 mm)	650 pounds/cu.yd. (385 kg/m ³)
1" (25 mm)	630 pounds/cu.yd. (375 kg/m ³)
- F. Compressive Strength: Minimum 28 day compressive strength for microsilica concrete shall be (5,000) psi [(35) MPa] unless stated otherwise in Section 2.03 A. Application Rate.
- G. Concrete Slump for Flatwork: 5 to 8 inches (125 to 200 mm). Concrete slump may be 2 inches (50 mm) over normal concrete slumps as microsilica concrete can be sticky and has a surface that is harder to close than normal concrete.
- H. Concrete Admixtures: High-range water reducers are mandatory to control slump, mixing, cementitious ratio and proper distribution of the microsilica, and shall be plant added. Additional water reducers may be added at the job site when required.
- I. Additional Concrete Admixtures: Additional concrete admixtures conforming to ASTM C 494 or equivalent CSA 266 standards may be used as required including the following:
 1. Type A: Water-reducing admixture, WRDA® series or Daracem®-55 by Grace Construction Products.
 2. Type D: Water-reducing and retarding admixture, Daratard®-17 by Grace Construction Products.
 3. Type F or G: Water-reducing, high-range admixture, WRDA-19, Daracem-100 by Grace Construction Products. This type of admixture must be included in all Force 10,000 concrete.
 4. Type C: Accelerating admixture, PolarSet® by Grace Construction Products.
 5. Grace MicroFibers® for flatwork, at 1 pound per cubic yard (600 grams/m³) addition rate.
 6. DCI® or DCI-S Corrosion Inhibitor by Grace Construction Products may also be used if required at rate recommended by manufacturer.
- J. Special Mixing Requirements for Densified Microsilica: Densified microsilica requires enhanced mixing to ensure full dispersion. The following mix requirements shall be adhered to:
 1. For all types of mixing equipment, mix times shall be increased by 40% over the minimum mix time required to achieve mix uniformity as defined by ASTM C 94.
 2. For truck-mixed and central mixed concrete, maximum allowable batch size shall be 80% of the maximum as called out by ASTM C 94.

PART 3 - EXECUTION

3.01 EXAMINATION

- A. Examine conditions of substrates and other conditions under which work is to be performed and notify Owner, in writing, of circumstances detrimental to the proper completion of the work. Do not proceed until unsatisfactory conditions are corrected.

3.02 CONCRETE PLACEMENT, FINISHING AND CURING

- A. Concrete Finishing and Curing: Microsilica concrete typically exhibits little or no bleeding. To reduce plastic or drying shrinkage cracks, comply with ACI 302 "Guide for Concrete Floor and Slab Construction", ACI 308 "Standard Practice for Curing Concrete", ACI 306 "Standard Practice for Cold Weather Concreting", and ACI 305 "Hot Weather Concreting."

1. Underfinish microsilica concrete by limiting finishing operation to screeding, bull-float, and broom finish. Curing shall be initiated within one hour of concrete placement.
2. The use of wind breaks, sun shades, and fog misting are recommended to minimize the rate of evaporation at the concrete surface.
3. Light fog misting above the concrete to keep the environment above the concrete surface at high humidity is recommended during the placing and finish operations.
4. Fog misting is required when the rate of evaporation at the concrete surface exceeds 0.1 pound per square foot per hour as determined by ACI 308 Section 1.2.1. Fogging shall continue after the finishing operation until prewetted burlap or other approved curing material is placed over the concrete. When fog misting is not available or possible, an evaporation retarder shall be applied before and after bull-floating and during final finish to protect the concrete.
5. Wet curing is the preferred method for curing. Use prewetted burlap to cover all flatwork and keep wet for a minimum of seven days or until the time necessary to attain 70 percent of the specified compressive strength, as recommended by ACI 308 Section 3.1.3.

3.03 PROTECTION

- A. Protect completed work from damage and construction operations throughout finishing and curing operations.

END OF SECTION

North American Customer Service: 1-877-4AD-MIX1 (1-877-423-6491)



Visit our website at: www.graceconstruction.com

W.R. Grace & Co.-Conn. 62 Whittemore Avenue Cambridge, MA 02140 Tel: 617-876-1400

Durock, Durocem, Durogel, Duroret, Durox, DUCI, Forno-11, Hilti, PilsaGel and WRDA are registered trademarks and Memphiber (TM) is a trademark of W.R. Grace & Co.-Conn.

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D-3: GRACE Microfibers

Grace Concrete Products



GRACE MICROFIBER™

Synthetic fiber for concrete

ASTM C1116, ASTM C94

Product Description

Grace MicroFiber™ is a synthetic fiber for concrete, manufactured from 100% virgin polypropylene in a microfilament form. Grace MicroFiber is produced on a state-of-the-art production line which is specifically designed to yield an ultrathin concrete reinforcing fiber. Grace MicroFiber contains over 50 million individual fibers for each 1.0 lb./yd³ dosed. Engineered specifically for use in concrete, it is alkali resistant, non-absorptive and completely noncorrosive. Grace MicroFiber protects concrete from stresses which cause cracking while the concrete is most vulnerable during the first 24 hours after placement. Grace MicroFiber complies with ASTM Designation C1116, *Standard Specification for Fiber-Reinforced Concrete and Shotcrete, Type III Synthetic Fiber-Reinforced Concrete or Shotcrete*. Grace MicroFiber is 3/8 in. (19 mm) in length.

Uses

Grace MicroFiber may be used in any application where decreased plastic shrinkage cracking and improved durability are desired. Specifically, such applications include but are not limited to, slabs on grade, pavements, overlays, sloped walls, pools, shotcrete,

stucco, precast and prestressed products.

It is suggested that this product be used in conjunction with properly compacted base materials and jointing in accordance with ACI guidelines and standards.

Grace MicroFiber may be used as an alternative to welded wire fabric, depending on the application. Grace MicroFiber may not be used as a replacement for structural or post-crack control steel reinforcement. For temperature or shrinkage post-crack control, please consult a Grace representative regarding our STRUX® synthetic macro fibers.

Advantages

Grace MicroFiber uniformly distributes multi-dimensionally throughout the concrete mixture. The extremely high number of fibers in the fresh concrete matrix protects the concrete when its tensile strength is lowest, reducing the formation of plastic shrinkage cracking. This cracking and other internal stresses would otherwise permanently weaken the resulting concrete. The concrete permeability is decreased, while surface characteristics, impact and toughness properties are improved.

Product Advantages

- Reduces plastic shrinkage cracking and improves durability
- Protects concrete from stresses that cause cracking
- Provides cost effective control of plastic shrinkage
- Provides overall higher quality of concrete



Technically advanced production techniques make Grace MicroFiber a highly durable fiber that is virtually invisible in fresh concrete. This minimizes fiber-reinforced concrete finishing concerns while providing the highest level of crack protection available.

Typical Properties

Specific gravity	0.91
Absorption	None
Modulus of elasticity	500 ksi
Melt point	320°F (160°C)
Ignition point	1094°F (590°C)
Alkali, acid and salt resistance	High

Addition Rates

Grace MicroFiber may be added to concrete at any point during the batching or mixing process. Grace MicroFiber may be added to the aggregate during weighing or charging, or to the central mixer or truck before, during, or after charging. The concrete must be mixed at high speed for 5 minutes, or 70 revolutions, after the addition of Grace MicroFiber to ensure uniform distribution. The standard range of addition for Grace MicroFiber is 0.5 to 1.0 lb/yd³ (300 to 600 g/m³) of concrete.

Compatibility with Other Admixtures

Grace MicroFiber is compatible with all Grace admixtures. Its action in concrete is purely mechanical and will not affect the hydration process. Each admixture should be added separately.

Packaging & Handling

Grace MicroFiber is available in convenient Concrete-Ready™ Bags which are added, unopened, to the truck drum or central mixer. The specially designed cellulose fiber bags disintegrate and disperse the fibers throughout the mix. Grace MicroFiber is available in 0.5 lb and 1.0 lb Concrete-Ready Bags in the U.S. and 600 g Concrete-Ready Bags in Canada.

www.graceconstruction.com

North American Customer Service: 1-877-4AD-MIX1 (1-877-429-6491)

MicroFiber is a trademark of W. R. Grace & Co.—Conn.

We hope the information here will be helpful. It is based on data and knowledge considered to be true and accurate and is offered for the users' consideration, investigation and verification, but we do not warrant the results to be obtained. Please read all statements, recommendations or suggestions in conjunction with our conditions of sale, which apply to all goods supplied by us. No statement, recommendation or suggestion is intended for any use which would infringe any patent or copyright. W. R. Grace & Co.—Conn., 60 Whittemore Avenue, Cambridge, MA 02140. In Canada, Grace Canada, Inc., 294 Clements Road, West Ajax, Ontario, Canada L1S 5C6.

This product may be covered by patents or patents pending.
DMF-16P Printed in U.S.A. 03/12

Specifications

Fibers shall be 3/4 in. (19 mm) microfilament polypropylene fibers as supplied by Grace Construction Products, 60 Whittemore Avenue, Cambridge, MA 02140. One pound (450 grams) of fibers shall contain no less than 50 million individual fibers, 0.5 lb (225 grams) of fibers shall contain no less than 25 million individual fibers. Required dosage rate shall be as specified by the design engineer or architect. Grace MicroFiber shall be used in strict accordance with the supplier's recommendations and within time as specified in ASTM C94. The fiber shall comply with ASTM Designation C1116 Type III 4.1.3. Standard ACI 302 procedures for placing, finishing and curing shall be followed when using Grace MicroFiber.

References

Building Codes—
BOCA National Building Codes, SBCCI Standard Building Code, ICBO Uniform Building Code and all supplements as adopted by the Council of American Building Officials

American Concrete Institute (ACI)—
ACI 544.1 R. *State of the Art Report of Fiber-Reinforced Concrete*
ACI 302 *Guide for Concrete Floor and Slab Construction*

American Society of Testing and Materials (ASTM)—
ASTM C1116 *Standard Specification for Fiber-Reinforced Concrete and Shotcrete*

ASTM C1579 *Standard Test Method for Evaluating Plastic Shrinkage Cracking of Restrained Fiber Reinforced Concrete (Using a Steel Form Insert)*

ASTM C94 *Standard Specification for Ready-Mixed Concrete*

GRACE

D-4: Haydite Expanded Shale

The Original Lightweight Aggregate



317-831-0710
Fax 317-831-8975

March 29, 2011

Sonja Tews
IPFW School of Civil Engineering
Engineering, Technology & Computer Science Building
2101 E. Coliseum Blvd.
Fort Wayne, IN 46805

Sonia,

Hydraulic Press Brick Company hereby certifies that its Haydite structural lightweight aggregate, size "A" and "AX" expanded shale fines, used as a structural lightweight aggregated for structural lightweight concrete meets and or exceeds the standards set forth in ASTM C330 and C331.

Sincerely,

Tom Morris

Thomas Morris
Sales Engineer
Hydraulic Press Brick Company
P.O. Box 130
Brooklyn, IN 46111
(317) 997-9880

Hydraulic Press Brick Company
PO Box 130
Brooklyn, IN 46111

D-5: Poraver Glass Beads



Imperial
Technical data sheet

according to ASTM C330, C331, C332

Designation	Standard	Poraver® granular sizes							
		0040/25	0.1-0.3	0.25-0.5	0.5-1	1-2	2-4	4-8	
Granular size mm									
Granular size (Mesh #)	ASTM C136	400-120	140-50	60-35	35-18	18-10	10-5	5-3/16"	
Fineness modulus		*	0,66	1,02	2,72	3,81	4,7	5,73	
Dry loose bulk density lbs./ft ³	ASTM C6/C29M	33.3 +/- 4.4	25 +/- 3.8	21.2 +/- 3.2	16.9 +/- 3.0	14.4 +/- 2.1	11.9 +/- 1.8	11.2 +/- 1.7	
Oven dry density lbs./ft ³	ASTM C128	-	36.2 +/- 8.4	36.8 +/- 9.6	29.3 +/- 4.4	24.3 +/- 3.6	20 +/- 3.0	18.8 +/- 2.7	
Compressive strength PSI	EN 12051-2002	*	348	348	261	232	203	174	
% absorption by mass [†]	ASTM C128	*	25	25	25	25	27,5	30	
Organic impurities	ASTM C40	No organic compounds							
Staining index (index number)	ASTM C641	0							
Loss on ignition %	ASTM C114	-1.0							
Clay lumps and friable particles %	ASTM C142	-	-	-	-	< 2.0	< 2.0	< 2.0	
Oversize	EN 12055-1-2002	10 M. X							
Undersize		15 M. X							

* on request
[†] % determined by mass determined after 1 minute submerged in water

The following data are valid for all gran sizes:

pH value	9-12
Moisture content on delivery	< 0.5%
Softening point	approx. 1300 °F
Colour	crystal white
Thermal conductivity BTU-in/ft ² -°F	- - - - - 0,486** 0,486**

** calculated values DIB according to approval F03.11-114

The Poraver® strength grades may vary within the tolerance range of bulk densities. Limited special granular sizes available upon request.



D-6: Davis Colors Concrete Color



MIX-IN COLORS FOR CONCRETE

Uses: Davis Colors are used in cast-in-place, slab-on-grade, precast, tilt-up and decorative concrete; shotcrete, mortar, concrete masonry units, pavers, retaining wall units and retable. They can also be used to color cast stone, plaster, stucco and other cement-based construction materials. Designed for mix-in use only, they should not be sprinkled or dusted onto the concrete surface.

Ingredients: Pure, concentrated pigments made of high-quality metal oxides recycled from iron or refined from the earth and specially processed for mixing into concrete. Davis Colors comply with ASTM C379 Pigments for Inherently Colored Concrete. They are lightfast, alkali-resistant, weather-resistant, durable and long-lasting like concrete. Davis Colors are available in a wide spectrum of standard colors and can be custom formulated to match design requirements. * Unlike other Davis Colors, Supra-Instar® Black #8084 is a specially treated carbon black. Carbon black is the highest in tint strength and the most economical, but can fade if concrete is not sealed against water penetration. Sealing and periodic re-sealing can minimize this effect.

Packaging: Concrete suppliers use our Mix-Ready® dosing bags or Chameleon® bulk handling system. The Chameleon® is a computer-controlled automatic color dosing system used by concrete producers. Mix-Ready® bags are tossed into the mix without opening or pouring. They dosing bags reduce mixing action, releasing pigments to disperse uniformly leaving no bags to litter the environment.

Installation: Inherently colored concrete is installed the same way as high quality uncolored concrete. Choose a color on the inside of this color card and specify it by name and color number. Create a custom color by varying the amount of color added to the mix. Confirm desired color with a fully-cured job-site test panel. Dry color dose rates range from 1/2 to 7 lbs. per 94 lbs. of cement content and should never exceed 10% of cement content. (Liquid dose rates are higher). Cement content includes portland cement, fly ash, silica fume, lime and other cementitious materials but does not include aggregate or sand. Davis Colors have been used successfully in a wide variety of mix designs and are compatible with commercially available admixtures. The only known incompatibility is with calcium chloride set accelerator which causes blotching and discoloration. * Supra-Instar® black #8084 reduces or negates the effect of air-entraining admixtures.

Finishes: Paving and floors can be finished with pattern-stamped, broomed, growled, exposed aggregate, salt-finished, sand-blasted, diamond-polishing or many other visually appealing textures. Cast-in-place, precast and tilt-up structures can be treated with sand blasting, bushhammering, grinding, polishing, special forms or form liners. The combinations and possibilities are endless. Here are just a few:



Curing & Sealing: W-1000 Guard™ is a non-cloaking, spray-on cure and sealer that meets or exceeds ASTM C691 standards and is specially formulated for colored concrete and exposed aggregate finishes. Other curing methods, such as water curing or plastic sheets cause discoloration. Color Seal™ is an optional, thin-film sealer that is used to match the sheen on this Color Selector. When applied over colored concrete or the W-1000 Guard™, it provides a more uniform appearance.

Quality Tips: For best results, material, curing, weather conditions and workmanship should be uniform throughout a project. Quality starts with the concrete mix; use a low water-content, high performance mix design. When planning a project, budget for craftsmanship.

Consumer Advice: Contractors are independently owned and operated without affiliation to Davis Colors. Choose a licensed and qualified contractor who provides written information and example projects you can see before you buy. Check the yellow pages, ask your local ready mix or building material dealer or visit www.concretedesign.com to find contractors who specialize in colored concrete.

Specify Davis: Choose a color from this color selector and specify it by name and color number. Add color call-out to plan documents or specifications. For complete architectural and guide spec information, visit our web site, refer to our architectural binder, call, fax or write. Our guide specifications can be found in SweetSource®, Spec-Data®, ARMA/Spec-Desk® or at www.daviscolors.com/specs.

For samples or additional information contact:



Tel: 800-356-4848
Fax: 323-269-1053
www.daviscolors.com

Because the conditions of use and application of our products are beyond our control, DAVIS COLORS MAKES NO WARRANTY OF MERCHANTABILITY OR FITNESS FOR ANY PARTICULAR PURPOSES and expressly disclaims liability for consequential or incidental damages, whether based on warranty or negligence. Buyer's sole remedy shall be return of color particles prior to final point of purchase.

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Mixing Guide:

Use the same pigment-to-cement ratio, type and brand of cement and aggregate throughout project. Changes in cement and aggregate color affect final color.

Keep slump less than 5" (12.5 cm) and wear cement resistant. High water content causes concrete to appear pale or "bleed". If higher slump is required, use a water reducing admixture instead of adding water.

Calcium Chloride set accelerator causes discoloration. Do not use with color.

Specify air content of 5% to 7% for improved workability and long term durability in freeze-thaw climates.

Schedule loads for consistent mix times. Delays and discharge in less than 1-1/2 hours. Clean mixer thoroughly between color change-overs.

Confirm color number and weight in Mix-Ready® bag (or combination of bags) is the same required by mix design.

Mix mortar with 1/2 to 2/3 seal batch water. Toss in Mix-Ready® bags and mix at charging speed for at least one minute. Add cement, aggregate and remaining batch water. Continue mixing at charging speed for at least 5 minutes (7 minutes for post-grind mixes).

Notes: In mixes with small aggregate or batches with short mixing duration, Mix-Ready® bags may not completely discharge. In sand/stone or exposed aggregate finishes, use small bag sizes (15 lbs. maximum) or open bag and pour color normally.

The Chameleon® is a computer-controlled color dosing system for Ready Mix operations excluded from Davis. It improves color accuracy and maintainability. Chameleon® dose rates differ from the rates on front of this card. For more information, go to www.daviscolors.com/hamilton.

Contractor's Guide:

Prepare a well-drained subgrade. Add a 2 to 3 inch (50 to 75 mm) layer of sand, gravel or crushed stone. Thoroughly compact the subgrade and moisture evenly before or padlock, standing water, ice, frost, or muddy areas.

If vapor barrier is used, overlap sheets and tape over laps in barrier. Place a 1" (25 mm) layer of granular soil-draining compactible fill over the barrier to minimize shrinkage cracking.

Position forms for uniform slab thickness. Follow American Concrete Institute standards for reinforcement and joint placement to control cracking.

Allow ample time and manpower for placement and finish work. Finish evenly and with care.

Begin brooming after bleed water evaporates. Late or fast brooming and riding causes "burn" or dark spot.

Water added at job-site to mixer or pump will cause color to pale. Keep additives to a minimum and constant among batches. Don't wet finishing tools or brooms or sprinkle water on the surface.

Do not apply pigment or cement onto the surface.

Rainy, dry broom, pattern stamped or rough finishes usually cure more even-colored than smooth-broomed finishes. Avoid curing-contracting-aggregate color. Cure colored concrete with Davis W-1000 Guard™ cure and seal. (Info at www.daviscolors.com/W1000.)

Do not use plastic sheet, water curing or curing products when discolor. Wood and other objects left on curing concrete cause discoloration.

Efflorescence is a white powdery substance that appears on concrete surfaces. A result of water evaporation, it is more noticeable on colored surfaces making them look faded or lighter in color when not cleaned off. Proper curing and practices against water penetration reduces likelihood for efflorescence to occur. Remove with detergent or mild acid cleaners formulated to remove efflorescence. Follow cleaner instructions and test in a small area to make sure cleaner will not etch or discolor the surface. Wear rubber gloves and eye protection.

D-7: Direct Colors Concrete Pigment

SPEC DATA

COMMON WORK RESULTS FOR CONCRETE 03 05 00



Direct Colors, Inc.

1. Product Name
Direct Colors Concrete Pigments

2. Manufacturer
Direct Colors, Inc. (DCI)
430 East 10th Street
Shawnee, OK 74801
(577) 265-2666
(800) 275-6667
Fax: (405) 275-2616
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, Inc. (DCI) concrete pigments can be used to add color to concrete floors, countertops, cultured and architectural stone, statuary and an assortment of other garden decor items.

DCI Concrete pigments are also used to tint concrete sealers and liquid release agents to over 30 translucent colors for use in both indoor and outdoor flooring applications. Additionally, DCI oxistone-based concrete dyes, made with concrete pigments, can be applied to existing concrete surfaces for even, consistent coloration and are especially valuable for floors that cannot be add 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 C109 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
- Wide range and variety of colors available
- Superior customer service and technical support
- Free freight in the lower 48 states

ACCESSORIES

- Concrete sealers
- Multipurpose wear
- Concrete dyes
- DCI overlays
- Liquid Colored Antiqué
- Decorative aggregates
- Stamps and blends

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.

• 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 conserve the same effect. See "Reducing Efflorescence" under "Installation" for techniques to help reduce the occurrence of efflorescence.

4. Technical Data

APPLICABLE STANDARDS
ASTM International (ASTM) - ASTM C109 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
- Chemically inert
- Insoluble in water
- Inorganic
- Synthetic
- Specific gravity - Heavier than water
- Evaporation rate - None
- Reddish-brown appearance
- Odorless



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D-8: BASF Master Builders Air-entraining Admixture



The Chemical Company

3	03 30 00	Product Data
	03 40 00	Cast-In-Place Concrete
	03 70 00	Precast Concrete Mass Concrete

Description

Micro Air air-entraining admixture provides concrete with extra protection by creating air bubbles that are ultra-stable, small and closely spaced – a characteristic especially useful in the types of concrete known for their difficulty to entrain and maintain the air content desired.

Even when used at a lower dosage than standard air-entraining admixtures, Micro Air admixture meets the requirements of ASTM C 260, AASHTO M 154, and CRD-C 13.

Applications

Recommended for use in:

- Concrete exposed to cyclic freezing and thawing
- Production of high-quality normal or lightweight concrete (heavyweight concrete normally does not contain entrained air)

MICRO AIR®

Air-Entraining Admixture

Features

- Ready-to-use in the proper concentration for rapid, accurate dispensing
- Greatly improved stability of air-entrainment
- Ultra stable air bubbles

Benefits

- Increased resistance to damage from cyclic freezing and thawing
- Increased resistance to scaling from deicing salts
- Improved plasticity and workability
- Improved air-void system in hardened concrete
- Improved ability to entrain and retain air in low-slump concrete, concrete containing high-carbon content fly ash, concrete using large amounts of fine materials, concrete using high-alkali cements, high-temperature concrete, and concrete with extended mixing times
- Reduced permeability – increased watertightness
- Reduced segregation and bleeding

Performance Characteristics

Concrete durability research has established that the best protection for concrete from the adverse effects of freezing and thawing cycles and deicing salts results from: proper air content in the hardened concrete, a suitable air-void system in terms of bubble size and spacing and adequate concrete strength, assuming the use of sound aggregates and proper mixing, transporting, placing, consolidation, finishing and curing techniques. Micro Air admixture can be used to obtain adequate freezing and thawing durability in a properly proportioned concrete mixture, if standard industry practices are followed.

Air Content Determination: The total air content of normal weight concrete should be measured in strict accordance with ASTM C 231, "Standard Test Method for Air Content of Freshly Mixed Concrete by the Pressure Method" or ASTM C 173/C 173M, "Standard Test Method for Air Content of Freshly Mixed Concrete by the Volumetric Method."

The air content of lightweight concrete should only be determined using the Volumetric Method. The air content should be verified by calculating the gravimetric air content in accordance with ASTM C 138/C 138M, "Standard Test Method for Density (Unit Weight), Yield, and Air Content (Gravimetric) of Concrete." If the total air content, as measured by the Pressure Method or Volumetric Method and as verified by the Gravimetric Method, deviates by more than 1-1/2%, the cause should be determined and corrected through equipment calibration or by whatever process is deemed necessary.

Product Data: MICRO AIR®

Guidelines for Use

Dosage: There is no standard dosage for Micro Air admixture. The exact quantity of air-entraining admixture needed for a given air content of concrete varies because of differences in concrete making materials and ambient conditions. Typical factors that might influence the amount of air entrained include: temperature, cementitious materials, sand gradation, sand-aggregate ratio, mixture proportions, slump, means of conveying and placement, consolidation and finishing techniques.

The amount of Micro Air admixture used will depend upon the amount of entrained air required under actual job conditions. In a trial mixture, use 1/8 to 1-1/2 fl oz/cwt (8-98 mL/100 kg) of cement. In mixtures containing water-reducing or set-control admixtures, the amount of Micro Air admixture needed is somewhat less than the amount required in plain concrete. Due to possible changes in the factors that can affect the dosage of Micro Air admixture, frequent air content checks should be made during the course of the work. Adjustments to the dosage should be based on the amount of entrained air required in the mixture at the point of placement. If an unusually high or low dosage of Micro Air admixture is required to obtain the desired air content, consult your BASF Construction Chemicals representative. In such cases, it may be necessary to determine that, in addition to a proper air content in the fresh concrete, a suitable air-void system is achieved in the hardened concrete.

Dispensing and Mixing: Add Micro Air admixture to the concrete mixture using a dispenser designed for air-entraining admixtures; or add manually using a suitable measuring device that ensures accuracy within plus or minus 3% of the required amount. For optimum, consistent performance, the air-entraining admixture should be dispensed on damp, fine aggregate or with the initial batch water. If the concrete mixture contains lightweight aggregate, field evaluations should be conducted to determine the best method to dispense the air-entraining admixture.

Precaution

In a 2005 publication from the Portland Cement Association (PCA R&D Serial No. 2789), it was reported that problematic air-void clustering that can potentially lead to above normal decreases in strength was found to coincide with late additions of water to air-entrained concretes. Late additions of water include the conventional practice of holding back water during batching for addition at the jobsite. Therefore, caution should be exercised with delayed additions to air-entrained concrete. Furthermore, an air content check should be performed after any post-batching addition to an air-entrained concrete mixture.

Product Notes

Compatibility - Non-Chloride, Non-Corrosive: Micro Air admixture will neither initiate nor promote corrosion of reinforcing and prestressing steel embedded in concrete, or of galvanized steel floor and roof systems. No calcium chloride or other chloride-based ingredients are used in the manufacture of this admixture.

Compatibility: Micro Air admixture may be used in combination with any BASF Construction Chemicals admixture, unless stated otherwise on the data sheet for the other product. When used in conjunction with other admixtures, each admixture must be dispensed separately into the mixture.

Storage and Handling

Storage Temperature: Micro Air admixture should be stored and dispensed at 35 °F (2 °C) or higher. Although freezing does not harm this product, precautions should be taken to protect it from freezing. If it freezes, thaw and reconstitute by mild mechanical agitation. **Do not use pressurized air for agitation.**

Shelf Life: Micro Air admixture has a minimum shelf life of 18 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 Micro Air admixture has been exceeded.

Safety: Micro Air admixture is a caustic solution. Chemical goggles and gloves are recommended when transferring or handling this material. (See MSDS and/or product label for complete information.)

Packaging

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

Related Documents

Material Safety Data Sheets: Micro Air admixture.

Additional Information

For suggested specification information or for additional product data on Micro Air admixture, 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 mix, 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, LLC
Admixture Systems

www.masterbuilders.com

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Canada: 1800 Clark Boulevard, Brentford, Ontario L8T 4M7 • Tel: 800-387-0262 • Fax: 905-750-4651

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Master
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D-9: BASF Glenium Water Reducing Admixture



3 4	03 30 00	Product Data
	05 40 00	Cast-in-Place Concrete
	03 70 00	Precast Concrete
	04 05 16	Masa Concrete Masonry Grouting

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

GLENIUM® 3030 NS

Full-Range Water-Reducing Admixture

Features

- Dosage flexibility for normal, mid and high-range water reduction
- Reduced water content for a given slump
- 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

The dosage flexibility of Glenium 3030 NS allows it to be used as a normal, mid-range and high-range water reducer.

Mixture Data: 600 lb/cyd³ of Type I cement (360 kg/m³); 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	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)

Master Builders

Product Data: GLENIUM® 3030 NS

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/owt (195 mL/100 kg) for Type A applications, 3-6 fl oz/owt (195-390 mL/100 kg) for mid-range use and up to 18 fl oz/owt (1,170 mL/100 kg) for Type F applications. The dosage range is applicable to most mid to high-range 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

Compatibility – 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's Construction Chemicals division 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.

LIMITED WARRANTY NOTICE: We warrant our products to be of good quality and will replace or, at our discretion, refund the purchase price of any products proved defective. Satisfactory results depend not only upon quality products, but also upon many factors beyond our control. Therefore, except for such replacement or refund, BASF MAKES NO WARRANTY OR REPRESENTATION, EXPRESS OR IMPLIED, INCLUDING REPRESENTATIONS OF FITNESS FOR A PARTICULAR PURPOSE OR MERCHANTABILITY, RESPECTING ITS PRODUCTS, and BASF shall have no other liability with respect thereto. Any claims regarding product defect must be received in writing within one (1) year from the date of shipment. User shall determine the suitability of the products for the intended use and assume all risks and liability in connection therewith. Any authorized change in the printed recommendations concerning the use of our products must bear the signature of the BASF Technical Manager.

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D-10: Parex Reinforcing Mesh

PAREXUSA

Reinforcing Meshes

DESCRIPTION	USES
355 Standard Mesh 4.5 oz fiberglass 38 in. (96.5 cm) mesh. Highly flexible for full walls or details. Alkali-resistant.	Standard reinforcement of Parex USA EIFS walls for impact resistance and details. Required in combination with Parex 358.14 High Impact Mesh or 358.20 Ultra High Impact Mesh. May be used in Parex USA Krak-Shield assemblies.
356 Short Detail Mesh 4.5 oz fiberglass mesh 9.5 in. (24 cm) wide. Highly flexible for details. Alkali-resistant.	Backwrapping, corners, reveals and trim.
352 Adhesive Mesh 4.5 oz fiberglass mesh. Self-adhesive, facilitates the wrapping of complex contours. Highly flexible for details. Alkali-resistant.	Complex architectural details only.
358.6 6 oz Mesh 6 oz fiberglass 38 in. (96.5 cm) mesh. For full walls. Alkali Resistant.	Standard reinforcement of Parex USA EIFS. Can be used in combination with 358.14 High Impact Mesh or 358.20 Ultra High Impact Mesh.
358.10 Intermediate Impact Mesh 12 oz fiberglass 38 in. (96.5 cm) mesh. Intermediate strength to enhance impact and abuse resistance. Alkali-resistant.	Use with Parex USA EIFS to achieve EIMA's medium-impact strength classification. May be used in Parex USA Krak-Shield assembly.
358.14 High Impact Mesh 15 oz fiberglass 38 in. (96.5 cm) mesh. High strength to enhance impact and abuse resistance. Alkali resistant.	Use with Parex USA EIFS to achieve EIMA's high-impact strength classification.
358.20 Ultra High Impact Mesh 20 oz fiberglass 38 in. (96.5 cm) mesh. Ultra high strength to enhance impact and abuse resistance. Alkali-resistant.	Use with Parex USA EIFS to achieve EIMA's ultra-high impact strength classification.
357 Corner Mesh 7.2 oz fiberglass 19 in. (48.2 cm) mesh. Heavy duty. Factory pre-bent to fold uniformly around corners. Designed to enhance impact and abuse resistance at corners. Alkali-resistant.	Corner reinforcement, required with 358.20 Ultra High Impact Mesh.

Alkali resistant is defined as 120 psi (21 dN/cm) retained tensile strength per ASTM E 2098 EMA 105.01 after 28 days soaked in 5% sodium hydroxide solution.

PAREXUSA

Standard Mesh				
	Standard	Short Detail	6 oz.	Adhesive
	355	356	358.6	352
Weight*	4.5 oz./sq. yd. (153 g/m ²)	4.5 oz./sq. yd. (153 g/m ²)	6 oz./sq. yd. (207 g/m ²)	4.5 oz./sq. yd. (153 g/m ²)
Coverage	475 sq. ft. (43.6 sq. m) /roll	150 ft. (45.7 m) /roll	475 sq. ft. (43.6 sq. m) /roll	227 sq. ft. (21.7 sq. m) /roll
Width	38 in. (96.5 cm)	9.5 in. (24 cm)	38 in. (96.5 cm)	19 in. (48.2 cm)
Packaging	4 rolls/box	16 rolls/box	4 rolls/box	8 rolls/box
Storage	Avoid storing rolls on end or in direct sunlight.			
Application	The fiberglass mesh must be embedded into the wet base coat and be smoothed with a trowel until fully embedded with the mesh color not visible. Avoid wrinkles. The mesh must be continuous at all corners and must be lapped a minimum of 2-1/2 in. (63.5 mm) at the mesh seams.			352 Adhesive Mesh is adhered to the insulation before the base coat is applied. Apply the base coat and smooth it until the mesh color is not visible. The mesh must be continuous at all corners and must be lapped a minimum of 2-1/2 in. (63.5 mm) at the mesh seams.
Impact Mesh				
	Intermediate Impact 10	High Impact 14	Ultra-High Impact 20	Specialty Mesh
	358.10	358.14	358.20	357
Weight*	12 oz./sq. yd. (407 g/m ²)	15 oz./sq. yd. (509 g/m ²)	20 oz./sq. yd. (692 g/m ²)	7.2 oz./sq. yd. (244 g/m ²)
Coverage	227 sq. ft. (21.7 sq. m) /roll	227 sq. ft. (21.7 sq. m) /roll	227 sq. ft. (21.7 sq. m) /roll	150 ft. (45.7 m) /roll
Width	38 in. (96.5 cm)	38 in. (96.5 cm)	38 in. (96.5 cm)	9.5 in. (23.5 cm)
Packaging	4 rolls/box	4 rolls/box	1 roll/box	4 rolls/box
Storage	Avoid storing rolls on end or in direct sunlight.			
Application	The fiberglass mesh must be embedded into the wet base coat and be smoothed with a trowel until fully embedded with the mesh color not visible. Tightly butt mesh edges but do not overlap them. Install Parex USA 357 Corner Mesh at all edges. Where mesh edges butt together, the joint has to be covered with a layer of Standard or Detail mesh with a minimum lap of 4 in. (102 mm). For 358.14 High Impact Mesh and 358.20 Ultra High Impact Mesh, a second coat of 355 Standard Mesh must be applied on the whole surface.			The fiberglass mesh must be embedded into the wet base coat and be smoothed with a trowel until fully embedded with the mesh color not visible. Tightly butt mesh edges but do not overlap them. Install mesh lapping care to avoid wrinkles. Where mesh edges butt together, the joint has to be covered with a layer of Standard or Detail mesh with a minimum lap of 4 in. (102 mm).
ASTM E2486 Impact Classification (formerly EIMA 101.86) ASTM E2486 classification and impact ranges as follow: A. Standard Impact Resistance, 25-49 in-lbs (2.8 - 5.6 J) Impact Range B. Medium Impact Resistance, 50-89 in-lbs (5.7-10.1 J) Impact Range C. High Impact Resistance, 90-150 in-lbs (10.2-17.0 J) Impact Range D. Ultra High Impact Resistance, >150 in-lbs (> 17.0 J) Impact Range				

PAREXUSA

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D-11: Steel Reinforcing Bar



National Hardware® 4055BC 1/8 in. x 48 in. Smooth Rod, Plain Steel



SKU Number: 3501160

Manufacturers Number: 266072
Brand: National Hardware®
Product Type: Round Rod
Product Width: 1/8 in.
Product Surface: Smooth
Product Length: 48 in.
Product Height: 1/8 in.
Product Thickness: 1/8 in.
Material: Cold-rolled Steel
Product Finish: Plain Steel
Package Quantity: 1
Warranty: Limited Lifetime Warranty

Designed for many industrial applications, this National Hardware® 1/8 in. x 48 in. plain steel cold-rolled smooth rod has excellent forming and welding characteristics. The cold-rolled steel has a more precise diameter and meets ASTM specification A-510.

- 1/8 in. x 48 in. x 1/8 in.
- Product surface: Smooth
- Product material: Cold-rolled steel
- Product finish: Plain steel
- Limited lifetime warranty

With over a century of service National Hardware® is committed to maintaining the highest level of product quality, innovation and manufacturing technology.

D-12: Seal Krete Concrete Paint



New SEAL-KRETE® EPOXY-SEAL® Clean Air, Low VOC Formula is a ready-to-use, acrylic-epoxy blend formulated to resist hot tire pick-up, oil, grease and gasoline. This epoxy-fortified formula dries to a durable, UV-resistant, satin finish that resists scuffing, peeling, blistering and fading. EPOXY-SEAL is easy to maintain, making it ideal for both interior and exterior high-traffic areas including garage floors, driveways, shop floors, basements, pool decks, walkways, patios, porches and more. **Important: Read all directions thoroughly. Always wear gloves and eye protection.**

SURFACE PREP

Note: Proper surface prep is critical to product performance. The surface should be clean, dry, sound and free of dirt, dust, oil, wax and grease. You may need an oil stain remover such as SEAL-KRETE DSR® to lift stubborn oil stains.

BARE CONCRETE: Concrete must have cured for a minimum of 30 days before application. Etch the surface with SEAL-KRETE Concrete Clean & Etch to allow for proper penetration and adhesion. Etching is especially important for smooth-finished concrete surfaces (like garage and basement floors) and is also recommended for rough-finished surfaces. After etching, rinse the surface thoroughly and let dry. For best adhesion results, apply one thin coat of SEAL-KRETE Lock-Down Epoxy Bonding Floor Primer.

PREVIOUSLY STAINED OR PAINTED CONCRETE: Remove loose or peeling paint and degloss surface by sanding (150-200 grit paper). Follow with a general cleaning. Rinse thoroughly and let dry. Then coat the surface with SEAL-KRETE Lock-Down Epoxy Bonding Floor Primer.

APPLICATION

Use only when air and surface temperatures are 55-90°F and are not expected to fall below 55°F for 24 hours before and after application. If more than one gallon is used, infirmix all product to ensure color uniformity; stir well. Apply a very thin coat with a roller* or nylon-polyester brush. Wait 4-6 hours.** Apply second coat in a direction perpendicular to the first.

* Use 1/4" nap for smooth-finished surface, 3/8" nap for broom-finished surface, 1/2" nap for rough or textured surface.

** Additional dry time is needed in lower temperatures or when relative humidity is more than 50%.

COVERAGE: 300 - 500 sq.ft. per gallon, depending on surface porosity.
DRY TIME: Dry to the touch in 2 hours (77°, 50% RH). Dry to light foot traffic in 24 hours, heavy foot traffic in 72 hours. Allow a minimum of 5 days before subjecting to automotive traffic. Premature traffic could cause paint to lift.

*Sanding or removing paint containing lead may be hazardous. For information contact the National Lead Information Center at 1-800-424-5308 or www.epa.gov/lead.

CLEAN-UP & STORAGE: Clean tools with soap and water. Contact your household refuse collection service for disposal of empty containers and unused paint. **Important: Wait 30 days before rinsing or cleaning surface. To avoid premature paint failure, do not use abrasive cleaners or pressure-washer on surface.**

LIMITATIONS: Not recommended for wood, metal, glazed surfaces or areas subject to standing water or hydrostatic pressure. Areas receiving heavy tire traffic should be coated with an approved SEAL-KRETE clear sealer. Do not use if rain is expected within 24 hours.

WARNING! IRRITANT! CONTAINS EPOXY RESIN AND ACRYLATES.

CAUTION: KEEP OUT OF REACH OF CHILDREN. DO NOT TAKE INTERNALLY.

USE WITH ADEQUATE VENTILATION. To avoid breathing vapors and spray mist, open windows and doors or use other means to ensure fresh air entry during application and drying. If you experience eye watering, headache or dizziness, increase fresh air and use a properly fitted respirator (NIOSH-approved for organic vapor with P Series particulate prefilter). Obtain professional advice before using. A dust mask does not provide protection against vapors. Avoid contact with eyes and skin. Wash thoroughly after handling. Close container after each use.

FIRST AID: If you experience difficulty breathing, leave the area to obtain fresh air. If continued difficulty occurs, get medical attention immediately. In case of eye contact, flush immediately with plenty of water for 15 minutes and get medical attention. For skin contact, wash thoroughly with soap and water. If swallowed, get medical attention immediately.

WARRANTY: Manufacturer/seller makes no warranty of any kind except that this product is free from defect and is of merchantable quality. Buyer remedy for breach of warranty is limited to replacement of product or refund of purchase price. Convenience Products will not be responsible for labor or the cost of labor for removal or application of any product.

TECHNICAL SUPPORT: For more information on surface prep or application guidelines, or to obtain a Material Safety Data Sheet, call 1-800-323-7357, M-F (8:00 am - 5:00 pm EST) or visit our website at www.seal-krete.com.



Product	No.	Size	UPC Code	Case Bar Code	Case Dim (L x W x H)	Case Size (cubic ft / lbs)	Case Qty	Pallet Qty
EPOXY-SEAL Low VOC White Base	960001	1 gallon	0 15944 96001 3	9 00 15944 96001 6	14 x 14 x 8	.91 / 42	4	45 cases
EPOXY-SEAL Low VOC Deep Base	970001	1 gallon	0 15944 97001 2	9 00 15944 97001 5	14 x 14 x 8	.91 / 41	4	45 cases
EPOXY-SEAL Low VOC Armor Gray	981001	1 gallon	0 15944 98101 0	9 00 15944 98101 7	14 x 14 x 8	.91 / 44	4	45 cases
EPOXY-SEAL Low VOC Slate Gray	982001	1 gallon	0 15944 98201 7	9 00 15944 98201 4	14 x 14 x 8	.91 / 44	4	45 cases

READY-TO-USE • RESISTS OIL, CHEMICALS, HOT TIRE PICKUP
HI-HIDE • INTERIOR / EXTERIOR • SOAP & WATER CLEAN-UP

SEAL KRETE **EPOXY-SEAL** CONCRETE & GARAGE FLOOR PAINT

TECHNICAL INFORMATION:

- Finish: Premium satin
- Colors: 18 available
- Colorant Limits: White Base 5 oz., Deep Base 8 oz.
- Volume Solids: 28.00 ± 1%
- Weight Solids: 44.00 ± 1%
- VOC (EPA method 24): < 50 g/L
- Odor: Very low
- Recommended spread rate (per coat):
 - Wet mils: 3.2 - 5.3
 - Dry mils: 1.2 - 2.1
- Coverage: 300-500 sq ft/gal
- Shelf Life: 2 yrs (unopened container stored at 77°F)
- Flash Point: > 200°F closed cup method
- Dry Time (4 mils wet film thickness, 50%RH):

	55°F	77°F	90°F
Dry to touch:	3 hrs	2 hrs	1 hr
Recoat:	6 hrs	4 hrs	2 hrs
Light foot traffic:	36 hrs	24 hrs	12 hrs
Heavy foot traffic:	5 days	72 hrs	36 hrs
Vehicular traffic:	10 days	5 days	5 days

- ASTM TESTING (on smooth, bare, etched concrete – 2 coats, 4 mils dry film thickness):
 - ASTM D-4541 (adhesion, 500 psi): 100% concrete failure
 - ASTM D-4060 (abrasion, CS-17 wheel, 1000 cycles): 111 mg loss
 - ASTM D-2794 (Impact resistance): 30 inch lbs.
 - ASTM D-622 (flexibility, 180 bend, 1/8" mandrel): Pass
 - ASTM D-4585 (humidity resistance): 500 hr. rating of 10 for blistering
 - ASTM D-3363 (pencil hardness): 2B
 - ASTM D-2486 (scrub resistance): Passes 1000 cycles
 - ASTM C-1028-96 (slip resistance): .60 minimum static coefficient of friction rating

UV-resistant. Very low odor. Hi-hide. Great for concrete garage floors, shop floors, basements, driveways, porches, patios, walkways, pool decks and more!

3 TIMES THE DURABILITY OF PORCH & FLOOR PAINT



Convenience Products
 335 Gandy Rd., Astorville, FL 32829 USA
 Questions or comments? e-mail: technical@seal-krete.com
 or call: 1-800-323-7357

How to treat concrete
www.seal-krete.com

D-13: Seal Krete Concrete Sealer



SEAL-KRETE® CLEAR-SEAL is a clear, urethane-fortified acrylic sealer developed to provide a high-gloss, premium finish to painted, stained or bare concrete. It's durable, long-wearing, scratch-resistant, stain-resistant, oil and gas-resistant, and it extends paint life. CLEAR-SEAL also protects against moisture damage and enhances the natural color of brick, tile, stone, exposed aggregate, stucco, clay pavers, and stamped concrete.

Important: Read all directions thoroughly. Recommended: Wear gloves and safety glasses.

SURFACE PREP

Note: The surface should be clean and dry. You may need an oil silt remover such as SEAL-KRETE D-SPF to lift stubborn oil stains. Power washing is recommended.

BARE CONCRETE: Concrete must have cured for a minimum of 30 days. Etch smooth-finished concrete (such as basement or garage floors) with a concrete etching solution like SEAL-KRETE Clean-N-Etch. **Note:** If etching with muriatic acid, the area must be neutralized before proceeding. For more information visit www.seal-krete.com.

PAINTED SURFACES: Freshly painted surfaces must have cured for a minimum of 72 hours. Paint must be sound (not blistering or peeling). Existing painted surfaces should be cleaned with a solution of Trisodium Phosphate (TSP) and water. Rinse well and allow to dry.

APPLICATION

Read "LIMITATIONS" section before use. This product is ready to use (do not dilute). Stir gently; do not shake. Apply in light, even coats. One coat is recommended; however, over porous surfaces (like stucco tile) or when a higher sheen is desired, apply a second coat. **Note:** Sealer goes on milky white but dries clear.

Roller: Dump roller, remove excess water, then saturate roller with product. Keep a wet edge while rolling. Do not allow to puddle, foam or run. (Use a 5/8" nap for smooth surfaces, 3/8" nap for rough or porous surfaces.)

Pump Sprayer: Set at a fine spray and apply using a circular motion. To eliminate puddling or to achieve a more uniform finish, backroll immediately after spraying.

COVERAGE: 150-200 sq.ft. per gallon, depending on surface porosity.

DRY TIME: Dry to touch in 1 hour (77°F (25°C), 60% RH). Recoat in 2 hours. Dry to foot traffic in 24 hours. Will accept vehicular traffic in 72 hours. Dry times should be extended in colder climates.

CLEAN-UP & STORAGE: Clean tools with soap and water immediately after use. Store in a dry area. Do not allow product to freeze.

MAINTENANCE: Clean with a mild soap and water solution. Do not use solvent-based cleaners.

LIMITATIONS: Temperatures should be between 50°-90°F (10°-37°C) and should not fall below 50°F (10°C) within 24 hours of application. Do not apply if rain is expected within 72 hours. Do not use over water-based or solvent-based (oil-based) epoxy paints. Do not use on glazed tile. Do not use in areas subject to hydrostatic pressure. Smooth-finished concrete may be slippery when wet; consider using an anti-slip additive like SEAL-KRETE Clear Grip on high foot traffic areas. Do not apply over acid based stains.

CAUTION: EYE IRRITANT.

Contains: Dipropylene Glycol Di-Propyl Ether. Avoid contact with eyes and prolonged contact with skin. Do not ingest.

FIRST AID: In case of eye contact, flush with water for 15 minutes. If irritation persists, get medical attention. In case of skin contact, wash thoroughly with soap and water. If swallowed, drink 1-2 glasses of water and immediately contact medical services regarding any instructions to induce vomiting.

KEEP OUT OF REACH OF CHILDREN - DO NOT TAKE INTERNALLY.



Product	No.	Unit	UPC Code	Carton Bar Code	Carton Size (L x W x H)	Carton Size (cubic ft./lbs)	Carton Qty	Pallet Qty
Clear-Seal High Gloss Sealer	602501	1 gallon	0 19544 60250 0	1 00 19544 60201 7	14 x 14 x 8	.31 / 30	4	45



SEAL-KRETE CLEAR-SEAL PREMIUM HIGH GLOSS SEALER

TECHNICAL INFORMATION

- Viscosity: 50 KU
- VOC: < 100 g/l - EPA Method 24 - Waterproofing Sealer
- Clean-up: soap and water
- Shelf life: 2 years min. (closed container)
- Visual appearance: milky white (wet); glossy (dry)
- Gloss: 60
- Gloss retention: excellent
- Cleanability (occasional): excellent
- Tire marking: resistant to most tires
- Proprietary urethane-acrylic blend
- Water-based
- Low odor

ASTM TESTING (on smooth, bare, etched concrete)

- ASTM D-1475: pounds/gallon 8.59 ± .15
- ASTM E-70: pH 8.5-9.0
- ASTM D-2269-92: solids 25%
- ASTM D-1640: dry-to-touch 1-2 hours; dry to recoat 2-3 hours; dry to light foot traffic 24 hours; dry to vehicular traffic 72 hours
- Konig hardness
- ASTM D-3359 Intercoat adhesion: excellent
- ASTM G-53 ultraviolet resistance: excellent

CHEMICAL/SOLVENT RESISTANCE - ASTM D-1308

- (One hour spot test)
- Water: resistant
 - Gasoline: resistant
 - Oil: resistant
 - Salt: resistant
 - Chlorine: resistant

LIMITED WARRANTY: Manufacturer/Seller makes no warranty of any kind except that this product is free from defect and is of merchantable quality. Any remedy for breach of warranty is limited to replacement of Seal-Krete product or refund of purchase price. Convenience Products will not be responsible for labor or the cost of labor for removal or application of any product.

TECHNICAL SUPPORT: For more information on surface prep or application guidelines, or to obtain a Material Safety Data Sheet, call 1-800-332-7267, M-F (9:00 am - 5:00 pm EST) or visit our website at www.seal-krete.com



It's a great topcoat for painted surfaces. At increased reaction on smooth concrete, try adding SEAL-KRETE Clear Seal™ anti-slip additive to Gloss Sealer before applying the final coat, a great idea for high foot-traffic areas.



SEAL-KRETE CLEAR-SEAL protects against moisture damage and enhances the natural color of brick, stone, sepi's, unglazed tile, city/stone pavers, exposed aggregate and stamped concrete!

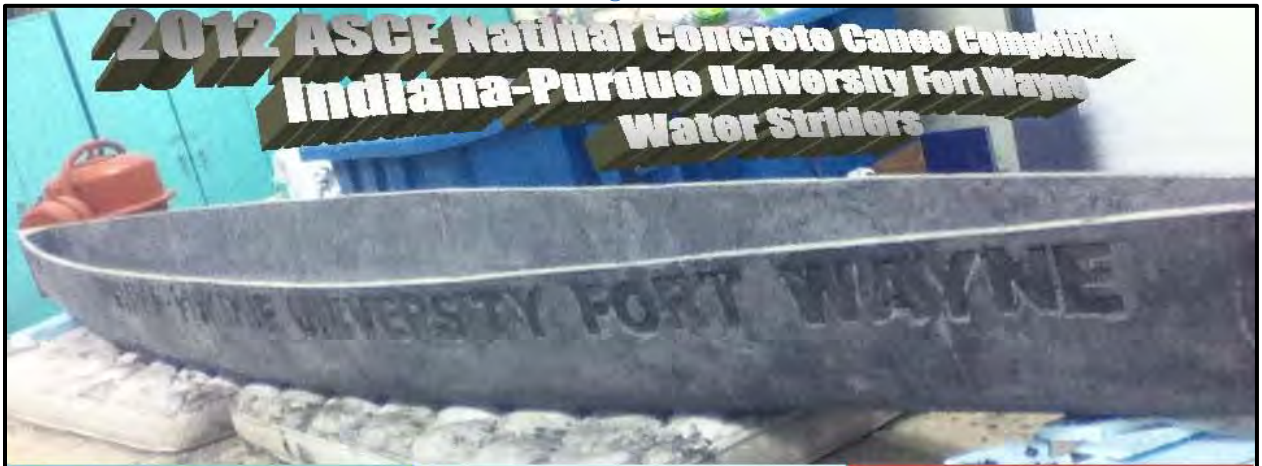
*Sealing or removing paint containing lead may be hazardous. For information contact the National Lead Poisoning Center at 1-800-438-6331 or www.epa.gov/lead

Country of Origin: U.S.A.

Convenience Products
 336 Gandy Rd., Auburndale, FL 33823 USA
www.seal-krete.com or technical@seal-krete.com
 or call: 1-800-332-7267

HOW TO TREAT CONCRETE
www.seal-krete.com

Appendix E



Final Product

The final product is worth 25% of the overall score in the canoe competition. This incorporates the canoe itself, a display, a stand, and an Engineer's Notebook.

The Canoe must be less than 22 feet long and less than 36 inches wide.



The display must contain a cut-away section of the canoe and the mold. This shows how the canoe was made. Also, samples of the aggregates and reinforcement used, and concrete cylinders must be on the display.

The Engineer's Notebook shows that all the material meets ASTM requirements and shows pictures of the construction process.

The stand is what will hold up the canoe for people to view while the team is not racing. The stand must be durable and aesthetic. The concept of this year's stand is shown below.

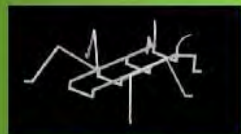


Figure 1: Canoe Stand Concept

Races

The races are worth 25% of the overall score in the competition and there are five races in the canoe competition: the men's endurance race, the women's endurance race, the men's sprint, the women's sprint and the co-ed sprint.

The men's races consist of two men and the women's races consist of two women. This is a minor change from last year because previously the races consisted of three men for the men's endurance races and three women for the women endurance races. Like previous years the co-ed race consists of two men and two women and the men's and women's sprint race consists of two men and two women, respectively.



The men's and women's endurance races both are a 600 meter race. The men's and women's sprint races are both a 200 meter race. The co-ed sprint is a 400 meter race.



Each endurance race is worth 20% of the overall scoring for the races. The sprint races are worth 18% each. The co-ed race is worth 24% of the overall score of the racing portion of the competition.

Design Paper

The design paper is worth 25% of the overall score in the competition. The paper describes how the hull was designed, the structural analysis, development and testing of the concrete, construction of the mold and the canoe, and management of the project. The rules are very strict on how long each section must be and how it is organized. The paper is usually due a month in advance so that the judges can have them reviewed before the competition.



Oral Presentation

The oral presentation is worth 25% of the overall score in the concrete canoe competition. The oral presentation is the last thing the team must do in the competition. The presentation is required to have a maximum time of five minutes and five seconds and then seven minutes are allowed for question from the judges.

