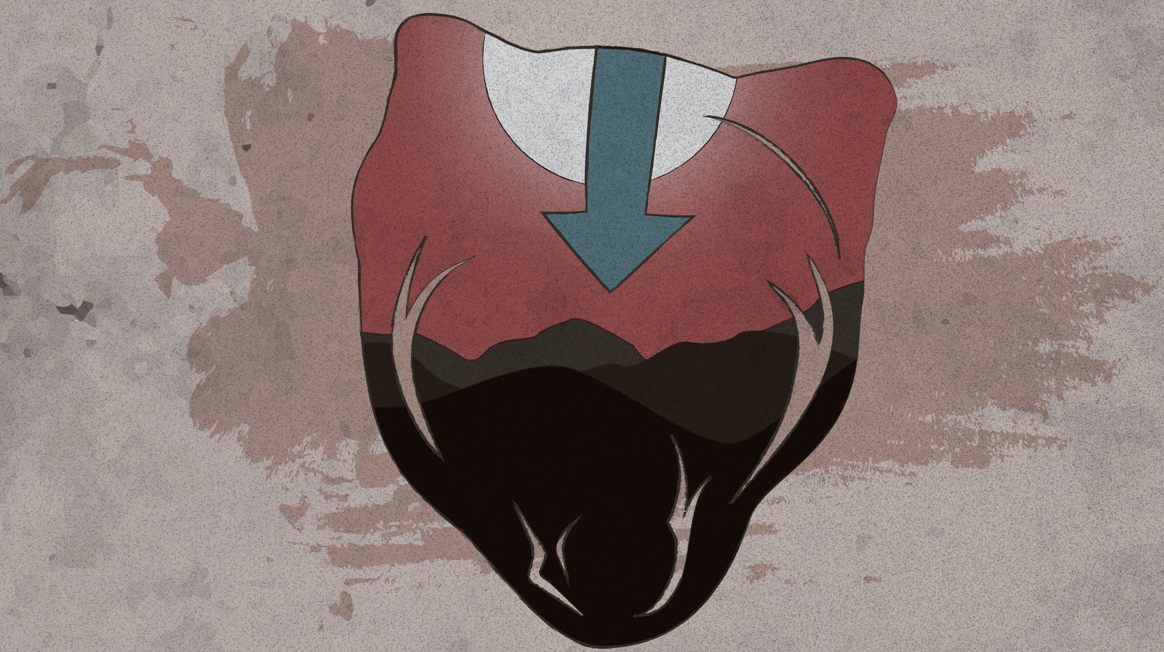
2021 · TECHNICAL PROPOSAL

UNIVERSITY OF CALIFORNIA, BERKELEY



水泥輕舟

CAL CONCRETE CANOE

THE LAST BEARBENDER

University of California, Berkeley

Concrete Canoe: *The Last Bearbender*

To: **Committee on National Concrete Canoe Competitions (CNCCC)**
Mid-Pacific Conference

From: **UC Berkeley Concrete Canoe**

Date: **February 8, 2021**

Re: ***2021 ASCE National Concrete Canoe Competition™ Request for Proposals***

Enclosed please find our *Technical Proposal* for the 2021 Mid-Pacific Conference Concrete Canoe Competition containing the approach to our concrete canoe prototype, *The Last Bearbender*. The report details the research, design, and construction processes of our prototype and includes relevant information about the project management, innovations, and sustainable aspects of the project.

In addition, the 2021 Concrete Canoe team from the University of California, Berkeley certifies the following:

1) The design and construction of the canoe has been performed in full compliance with the specifications outlined in the *Request for Proposals*.
2) The team acknowledges all Material Technical Data Sheets (MTDS) and Safety Data Sheets (SDS) have been reviewed by the team.
3) The team acknowledges receipt of the *Request for Information* (RFI) Summary and that their entry complies with responses provided.
4) The anticipated registered participants below are qualified student members and National Student Members of ASCE and meet all eligibility requirements.

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Marcus D'Avignon	11822778
Julian Falagan	11966093
Jessica Lee	11952387
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executive summary

Our generation had the privilege to grow up with *Avatar: The Last Airbender.* This Emmy award-winning American animated television show aired on Nickelodeon and drew on influences from worldwide martial arts, Western animation, East Asian heritage, and international culture. The story follows the bright and energetic teenager (well technically 112-year-old) Aang and his hopeful, adventurous, and fantastical journeys across a world where people can control elements and the stakes of the world are eminent.

Cal Concrete Canoe faces similar stakes today. With a closed university and no access to laboratory equipment or space, we are unable to build a canoe for a second year in a row. With a global pandemic, we're faced with imminent setbacks from our world and for our competition team community. Despite these unprecedented times, like Aang and Team Avatar, we are hopeful, adventurous, and creative with our canoe prototype, an uncreated, yet still magnificent prototype plan. With team members from all over the world, we have created a fantastical masterpiece.

Our Concrete Canoe team has faced many challenges in the past, and each year we have risen to that. Ultimately, from 33 years of competing in the National Concrete Canoe Competition, with 20 total Nationals qualifications, 5 championships, and 15 Top-5 finishes, UC Berkeley's team aims to return to Nationals once again and present *The Last Bearbender* as the new standard for future ASCE competitions.

Our team is the best candidate to be awarded a contract to provide the standard canoe design. *The Last Bearbender* features a sustainable and innovative design that minimizes manufacturing waste and maximizes complete resource usage. With a special focus on constructibility and ease of quality assurance and quality control, the team's prototype design produces consistent results, ideal for a standardized canoe. By investing in front-end design work, the team created a process for building a canoe that requires minimal personnel training and labor.

Over the many years that UC Berkeley has been creating concrete canoes, the team has created a hull design that presents the optimum balance of straight-line speed and maneuverability for ideal race performance. *The Last Bearbender*'s reinforcement strategy has been proven to be both structurally adequate and easy to implement without the use of specialized equipment or training. The prototype's primary reinforcement consists of a basalt mesh cut to fit the shape of the canoe with Alkali-Resistant Glass, supplemented by polyvinyl alcohol (PVA) fibers in the concrete mix.

Table 1: *The Last Bearbender* Specifications	
Name	*The Last Bearbender*
Length	234 in.
Maximum Width	26.6 in.
Maximum Depth	14.8 in.
Average Thickness	0.6 in.
Weight	200 lbs*
Primary Reinforcement	Basalt Mesh and ARG Scrim
Secondary Reinforcement	13 mm PVA
*Estimated weight	

The Last Bearbender's development and testing team, devoted to producing designs that will inspire future teams, worked tirelessly to explore the field of lightweight concrete design like the Avatar team explored their world. They took the calculated risk of drastically changing the structural mix in order to remove glass microbubbles and microspheres, which had previously composed 12% and 46% by volume of the structural respectively. Such a monumental task was daunting and although formidable, the endlessly innovative team pushed through by creating optimization methods never before seen and reviving previous concepts. By reintroducing more complex gradations and by improving upon the idea through computer-software aided optimization methods, the team was able to successfully replace the low density structural aggregate by switching to a much lower density expanded shale than was previously used. Previous year mixes included Utelite, which has a density of 113 lb ft^3 . With research into other schools mixes, the team was able to find Riverlite, a much more lightweight alternative with a density of approximately 80 lb ft^3. With the newfound optimization techniques, the team further improved upon the mix. The structural mix WAN SHI TONG produces a medium-weight sturdy canoe that can weather extended use while also being light enough to effectively command.

Table 2: Material Properties

Mix	WAN SHI TONG
Plastic Unit Weight (pcf)	72.4
Oven-Dried Unit Weight (pcf)	63
28-Day Compressive Strength (psi)	1100
28-Day Tensile Strength (psi)	200
28-Day Composite Flexural Strength (psi)	200
Slump (in.)	1.25
Air Content (%)	5

The Last Bearbender will be using a female mold which will significantly decrease the amount of concrete wasted during the casting process (*Bearneath the Sea*). The mold construction process will also be tailor made for easy manufacturing. All parts of the mold will be precut and labeled for quick assembly. Specialized skill will only be necessary for the development of the design files; assembly itself will be facilitated by new members with basic training and safety protocol. Furthermore, the interlocking structure of the mold will allow it to be put together with incredibly low tolerance and minimal on-site layout work. This structure will be quick to check for quality, as it automatically guarantees the accurate location and plumbness of the pieces. In terms of sustainability, *The Last Bearbender* will excel with its compostable wooden mold, coated with an eco-friendly sealer and biodegradable demolding agent. Additionally, it will feature many compact-sized pieces that can be cut from scrap wood.

From a project management standpoint, the design choices made by the team facilitated flexible scheduling, which allowed for additional time savings. Since this academic year has been fully virtual, the project management team has utilized the year to both be innovative with design processes and organize the database from past canoe prototypes for future success. When fabrication will be performed in person, since much of the work could be done with only basic training, the project management team will be able to easily shift the workforce between tasks to account for variations in workload. The project managers will pay special attention to accurately documenting work hours using a self-created web time clock. By analyzing this data and taking into account officer reports on productivity, inefficiencies will be identified and mitigated.

Ultimately, *The Last Bearbender* triumphantly presents itself as the epitome of easy training, convenient quality checking, reliability, and sustainability. The UC Berkeley Concrete Canoe team hopes that *The Last Bearbender* becomes the standard for future concrete canoes competitions.

ASCE UC Berkeley Student Chapter

mission

To serve the civil engineering community on the UC Berkeley campus by providing social events, leadership and professional development opportunities, and support to the various student groups within the civil engineering department.

vision

To become the heart of the civil engineering community by becoming a chapter that is supported fully by both constituent institutions and students.

officers

President: Parson Galicia
Vice President: Kayla Curameng
Junior Vice President: Justin Chan
Chief of Staff: Sarah Chen
Treasurer: Connor Geudeker
Philanthropy Chair: Leah Mealey
Conference Director: Sumayia Hakim
Historian: Sophia Choi
Social Chair: Geraldine Fabro
Social Committee Member: Christina Lang
Faculty Advisor: Nick Sitar
Practitioner Advisor: Madeline Ziser

contact

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242	*Total number of chapter members*
125	*Number of members with Junior or Senior status*
10	*Total number of associated student organizations*
88	*Total number of ASCE National-Society members*
78%	*Percent of eligble Juniors and Seniors that are members*
8	*Number of associated competition teams*

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project managers

Responsible for budgeting, scheduling, logistics, and overall coordination of functional groups

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junior project manager

Assist project managers and work with division officers to ensure deadlines are consistently met

質

quality assurance & quality control

Oversee project progression to guarantee quality, improve efficiency, and minimize delays

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construction

Direct construction of canoe mold, casting, sanding and cross-section

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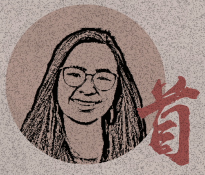
graphics

Design graphical elements of canoe, stands, product display, and paper

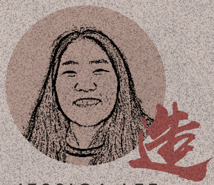


TRACY TANUSI

MATTHEW MICHALEK

MARCUS D'AVIGNON

HANA MEROTH



JESSICA LEE

AUSTIN CHEN

JASON PARK

型

hull design & structural analysis

Analyze past designs and develope new, optimized hull design in addition to analyzing critical loading cases and resulting material requirements

SHAAN JAGANI

DANIEL GONZALEZ

槳

paddling

Oversee paddler training sessions and instruct new paddlers

WILLIAM LIN

材

materials

Develop and test sustainable, compliant concrete mixes

JULIAN FALAGAN

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treasurer

Responsible for fundraising, budget allocation and reimbursement

MANNY RODRIGUEZ

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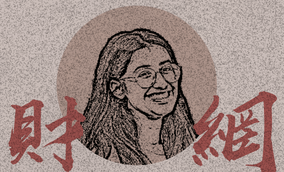
webmaster

Responsible for building and maintaining website for online presence



UMA KRISHNASWAMY

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Brandon Wong (Jr.)
Eric Fu (Fr.)
Marcus D'Avignon (Jr.)
TC Matthew Michalek (Jr.)
Shaan Jagani (Jr.)
TC Tracy Tanusi (Jr.)
Uma Krishnaswamy (Jr.)
Zachary Wu (Jr.)

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Alan Zhu (So.)
Brandon Wong (Jr.)
Emily Chien (Fr.)
Kellie Chan (Fr.)
Marcus D'Avignon (Jr.)
Melody Chen (So.)
Oswaldo Pastor (So.)
TC Tracy Tanusi (Jr.)

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DO Daniel Gonzalez (So.)
Aaron Soll (So.)
Emily Ma (Jr.)
Eric Fu (Fr.)
Jeffrey Cheng (Jr.)
Jennifer Terada (So.)
Kevin Cheng (So.)
TC Matthew Michalek (Jr.)
Oswaldo Pastor (So.)
Yusaku Nakano (So.)

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DO Jason Park (Jr.)
Andrew Ting (So.)
Emily Ma (Jr.)
Emily Zhao (So.)
Ethan Chen (Jr.)
Kellie Chan (Fr.)
Russo Hernandez (Jr.)
TC Tracy Tanusi (Jr.)
Zachary Wu (Jr.)

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DO Emmanuel Rodriguez-Marquez (So.)
Ben Clifner (So.)
Ellis Spickermann (Jr.)
Emily Chien (Fr.)
Emily Zhao (So.)
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William Lin (So.)

paddling

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Emily Chien (Fr.)
Emily Zhao (So.)
Eric Fu (Fr.)
Ethan Chen (Jr.)
Jessica Lee (So.)
TC Tracy Tanusi (Jr.)

TC: TEAM CAPTAIN
DO: DIVISION OFFICER

hull design

The Last Bearbender's primary hull design principle revolved around incorporating tried-and-true design parameters from the team's prior canoes while continuing to optimize features. Research, feedback, and racing data from prior canoes were used to create novel solutions to common performance issues such as turning radius. This complete re-examination and redesign solution approach will ensure that *The Last Bearbender* overcomes previous design hurdles and continues UC Berkeley Concrete Canoe's legacy of improvement and innovation.

Table 3: Hull Characteristics		
Max Depth (in.)	14.8	16.0
Length to Beam Ratio	8.8	9.4
Bow and Stern Angles (from vertical)	35° and 30°	35° and 30°
Bow and Stern Rockers (in.)	2.9 and 4.7	2.0 and 4.0
Minimum Hull Thickness (in.)	0.50	0.50
Average Hull Thickness (in.)	0.60	0.60
Weight (lbs)	200	260

Given that races focus on maneuverability under various loading conditions, improving ease of turning for paddlers was a central goal for the Hull Design Division. *The Last Bearbender* utilizes a design philosophy of prioritizing primary stability in the canoe while integrating other features to maintain adequate tracking ability and speed. Namely, an overall flatter belly and wider waterline beam were implemented to reduce the need for high wall height, since sharp turns and leaning will no longer push into the secondary stability regime of the canoe. The reduction of over 1.3 inches of wall height from *Bearneath the Sea* makes *The Last Bearbender* one of the shallowest canoes the team has produced. This allows for weight reduction of the canoe and subsequently greater straight-line speed, along with increased maneuverability. Furthermore, a heavy rocker was introduced for the bow and stern to reduce the wetted area of the canoe. Given the focus on slalom performance, the associated loss of tracking ability with an increased rocker was deemed to be viable.

Figure 1. Differences in hull shape between 2019 and 2021

Bow and stern entry angles were determined using data gathered from the team's previous canoes, *Bearneath the Sea* and *OptiCal Illusion*. Previous values of 35 degrees and 25 degrees, respectively, provided an adequate balance of speed and reduction of wetted area. Given the reduced freeboard associated with the heavy co-ed loading scenario, this feature was critical in maintaining sufficient turning ability in *The Last Bearbender*.

A model for *The Last Bearbender* was designed and rendered in SOLIDWORKS®, using independently drawn cross sections that were lofted together. An increased number of cross sections were used in the prototype to increase construction fidelity and overall control of design parameters and to create a smoother hull bottom in the completed prototype. Overall, *The Last Bearbender*'s design is reflective of experienced canoe making and exhaustive consideration of all engineering solutions implemented in the history of the UC Berkeley Concrete Canoe Team.

structural analysis

Detailed structural analysis was subsequently performed on the finalized hull design to confirm the design's structural robustness. Multiple loading cases were considered to determine a sufficient and cost-effective reinforcement scheme and ensure consistent integrity of *The Last Bearbender*.

For clarity, singularity functions and plots for all loading conditions were first determined by hand and then checked with the use of MATLAB® and Risa

2-D®. The canoe was modeled as a simply-supported, statically determinate beam, with uniform load distributions for buoyant forces and self-weight. Paddlers, handlers, and supports were modeled as point loads. Load and Resistance Factored Design (LRFD) methodology was used to determine the weight of the canoe. The weights of the paddlers were assumed to be 200 lbs and 150 lbs for the relevant load cases. Given the Material Division's estimate of 63 pcf and a casted volume of 3.25 cubic feet retrieved from the SOLIDWORKS® CAD model, the self-weight was determined to be 200 lbs, factored by 1.2 to a final value of 240 lbs. These values were determined to be sufficient to account for variations in the concrete density and shifting of the paddlers during the race.

Two loading cases for the canoe were analyzed: the co-ed races, with each paddler positioned at 15% and 90% of the length of the canoe, and the sample case, with two 200 pound paddlers and a 100 ft/lb distributed load.

The maximum bending moment experienced under both conditions was during the sample case, with a moment of 516.065 lb/ft occurring 9.74 ft from the bow. The cross section at this point was simplified with rectangular geometry, giving an estimate for the central axis and area moment of inertia. Given the assumption that these stresses are below yield strength, the corresponding compressive and tensile stresses were linearly distributed along the height of the cross section. Therefore, the maximum compressive stress was 134.6 psi at the gunwale and the maximum tensile stress was 43.38 psi at the keel.

Freeboard calculations were undertaken to ensure that the *The Last Bearbender* was designed to adequately carry out all load cases. Using SOLIDWORKS®, freeboard distances were derived under several loading conditions between the unloaded canoe and a uniform load of 1000 pounds. These values were reverse-fitted to a polynomial function which can be found in Appendix D.

Given a similar reinforcement scheme and calculated stresses as last year's canoe, the previous safety factor of 4 was deemed adequate for *The Last Bearbender* as well. The team established this value to ensure a forgiving margin of error in all manufacturing processes and canoe operation.

The values of maximum experienced stress fall under the range of values experienced by previous canoes such as *Bearneath the Sea*, so the same reinforcement scheme was deemed sufficient: two layers of basalt mesh along the hull and one layer of Alkali-Resistant Glass (ARG) at the bow and stern. Multiple layers provide adequate tensile reinforcement while maintaining compliant Percent Open Area and construction feasibility.

development & testing

To understand the elements, Cal Concrete Canoe needed to understand how to harness earth, fire, water, and air to make *The Last Bearbender* lighter, stronger, and more sustainable than previous canoe prototypes. This challenge to become the standard, along with new aggregate ruling, presented a formidable task. Because of this, the Materials Division focused on innovation through ideas not seen or attempted by the team in years past at UC Berkeley. The Materials Division aimed to create a canoe mix that was lightweight, stronger, and more sustainable than any other mix in the past.

The structural mix from a previous canoe, *Calaxy*, was used as the baseline for this year's mix. The strides made in gradation, overall weight, and sustainability were admirable, and this year's team wanted to continue that pattern of success. However, from the start the mixes looked very different, as the new rules necessitated major changes. Poraver expanded glass, the primary aggregate from *Calaxy*, was barred from competition, along with a new requirement for the amount of ASTM C330 aggregate to be raised to 50% by volume of the aggregate. Initial calculations with a new foamed glass aggregate were promising, but the C330 requirement led to a second year of difficulties managing the weight of the final mix.

To produce a properly weighted canoe, major sacrifices were made from the improvements of *Calaxy*. With the aim to minimize density, there was no place to use the previous innovation of recycled rubber chips. Similarly, the average density of the desired

APOLLO MIX						
Materials	Percentage, % (by volume)	Percentage % (by weight)	Density (lb/cu ft)	Volume per Batch (cu ft)	Weight per Batch (lbs)	Weight (g)
Cements						
OPC	4.9002	15.6%	196.6	1.3	260.1	117960.5
Slag	4.4022	12.9%	181.1	1.2	215.2	97610.6
Silica Fume	1.1254	2.5%	137.4	0.3	41.7	18931.4
Aggregates						
Poraver .1-.5	9.3173	5.49%	36.4000	2.52	91.57	41535.69
Poraver .5-1	10.029	4.46%	27.5000	2.71	74.47	33778.35
Poraver 2-4	20.686	6.23%	18.6000	5.59	103.89	47122.21
UTECF SSD	14.3420	26.5%	114.0000	3.87	441.45	200236.64
Rubber Chips	2.8883	3.04%	65.0000	0.78	50.69	22992.43
Fillers						
S22 Glass Bub.	11.9118	2.65%	13.72800	3.2	44.2	20026.9
Fibers						
13mm fibers	0.1179	0.15%	79.2800	0.03	2.52	1144.96
Admixtures						
ADVA	0.7038	0.76%	66.5800	0.19	12.65	5738.44
VMAR	0.7632	0.79%	63.5800	0.21	13.10	5942.44
Eclipse	0.1376	0.13%	57.6000	0.04	2.14	970.97
Water						
Water	18.6745	18.86%	62.4000	5.04	314.63	142712.52
Total						
Total	100.0	1.000	61.787	27.0000	1668.2483	

Figure 2. Previous year's APOLLO concrete mix with Poraver© expanded glass

foamed glass gradation was too great to properly offset the Riverlite aggregate proportion. With that in mind, a simpler two-aggregate mix was produced to minimize the density based on the given constraints.

Keeping in mind the diverse set of challenges faced by the Materials Division, the selection of aggregates was the main focus for development of the final mix. The largest stride was in replacing the previous years use of Utelite Crushed Fines with a graded Riverlite fine aggregate instead. The Riverlite (SG = 1.36) was a major improvement in density over the Utelite (SG = 1.83). This change was the key contributing factor to maintaining a density below that of water while satisfying the 50% ASTM C330 requirement. To add to the low density of the Riverlite, a replacement for Poraver was found in a foamed glass sphere aggregate (FGA). While all sizes of the FGA had lower densities than their cenosphere counterparts, the Materials division selected the largest and lightest aggregate as the counterbalance to the heavy Riverlite. With a SG of 0.2, the FGA was a priceless addition to the mix.

Without equal, the biggest obstacle during the design process was the lack of access to the concrete lab. This helped inform the major decision to limit innovation outside of the aggregate category. The Materials Division systematically worked from the old mix proportions to the new, focusing on a series of interrelated landmark values in lieu of traditional testing methods. These landmarks were the water to cement ratio, water to cementitious materials ratio, and the total aggregate percentage. Using these along with the optimization spreadsheets allowed for rapid mix design, giving the Materials Division a path forward towards a final mix. Monitoring these values as the proportion of Riverlite increased ensured that the team reached WAN SHI TONG. WAN SHI TONG was a mix that conformed to competition requirements without extensive compromise on qualities that the Materials Division focused on. By the time WAN SHI TONG reached its final state, the total aggregate percentage had only changed by around 10%, with minor increases in the w/c and w/cm ratios. It is only fitting that the mix is named after the owl spirit of knowledge, as this design is a testament to the combined knowledge of the whole Cal Concrete Canoe team.

The Materials Division looked at *Calaxy*'s work on admixtures to determine the amounts that should be used in *The Last Bearbender*. When *Calaxy* experimented with a new material (rubber chips), they encountered a problem where cylinders would immediately fall apart once removed from the mold. Since the team was using all new materials for the first time in several years (Agsco Foamed Glass and Riverlite) that have lower specific gravities than *Calaxy*'s aggregates, the team decided using VMAR-3 (ASTM C494) would be a safe step moving forward with the new mix. VMAR-3 was also implemented for its superb ability to prevent segregation. A setback of VMAR-3 is that it takes a toll on the overall strength, but the team deemed it to not be significant enough after the inclusion of high range water reducer (ADVA 530) and shrinkage reducer (Eclipse 2500). Only one mix was allowed for *The Last Bearbender*, unlike *Calaxy*'s three different mixes, so WAN SHI TONG had to consider requirements for the structural, patch, and finishing mix. Looking at the differences between the three, the main difference was the presence of air entraining admixtures in the finishing mix, but otherwise they contained the same admixtures. DAREX AEA was considered to be used as an air entraining agent and after inspecting the effects on previous mixes, inclusion of air entrainment agents would drastically reduce the mix's strength much lower than the team was comfortable with. This idea was ultimately scrapped, making the end result a theoretically workable and smooth mix.

Without access to testing, predictions had to be made for the probable final values for compressive strength and air content, along with general values for stock absorption of aggregates. The team conducted extensive research on the materials used to find theoretical values. The data the team used was based on tests done on Riverlite and Arcosa Foamed Glass. The team found that although there were losses in strength from the foamed glass, the strength of the Riverlite was greater than that of the previous aggregate, helping to offset the lower cement total and the lighter foamed glass. Finally, the fact that the only major changes were in the aggregates and the total volume of cements, not the internal percentages of cements, lended to a relatively high degree of certainty for the mix's final compressive strength of 1100 psi.

In order to maximize the strength and adhesion needed to make several thin layers without cold joints or shrinkage cracks from the bleeding of the concrete onto other layers, the optimal primary reinforcement was decided to be basalt mesh and ARG scrim. The basalt mesh was placed in the middle of the canoe while the ARG scrim was placed at the bow and stern of the canoe. This decision utilized the better workability and flexibility ARG scrim offers, thereby producing a better fit for the more complex geometry of the bow and stern. This would also minimize the amount of cracks and holes made, therefore minimizing the amount of patch mix needed.

Figure 3. Basalt mesh installed during casting day

construction

Future tests and innovations inspired the Construction Division, as the division's goal is to streamline and further improve upon the techniques pioneered by last year's team, *Calaxy*. The team will opt again for a female mold due to its ease of construction and use. The division's history of emphasizing environmental sustainability will continue to play a prominent role in *The Last Bearbender*'s construction practices. The division will choose a wooden mold that is compostable at campus facilities, eliminating the pollutants and carcinogens that come with a Styrofoam mold. As much material as possible will be collected from local scrap sources to further minimize the mold's environmental impact; donations from MacLeod Design, a local contractor, will provide a large supply of reusable wood, and scrap plywood from the university's makerspace lab will be utilized for the construction mold. The remaining cross-sections will be constructed from 1/2"-thick oriented strand board due to its multi-directional strength and resistance to splitting. 1/8"-thick birch plywood will be used for interior paneling for its flexibility and ease of use.

Before working on the full canoe mold, two full-scale mockups will be constructed to test techniques, troubleshoot potential problems, and train new members. These mockups will each be around four feet in length, representing different independent segments of the canoe. The first mockup will feature two sections, one of which will be covered with 1/2"-wide mahogany strips, while the second will be paneled with 1/8"-thick birch. The second mockup will be completely paneled and filled with an early version of the concrete structural mix to test its adhesion. This mockup will later provide a space to test various sanding techniques on the finalized concrete mix. Members will be versed in lab safety and will be given the chance to practice using the tools required for the final build with these mockups.

Figure 4. Mockup completed using plywood panels

Similar to past years, an interlocking system of U-shaped cross-sections inserted into a central spine will form the backbone of the mold. 22 cross-sections will be inserted into the 3-section spine at 10" intervals. An extra 1/8" of tolerance will be given to the spine slots to allow the cross-sections to fit with ease. The cross-sections have been designed in SOLIDWORKS® and then exported to AutoDesk® Fusion 360™ software where they will be prepared for Computer Numerical Control (CNC) milling. Parts will then be milled out of 1/2"-thick wood from donated scrap. L-brackets will be inserted at intersections between the cross-sections and spine to restrict rotational movement. Plywood spacers made of 1/4"-thick birch will be temporarily inserted at the top of the cross-sections to maintain even spacing for paneling.

Figure 5. Interlocking skeleton with spacers for panel installation

Panels to line the mold have been designed in SOLIDWORKS® and formatted in Adobe™ Illustrator®. These panels will be laser-cut from 1/8"-thick birch plywood and soaked in water for up to 24 hours to make them more pliable. The panels closest to the bow and stern will be designed with living hinges, a series of perforations enhancing flexibility, to precisely fit the contours and create a pointed stern keel. Panels will also be cut to be 1/4" shorter than the designed cross section to allow room for expansion and proper fitment. Nail guns will be used to secure the panels to the cross-sections at 1/2" intervals. Unlike wood glue, the nails will enable the panel to instantly fasten to the cross-section despite resistance from the curved contours of the hull. The nails will also be easily removed upon demolding to enable the wood to be composted. To prevent horizontal bowing between cross-sections, laminated strips of 1/2"-wide plywood will be inserted perpendicularly for added rigidity.

Figure 6. Panels with living hinges extending from the chine to bottom of the canoe

Figure 7. Installed braces to prevent bulging in panels

The stern and bow will be 3D printed with polylactic acid (PLA) plastic for ease of installation and increased precision. They will be formed from three interlocking pieces inserted on the ends of the spine and will be both glued and duct-taped in place.

The team will line the top of the mold with 1/2"-wide plywood strips to form the top edge for the gunwales of the canoe. Two strips will be laminated on top of each other with water-based biodegradable PVA wood glue to provide more flexibility in fitting the contour of the canoe. These will be secured to the cross-sections with nails.

The mold will be finished by sanding edges and filling in gaps with a mixture of wood glue and sawdust. The cross-sections will be waterproofed with ECO Advance Waterproofing, which emits fewer Volatile Organic Compound (VOC) pollutants than standard waterproofing. The interior will be coated with car wax, a biodegradable and safe demolding agent.

Before casting, the division will prepare the reinforcement to ensure that during casting, maximal time will be spent on the actual concrete placement. Two layers of basalt mesh will be pre-cut to size and inserted into the mold as reinforcement during casting. These will be placed on the surface of the concrete layer overlapping each other and will be fastened with wire ties. ARG scrim will be inserted at each end due to its superior flexibility.

After casting, the canoe will be enclosed in a polyvinyl chloride (PVC) frame which will then be covered in tarps to maintain a controlled curing environment. Moisture from four humidifiers will maintain constant humidity during the 31-day curing period over the team's winter break. Humidity during the curing process will be essential to the strength and durability of the canoe. Without adequate hydration, the concrete would become brittle and more prone to cracking.

Measures will be taken to eliminate collection of water, such as sloping the roof of the enclosure so water can drain down one side. The interior will be covered with burlap to trap moisture on the concrete itself. The outside of the canoe will be draped with plastic sheets, and the humidifiers will be set on sloped surfaces so as to prevent water collection in the canoe. The canoe will then be set to cure for the entirety of winter break.

Upon returning, the curing chamber will be disassembled and replaced with a larger enclosure for sanding. This enclosure will be similarly created utilizing PVC frames covered in tarps.

Sanding will consist of several stages, beginning with hand sanding of the interior with 60-100 grit sandpaper and progressing to orbital sanding on thicker patches along the walls. Members will all be equipped with gloves, N-95 masks, and safety goggles. Laser scans that will be taken before sanding will be used to locate thicker areas that required machine sanding. This will enable the team to more strategically focus on what sections of the canoe need more sanding. The bow and stern will then be filled with Styrofoam and covered in concrete to create bulkheads.

Afterwards, the canoe will be demolded, and sanding on the outside walls will begin. Demolding will be a simple process; with a female mold, the entire mold can be set on the ground and removed section by section. When removing the nails, screws, and L-brackets to compost the wooden mold, the team will save as many L-brackets and screws to be reused for future years. The canoe then will be flipped over and set back on the work table for exterior sanding. Similar to interior sanding, there will be a strategic approach as to which locations are thicker and require machine sanding versus sanding by hand. Once initial sanding is complete, all gaps will be filled in with patch mix and sanded by hand. Colored graphics mix will then be applied, which will utilize vinyl stencils to implement the design onto the canoe prototype. To polish, the team will use handheld rotary sanders with buffing fitting, and to finish, the entire canoe will be waterproofed to ensure maximum seaworthiness and preserve vividness of the graphics.

scope, schedule, & fee

This year, UC Berkeley's team worked on *The Last Bearbender*, the concrete canoe prototype. Due to COVID-19 and UC Berkeley's policies including restricted in-person access to labs, the scheduling underwent large-scale alterations to ensure requirements were met while remaining safe and working remotely. A two-year schedule was created to account for all the elements of planning that could be executed virtually as well as subsequent in-person fabrication, which would occur in the following academic year when the university opened to undergraduate student competition teams.

To make certain that sufficient time was dedicated to all critical activities, the project management team created a schedule that detailed the project timeline. This schedule divides into two years: the academic year of 2020-2021 leading until the regional and final competition, and the academic year of 2021-2022 leading through the completion of the canoe prototype. Major milestones were determined based on deadlines outlined in the Request for Proposals and by considering previous years' schedules. These milestones were then inputted into a preliminary schedule, then working backward from the deadlines, individual activities were added. As per the Critical Path Method in Microsoft® Project, predecessor-successor relationships were established between these activities to define the order in which they needed to be completed.

Special consideration was given to activities that were affected by COVID-19. Particularly due to the uncertain nature of the global pandemic and the safety, health, and productivity of team members, deliverables were set with early deadlines. This would give several months to complete the paper and presentation, the main deliverable of the competition. Before the summer interim, the critical path fell to material procurement, research, and testing. Along with lack of access to university labs, the mix design process posed a considerable risk to the critical path activities due to its nature. The duration of research is highly dependent on results, such as the strength and workability of the mix. This uncertainty in research gives it the potential to greatly affect the schedule. Should experiments produce results that are insufficient for desired purposes, the schedule could see significant delays. After the summer interim, the major milestones dictating scheduling were determined by previous years' schedules for fabrication and the construction process. The schedule's timeline for material production through completed fabrication was made possible by analyzing the available manpower and redirecting additional people to help with labor-intensive subtasks.

The optimization of manpower usage, demonstrated above, was facilitated by an internally designed and developed website to handle management needs, namely a web time clock, deployed on GitHub. In previous years, When I Work® was utilized to calculate man hours when creating the canoe prototype, but this software proved to be inefficient in its design and caused scheduling delays, exactly the job it sought to eliminate. This software also required each user to have his or her own account, yet another barrier to entry for a quick and easy time clock. The personal website was streamlined and custom made for the Concrete Canoe team, with a more intuitive interface that could be accessed on both mobile devices and desktops.

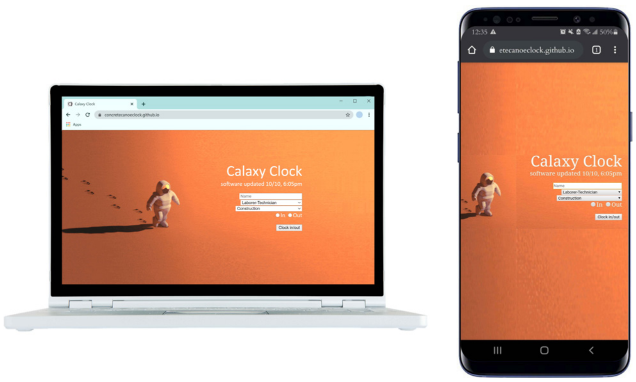


Figure 8. Web time clock accessible on mobile devices

Through this software, the project management team was able to accurately track labor costs, as well as identify costly and inefficient tasks. After analyzing the timesheets, the project management team could redirect labor from one task to another to optimize cost and efficiency. In doing so, the team successfully accelerated its progress towards the milestone of casting the canoe.

timeclock v1

Date	Name	Job	Division	In time	Out time	Time (hours:min)
10/1/2020	Emily Chien	Laborer-Technician	Materials	4:23:15 PM	6:04:00 PM	1:40
10/1/2020	Julian Falagan	Principle Design Engineer	Materials	4:25:47 PM	5:57:52 PM	1:32
10/1/2020	Manny Rodriguez	Design Manager	Materials	4:33:21 PM	5:50:19 PM	1:16
10/1/2020	Russo Hernandez	Laborer-Technician	Materials	4:25:56 PM	6:07:19 PM	1:41
10/2/2020	Shaan Jagani	Principle Design Engineer	Hull Design	1:27:48 PM	2:30:11 PM	1:02
10/2/2020	Tracy Tanusi	Laborer-Technician	Hull Design	1:18:57 PM	2:45:37 PM	1:26
10/2/2020	Daniel Gonzalez	Design Manager	Hull Design	1:23:15 PM	2:43:28 PM	1:20
10/2/2020	Matthew Michalek	Laborer-Technician	Hull Design	1:36:43 PM	2:42:15 PM	1:05
10/3/2020	Daniel Gonzalez	Design Manager	Structural	9:59:19 AM	11:52:02 AM	1:52
10/3/2020	Shaan Jagani	Principle Design Engineer	Structural	10:04:24 AM	12:04:10 PM	1:59
10/3/2020	Marcus D'Avignon	Laborer-Technician	Structural	10:03:14 AM	12:02:27 PM	1:59
10/6/2020	Julian Falagan	Principle Design Engineer	Materials	4:34:27 PM	6:18:46 PM	1:44
10/6/2020	Manny Rodriguez	Design Manager	Materials	4:38:09 PM	5:51:21 PM	1:13
10/6/2020	Russo Hernandez	Laborer-Technician	Materials	4:31:44 PM	6:13:44 PM	1:42

Figure 9. Sample of recorded hours from web time clock

By planning to cast the canoe during the fall semester of 2021 and curing it over winter break, more float time could be allowed to subsequent tasks to complete the canoe prototype by the deadline. Finishes to the canoe are projected to be more efficient; with new sanding techniques successfully tried in the past year, the sanding duration has a projected shorter duration. This allows for ample time to complete the application of graphics and other finishing activities.

This year's team has the benefit of a large labor force due to the already large team along with successful recruitment of new members. To ensure they produced quality work during this year and in future years, the officers continue to invest time to thoroughly train the large proportion of new members. This large trained force allows for more flexibility in the project schedule, as labor is not a limited resource.

In order to achieve the amount of coordination necessary to run the large team and to plan critical activities, the project management team and division leaders met each week. A weekly work plan was discussed to ensure all leaders were aware of all activities occurring that week. Weekly meetings organized the team from a top-down perspective. By having a cohesive project management team and an efficient division leader and officer team, the overall team found success through the example of the team's leadership.

Between 2019 and 2021, from the team's funding, a budget of $2600 was allocated to concrete material costs, an increase of $1000 from the 2018-2019 year's concrete materials costs. Since this year's structural mix uses strikingly different materials than the previous year's mix, the team had to invest in new aggregates, which is reflected by the projected costs. A budget of $600 will be allocated to construction materials and finishing tools, a decrease of $250 from the 2018-2019 year due to material donations from local construction companies.

The costs described above are based on actual spending, taking into account donations and materials purchased in bulk intended to last multiple years. The Itemized Fee in Appendix F details the calculated costs for the production of this year's canoe prototype specifically based on standardized costs provided in the Request for Proposals.

quality control & quality assurance

The Last Bearbender's Quality Assurance and Quality Control Division faced the unique challenge of maintaining strong quality standards, both during the virtual aspects of the competition and during the construction process. Before beginning the mix design, the QA/QC Division specified that all progress on mixes be noted for changes made and that complete inventory be taken at the beginning of the year to be updated monthly. For construction of the prototype, materials will be pre-batched before final casting to ensure a consistent mix. Each batch will be mixed for set periods of time at fixed intervals to provide a continual fresh concrete supply for placement on the prototype mold. The speed of concrete placement will be further monitored to avoid cold joints while casting. Depth of each concrete layer placed on the mold will also be measured using custom-made depth checkers, thus maintaining uniformity across all three layers. Furthermore, before being allowed to participate in casting, each member will be required to pass a practice casting assessment on one of the mold mockups.

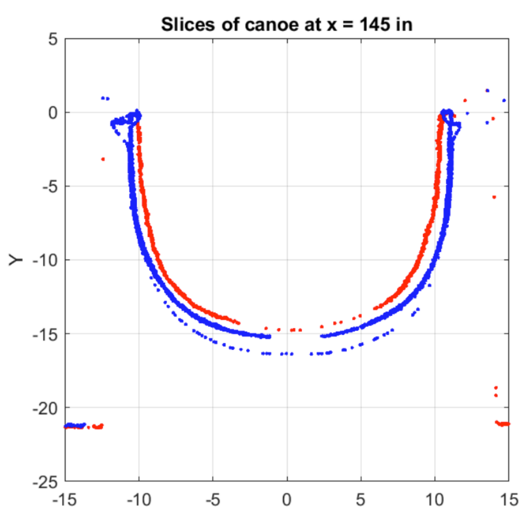


Figure 10. Laser scan slice of the canoe used to determine concrete thickness after casting

In addition, a laser scanning protocol will be utilized to maintain quality in the sanding process. The prototype will be scanned twice: once prior to concrete placement and again after the canoe is cast. The first scan will generate a point cloud of data representing the mold, which will then be overlaid with the second from casting. From this, the thickness will be determined for any part of the canoe. Thus, the team can determine which areas of the canoe need greater sanding versus areas that required patch mix.

For non-construction aspects of the canoe prototype, the QA/QC Division will work closely with the project managers to develop a system to help with adherence to the new set of guidelines for the prototype. The QA/QC division has already attended virtual meetings for divisions that can run virtually. In the next in-person academic year, QA/QC division members will attend meetings of other divisions to gain an understanding of all aspects that go into producing the concrete canoe prototype. Members will also oversee the quality of work done at these division meetings, to ensure consistency and protocol.

Division officers read thoroughly over their sections within the Request for Proposals documents together with the QA/QC team, submitted any necessary Requests for Information (RFI's). The RFI's were compiled and distributed to pertinent personnel as soon as they were released. The changed format of the technical proposal also prompted a system of checks where two members were assigned to each section to cross-check new elements and guidelines in the technical proposal. This structured approach with multiple systems of quality assurance guaranteed close documentation when creating the canoe prototype, which in and of itself is a critical method of quality control.

sustainability

This year's team will create the most sustainable canoe yet, reusing materials from local sources, reducing costs, and making environmentally friendly choices. Throughout the ongoing drafting, planning, and building process, the team utilized computer software to minimize paper waste, as well as facilitated collaboration and file sharing efficiently. Due to a virtual academic year, the team has incurred little environmental costs, since many tools and meetings were online. The Graphics Division has worked completely remotely in their design process, thus reducing the amount of paper drafts, physical models, and excess paint utilized in past years. The Paddling Division will reuse unwanted boats from a local boathouse for team paddling practices and upcycle old yoga mats and foam rollers to create seats for paddlers. By optimizing the mix design process through optimal regression methods, the Materials Division has predicted to reduce the concrete needed for future testing to half the amount of past years while also reusing cylinder molds. Furthermore, the Materials Division plans to incorporate industrial byproducts, such as ground-granulated blast furnace slag (GGBFS) and silica fume, into the concrete mixes. By replacing nearly half of the Ordinary Portland Cement (OPC) in the structural mix with these mineral admixtures, the team is projected to reduce its carbon footprint by 46%. The Construction Division will work with small business contractors to obtain reclaimed wood from local construction sites for use in the mold of the canoe. By reusing wood from the community, the overall economic costs of this year's prototype will be substantially lower. After demolding the canoe and removing all hardware and nails, this wooden mold will be composted, because it will be built with eco-friendly wax and sealer.

health, safety, & covid-19

All members will be required to take an online health and safety course. The online course discusses general emergency response practices, environmental sustainability, general workplace safety, hazardous materials, laboratory safety, safety management, and equipment safety.

After passing the online course and receiving a certificate of approval, the team will attend an in-person lab training with the lab manager. This training will cover the basic principles of where to go, and who to contact during an emergency, as well as familiarize the team with the layout of the lab, including the location of first aid kits, landline phones, emergency staircases, and fire alarms. When fabricating in person, division officers will train members for any tools and equipment relevant to their roles. Prior to beginning each new work task, the officers will brief members on relevant safety protocol, necessary personal protective equipment (PPE), and potential hazards or emergency situations. Respiratory PPE will be necessary throughout the duration of the canoe fabrication, since prolonged inhalation of crystalline silicates can cause long term health effects such as silicosis. Members will only be allowed to work under the supervision of an officer, and officers will be responsible for upholding safe practices during their shifts. This officer(s) will also be the contact person for near-misses or accidents; the officer(s) will have contact information for other staff members working in the lab, so a network of nearby lab managers and researchers would be notified immediately in case of an emergency. PPE will be consistently worn throughout the process of building the canoe, and division officers will ensure that safety precautions will be taken at all times.

In consideration of COVID-19, the team did not meet in person throughout the academic year of 2020-2021, supplementing with virtual meetings and planning. The team plans to follow the laboratory and university's in-person social distancing measures necessary with COVID-19, which include limiting the number of participants working in the lab at a given time, wearing masks, and maintaining social distance.

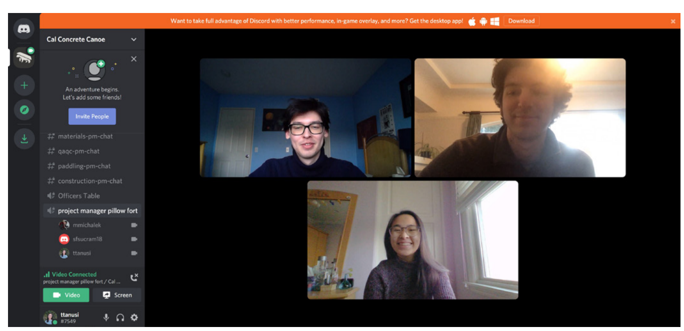
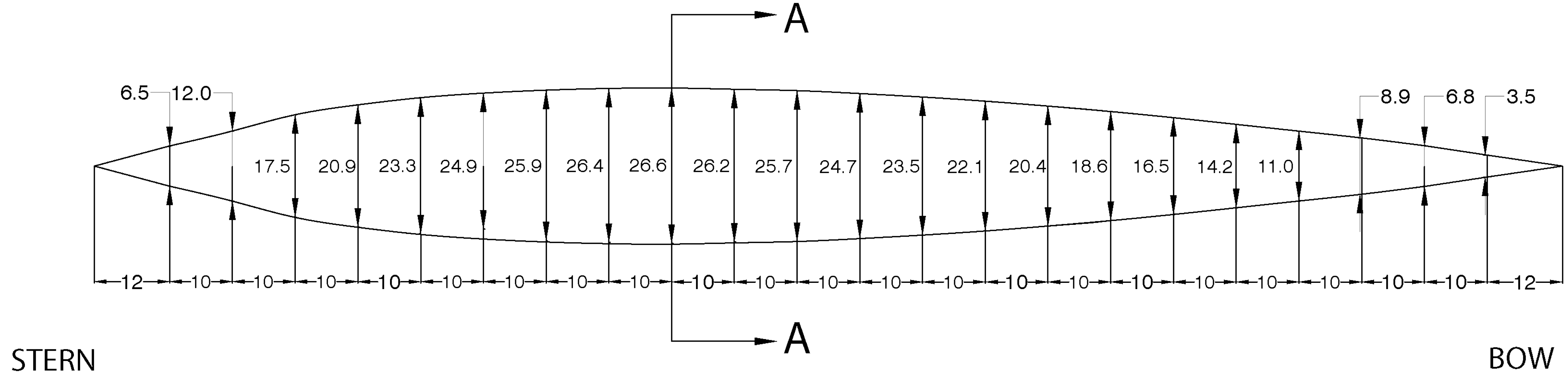
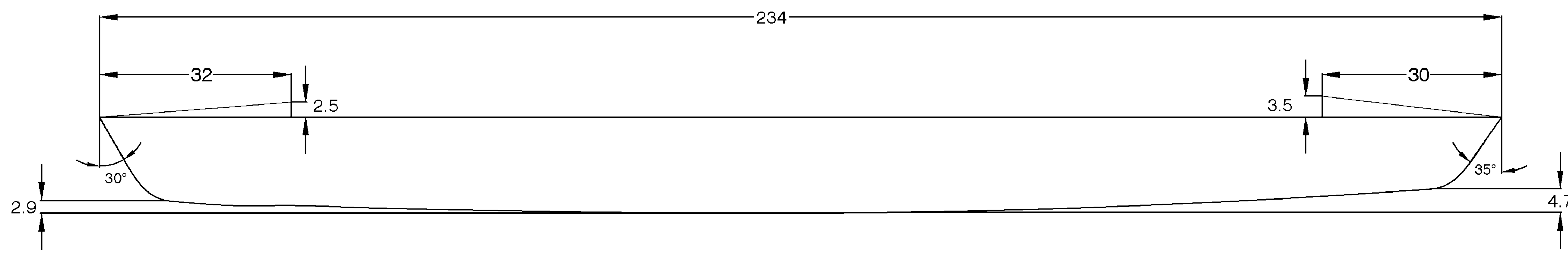


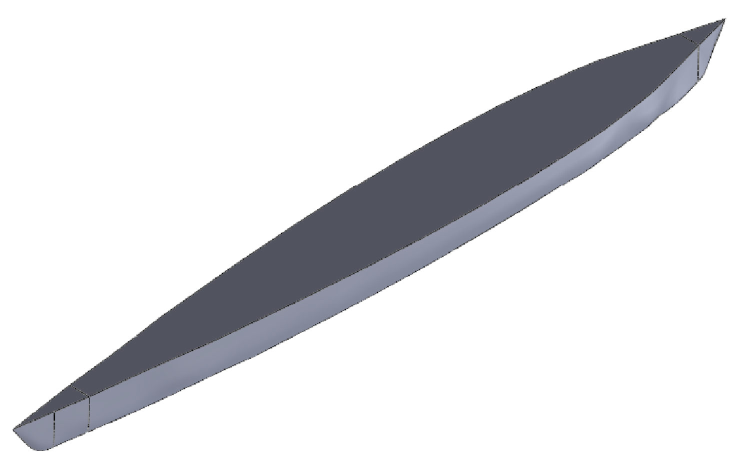
Figure 11. Virtual project management meeting on Discord

PLAN VIEW

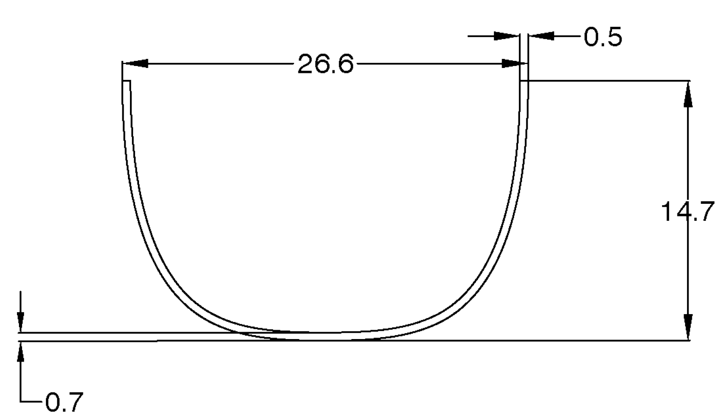


ELEVATION VIEW

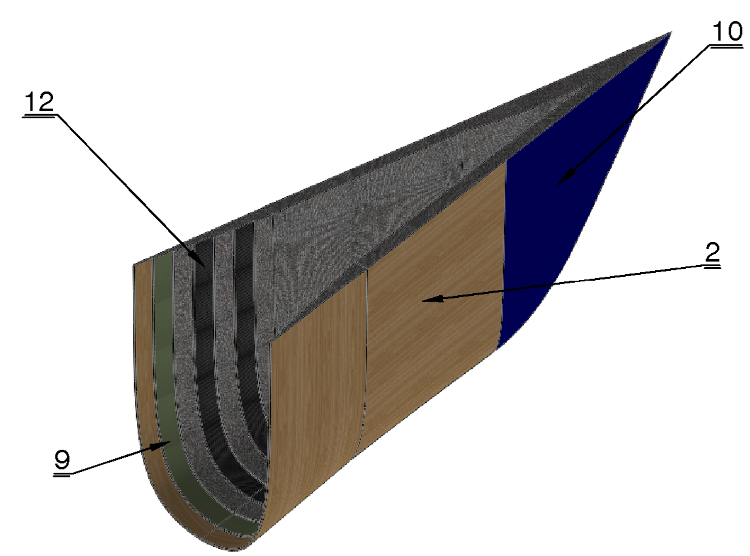




ISOMETRIC VIEW



SECTION A-A



CUTAWAY SECTION

Bill of Materials

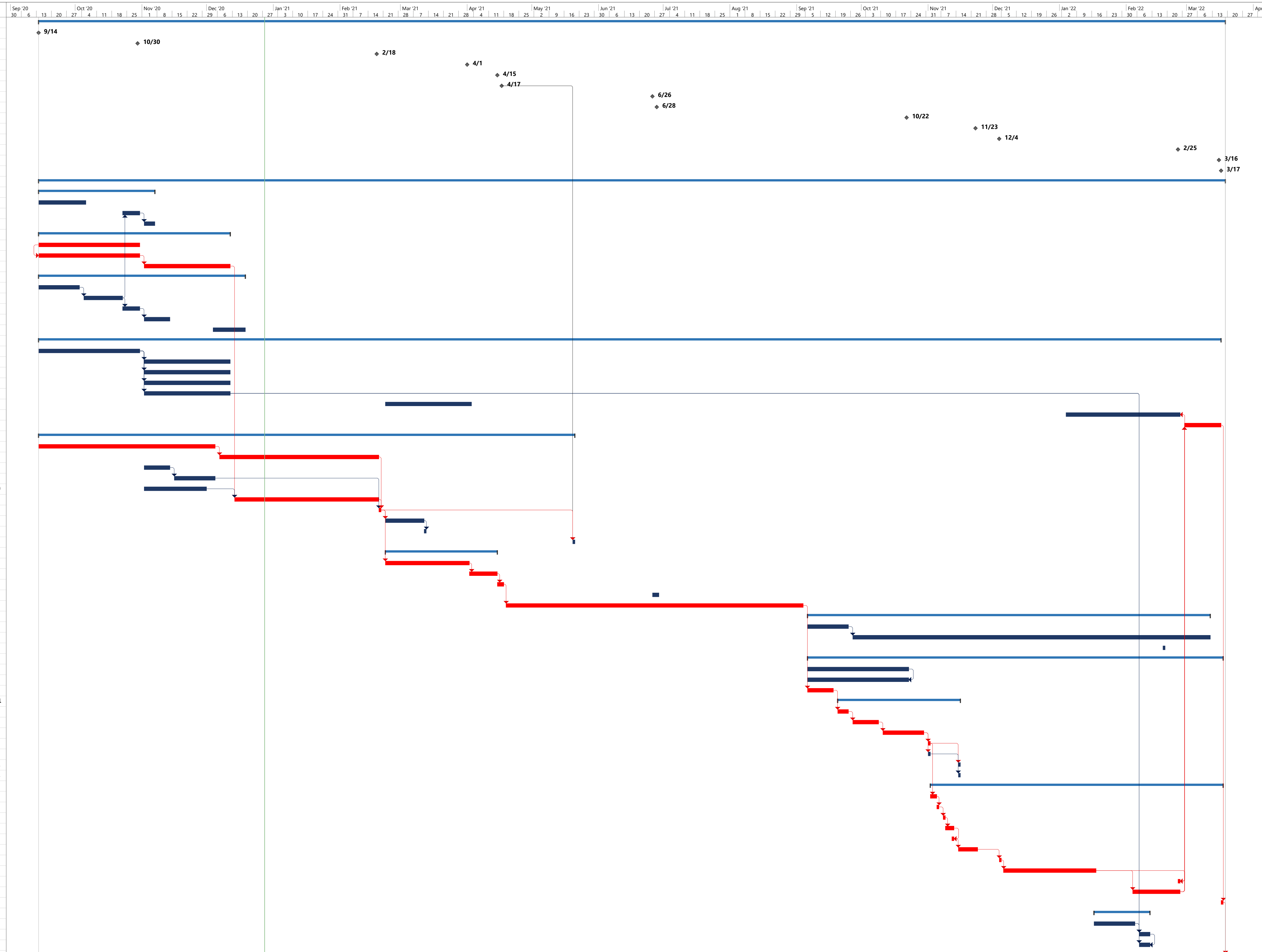
NO.	DESCRIPTION	QTY
1	Plywood 3/16"	1-4'x4'
2	Plywood 1/8"	16-2'x4'
3	Oriented Strand Board 1/2"	4-4'x8'
4	Metal Screws 1/2"	~170
5	Corner Braces	80-2"x2"
6	Galvanized Steel Strap	4-6"x0.13"
7	Brad Nails 1/2"	~750
8	Brad Nails 5/8"	~500
9	Wax	0.88 lbs.
10	Polylactic Acid (PLA)	4.79 lbs.
11	Duct Tape	4 ft.
12	Basalt Reinforcement	160 sq. ft.
13	Alkali-Resistant Glass (ARG)	60 sq. ft.
14	Recycled Styrofoam Flotation	~2 cu. ft.
15	Steel Ties	45-3"
16	Sealer	1 gallon
17	OPC (Cement)	63.3 lbs.
18	Slag Cement	55.3 lbs.
19	Silica Fume	8.59 lbs.
20	Poraver .1-5(Cenospheres)	17.43 lbs.
21	Poraver .5-1	17.99 lbs.
22	Poraver 2-4	18.4 lbs.
23	Utelite Crushed (Light. Agg.)	86.26 lbs.
24	Pumice Sand	10.1 lbs.
25	13 mm PVA Fibers	0.525 lbs.
26	3M K1 Glass Bubbles	0.34 lbs.
27	ADVA 530	0.38 lbs.
28	VMAR-3	2.9 lbs.
29	Eclipse 2500	0.64 lbs.
30	Rubber Chips	9.0 lbs.
31	Pigments	0.21 lbs.
32	Water	68.2 lbs.
33		
34		
35		
36		

The Last Bearbender
Design Drawing

All dimensions are in inches.

DRAWN BY:	DATE:
Shaan Jagani Daniel Gonzalez	01/24/2020

ID	Task Name	Duration	Start	Finish
1	**Project Milestones**	**398 days**	**Mon 9/14/20**	**Fri 3/18/22**
2	Project Start	0 days	Mon 9/14/20	Mon 9/14/20
3	Hull Design Completion	0 days	Fri 10/30/20	Fri 10/30/20
4	Technical Paper & Other Deliverables Completion	0 days	Thu 2/18/21	Thu 2/18/21
5	Presentation Slides Completion	0 days	Thu 4/1/21	Thu 4/1/21
6	MidPac Start	0 days	Thu 4/15/21	Thu 4/15/21
7	MidPac End	0 days	Sat 4/17/21	Sat 4/17/21
8	National Concrete Canoe Competition Start	0 days	Sat 6/26/21	Sat 6/26/21
9	National Concrete Canoe Competition End	0 days	Mon 6/28/21	Mon 6/28/21
10	Research of Construction Methods Completion	0 days	Fri 10/22/21	Fri 10/22/21
11	Canoe Formwork Completion	0 days	Tue 11/23/21	Tue 11/23/21
12	Casting Canoe	0 days	Sat 12/4/21	Sat 12/4/21
13	Sanding Completion	0 days	Fri 2/25/22	Fri 2/25/22
14	Graphics Completion	0 days	Wed 3/16/22	Wed 3/16/22
15	Canoe Construction Completion	0 days	Thu 3/17/22	Thu 3/17/22
16	**Functional Activities**	**398 days**	**Mon 9/14/20**	**Fri 3/18/22**
17	**Structural Analysis**	**40 days**	**Mon 9/14/20**	**Fri 11/6/20**
18	Analysis Classes and Research	16 days	Mon 9/14/20	Mon 10/5/20
19	Loading Case Analysis	6 days	Fri 10/23/20	Fri 10/30/20
20	Sample Calculations	5 days	Mon 11/2/20	Fri 11/6/20
21	**Materials & Mix Design**	**65 days**	**Mon 9/14/20**	**Fri 12/11/20**
22	Material Procurement	35 days	Mon 9/14/20	Fri 10/30/20
23	Research of Preliminary Mix Design	35 days	Mon 9/14/20	Fri 10/30/20
24	Trial Batching and Testing Mix	30 days	Mon 11/2/20	Fri 12/11/20
25	**Hull Design**	**70 days**	**Mon 9/14/20**	**Fri 12/18/20**
26	Research of Preliminary Hull Design	15 days	Mon 9/14/20	Fri 10/2/20
27	Hull Design Revisions	14 days	Mon 10/5/20	Thu 10/22/20
28	SolidWorks Modeling	6 days	Fri 10/23/20	Fri 10/30/20
29	Panel Drawing Extrapolation	10 days	Mon 11/2/20	Fri 11/13/20
30	Construction Drawing	11 days	Fri 12/4/20	Fri 12/18/20
31	**Graphics**	**396 days**	**Mon 9/14/20**	**Wed 3/16/22**
32	Theme Research and Development	35 days	Mon 9/14/20	Fri 10/30/20
33	Canoe Graphics Application Research	30 days	Mon 11/2/20	Fri 12/11/20
34	Canoe Paper Design	30 days	Mon 11/2/20	Fri 12/11/20
35	Display Design	30 days	Mon 11/2/20	Fri 12/11/20
36	Stand Design	30 days	Mon 11/2/20	Fri 12/11/20
37	Presentation Design	30 days	Mon 2/22/21	Fri 4/2/21
38	Canoe Graphics Design	39 days	Tue 1/4/22	Fri 2/25/22
39	Canoe Graphics Application	13 days	Mon 2/28/22	Wed 3/16/22
40	**Technical Paper & Other Deliverables**	**180 days**	**Mon 9/14/20**	**Thu 5/20/21**
41	Enhanced Focus Area Research	60 days	Mon 9/14/20	Fri 12/4/20
42	Enhanced Focus Area Writing and Editing	54 days	Mon 12/7/20	Thu 2/18/21
43	John Craig Legacy Competition Research	10 days	Mon 11/2/20	Fri 11/13/20
44	John Craig Legacy Competition Filming and Editing	15 days	Mon 11/16/20	Fri 12/4/20
45	Draft Paper	21 days	Mon 11/2/20	Mon 11/30/20
46	Paper Editing	49 days	Mon 12/14/20	Thu 2/18/21
47	Deliverables Submission	1 day	Fri 2/19/21	Fri 2/19/21
48	Peer Review Papers	14 days	Mon 2/22/21	Thu 3/11/21
49	Peer Review Papers Submission	1 day	Fri 3/12/21	Fri 3/12/21
50	National Paper Submission	1 day	Thu 5/20/21	Thu 5/20/21
51	**Presentation**	**38 days**	**Mon 2/22/21**	**Wed 4/14/21**
52	Script Writing	29 days	Mon 2/22/21	Thu 4/1/21
53	Presentation Rehearsal	9 days	Fri 4/2/21	Wed 4/14/21
54	MidPac Competition	3 days	Thu 4/15/21	Sat 4/17/21
55	National Concrete Canoe Competition	2 days	Sat 6/26/21	Mon 6/28/21
56	Summer Interim Period	101 days	Mon 4/19/21	Fri 9/3/21
57	**Paddling**	**136 days**	**Mon 9/6/21**	**Fri 3/11/22**
58	Padding Recruitment	15 days	Mon 9/6/21	Fri 9/24/21
59	Paddling Training	121 days	Mon 9/27/21	Fri 3/11/22
60	Time Trials	1 day	Fri 2/18/22	Fri 2/18/22
61	**Construction**	**140 days**	**Mon 9/6/21**	**Thu 3/17/22**
62	Material Procurement	35 days	Mon 9/6/21	Fri 10/22/21
63	Research of Construction Methods	35 days	Mon 9/6/21	Fri 10/22/21
64	Machine Equipment Training	10 days	Mon 9/6/21	Fri 9/17/21
65	**Mock Ups**	**41 days**	**Mon 9/20/21**	**Mon 11/15/21**
66	CNC Cross Sections	5 days	Mon 9/20/21	Fri 9/24/21
67	Install Cross Sections	10 days	Mon 9/27/21	Fri 10/8/21
68	Stripping and Paneling	15 days	Mon 10/11/21	Fri 10/29/21
69	Casting Mock Up 1	1 day	Mon 11/1/21	Mon 11/1/21
70	Casting Mock Up 2	1 day	Mon 11/1/21	Mon 11/1/21
71	Demold Mock Up 1	1 day	Mon 11/15/21	Mon 11/15/21
72	Demold Mock Up 2	1 day	Mon 11/15/21	Mon 11/15/21
73	**Calaxy**	**99 days**	**Tue 11/2/21**	**Thu 3/17/22**
74	CNC Cross Sections	3 days	Tue 11/2/21	Thu 11/4/21
75	Install Spine	1 day	Fri 11/5/21	Fri 11/5/21
76	Waterproofing Table and Spine	1 day	Mon 11/8/21	Mon 11/8/21
77	Install Cross Sections	4 days	Tue 11/9/21	Fri 11/12/21
78	Waterproofing Cross Sections	1 day	Fri 11/12/21	Fri 11/12/21
79	Paneling	7 days	Mon 11/15/21	Tue 11/23/21
80	Casting	1 day	Sat 12/4/21	Sat 12/4/21
81	Curing	31 days	Mon 12/6/21	Mon 1/17/22
82	Demolding	1 day	Fri 2/25/22	Fri 2/25/22
83	Sanding	16 days	Fri 2/4/22	Fri 2/25/22
84	Sealing	1 day	Thu 3/17/22	Thu 3/17/22
85	**Final Product Deliverables**	**20 days**	**Mon 1/17/22**	**Fri 2/11/22**
86	Cutaway Cross Section	15 days	Mon 1/17/22	Fri 2/4/22
87	Canoe Stand Construction	5 days	Mon 2/7/22	Fri 2/11/22
88	Display Table Construction	5 days	Mon 2/7/22	Fri 2/11/22
89	Canoe Construction Submission	1 day	Fri 3/18/22	Fri 3/18/22



Project: Canoe final schedule_b
Date: Mon 12/28/20

Task — Milestone ◆ — Summary — Critical

appendix a

bibliography

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appendix b

mixture proportions and primary mixture calculation

MIXTURE: ***Wan Shi Tong***

Cementitious Materials					
Component	***Specific Gravity***	***Volume***	***Amount of CM***		
Cement	3.15	1.269 ft^3	249.4	lb/yd^3	Total cm (includes c) __438__ lb/yd^3 c/cm ratio, by mass __1.56__
Slag	2.90	.81 ft^3	146.7	lb/yd^3	
Silica Fume	2.20	.305 ft^3	41.9	lb/yd^3	

Fibers					
Component	***Specific Gravity***	***Volume***	***Amount of Fibers***		
13mm PVA Fibers	1.27	.032 ft^3	2.52	lb/yd^3	Total Amount of Fibers __2.52__ lb/yd^3

Aggregates						
Aggregates	***Abs (%)***	SG_{OD}	SG_{SSD}	***Base Quantity, W***		***Volume,*** $V_{agg,\,SSD}$
				W_{OD}	W_{SSD}	
Riverlite 3/8	16.8 %	1.16	1.36	790.91 lb/yd^3	927.27 lb/yd^3	10.90 ft^3
Foamed Glass 2-4	24.7 %	.19	.237	130.7 lb/yd^3	163.37 lb/yd^3	10.92 ft^3

Liquid Admixtures					
Admixture	***lb/ US gal***	***Dosage (fl. oz / cwt)***	***% Solids***	***Amount of Water in Admixture***	
ADVA 530	8.9	26.6	30.6 %	5.62 lb/yd^3	Total Water from Liquid Admixtures, $\sum w_{admx}$ __15.07__ lb/yd^3
VMAR 3	8.5	29.5	.69 %	8.5 lb/yd^3	
Eclipse 4500	7.7	8.2	55.82 %	.95 lb/yd^3	

Water			
	Amount		***Volume***
Water, w, $[=\sum (w_{free} + w_{admx} + w_{batch})]$	w/c ratio, by mass __1.06__ w/cm ratio, by mass __.60__	264.5 lb/yd^3	4.24 ft^3
Total Free Water from All Aggregates, $\sum w_{free}$		92.752 lb/yd^3	
Total Water from All Admixtures, $\sum w_{admx}$		15.07 lb/yd^3	
Batch Water, w_{batch}		156.68 lb/yd^3	

Densities, Air Content, Ratios, and Slump						
Values for 1 cy of concrete	***cm***	***Fibers***	***Aggregate (SSD)***	***Solids,*** S_{total}	***Water, w***	***Total***
Mass, M	438 lb	2.52 lb	1090.65 lb	3.74 lb	156.69 lb	$\sum M$:1691.6 lb
Absolute Volume, V	2.384 ft^3	.032 ft^3	21.78 ft^3	.235 ft^3	2.51 ft^3	$\sum V$: 26.94 ft^3
Theoretical Density, T, $(=\sum M / \sum V)$	63.03 lb/ft^3		***Air Content, Air,*** $[= (T - D)/T \times 100\%]$			5 %
Anticipated Density, D	59.7 lb/ft^3		***Air Content, Air,*** $[= (27 - \sum V))/27 \times 100\%]$			.22 %
Total Aggregate Ratio $(=V_{agg,SSD} / 27)$	80.7%		***Slump, Slump flow, Spread*** (as applicable)			1.25 in.
C330 + RCA Ratio $(=V_{C330+RCA} / V_{agg})$	50 %					

Cementitious Materials

Volume of Cement:

$$Volume_{cement} = \frac{weight_{cement}}{SG_{cement} \times 62.4} = \frac{249.4}{3.15 \times 62.4} = 1.269\, ft^3$$

Ground Granulated Blasted Furnace Slag:

$$Volume_{slag} = \frac{weight_{slag}}{SG_{slag} \times 62.4} = \frac{146.7}{2.90 \times 62.4} = 0.810\, ft^3$$

Volume of Silica Fume:

$$Volume_{silica\ fume} = \frac{weight_{silica\ fume}}{SG_{silica\ fume} \times 62.4} = \frac{41.9}{2.20 \times 62.4} = 0.305\, ft^3$$

Total Weight of Cementitious Materials:

$$\Sigma W_{cm} = 249.4\, \frac{lb}{yd^3} + 146.7\, \frac{lb}{yd^3} + 41.9\, \frac{lb}{yd^3} = 438\, \frac{lb}{yd^3}$$

FIBERS

Volume of 13mm PVA Fibers:

$$Volume_{fibers} = \frac{weight_{fibers}}{SG_{fibers} \times 62.4} = \frac{2.52}{1.27 \times 62.4} = 0.032\, ft^3$$

Aggregates

Foamed Glass 2-4 (Stock was at OD):

$$\boldsymbol{Abs} = \frac{W_{SSD} - W_{OD}}{W_{OD}} \times 100\% = \frac{0.24 - 0.192}{0.192} \times 100\% = 25\%$$

$$\boldsymbol{MC_{total}} = \frac{W_{STK} - W_{OD}}{W_{OD}} \times 100\% = \frac{0.192 - 0.192}{0.192} \times 100\% = 0\%$$

$$\boldsymbol{MC_{free}} = MC_{total} - Abs = 0\% - 25\% = -25\%$$

$$\boldsymbol{W_{SSD}} = \left(1 + \frac{Abs}{100\%}\right) \times W_{OD} = \left(1 + \frac{25\%}{100\%}\right) \times 130.7 = 163.37\ lbs$$

$$\boldsymbol{w_{free}} = W_{OD} \times \frac{MC_{free}}{100\%} = 130.7 \times \frac{-25\%}{100\%} = -32.67\ lbs$$

$$\boldsymbol{W_{stk}} = W_{SSD} + w_{free} = 163.37 + (-32.67) = 130.7\ lbs$$

$$Volume_{Foamed\ Glass} = \frac{weight_{Foamed\ Glass}}{SG_{Foamed\ Glass} \times 62.4} = \frac{163.37}{.24 \times 62.4} = 10.90\, ft^3$$

⅜ Riverlite (Stock was at SSD):

$$\boldsymbol{Abs} = \frac{W_{SSD} - W_{OD}}{W_{OD}} \times 100\% = \frac{1.36 - 1.16}{1.16} \times 100\% = 17.2\%$$

$$\boldsymbol{MC_{total}} = \frac{W_{STK} - W_{OD}}{W_{OD}} \times 100\% = \frac{1.36 - 1.16}{1.16} \times 100\% = 17.2\%$$

$$\boldsymbol{MC_{free}} = MC_{total} - Abs = 17.2\% - 17.2\% = 0\%$$

$$\boldsymbol{W_{SSD}} = (1 + \frac{Abs}{100\%}) \times W_{OD} = (1 + \frac{17.2\%}{100\%}) \times 790.91 = 926.947\ lbs$$

$$\boldsymbol{w_{free}} = W_{OD} \times \frac{MC_{free}}{100\%} = 790.91 \times \frac{17.2\%}{100\%} = 136.037\ lbs$$

$$\boldsymbol{W_{stk}} = W_{SSD} + w_{free} = 926.947 + 136.037 = 1062.984\ lbs$$

$$Volume_{Riverlite} = \frac{weight_{Riverlite}}{SG_{Riverlite} \times 62.4} = \frac{926.947}{1.36 \times 62.4} = 10.923\ ft^3$$

Total Weight of Aggregates:

$$\Sigma W_{aggregates} = 162.983\ \frac{lb}{yd^3} + 926.947\ \frac{lb}{yd^3} = 1089.93\ \frac{lb}{yd^3}$$

Liquid Admixtures

Water from ADVA 530:

$$w_{ADVA\ 530} = dosage\ (fl\ oz) \times cwt\ of\ cm \times water\ content(\%) \times \frac{1gal}{128\ fl\ oz} \times \frac{lb}{gal\ of\ ADVA\ 530}$$
$$= \frac{26.6\ fl\ oz}{cwt} \times 4.38\ cwt\ of\ cm \times 0.694 \times \frac{1gal}{128\ fl\ oz} \times \frac{8.9lb}{gal\ of\ ADVA\ 530} = 5.62\ \frac{lb}{yd^3}$$

Water from V-Mar 3:

$$w_{V-MAR\ 3} = dosage\ (fl\ oz) \times cwt\ of\ cm \times water\ content(\%) \times \frac{1gal}{128\ fl\ oz} \times \frac{lb}{gal\ of\ V-Mar\ 3}$$
$$= \frac{29.5\ fl\ oz}{cwt} \times 4.38\ cwt\ of\ cm \times 0.9931 \times \frac{1gal}{128\ fl\ oz} \times \frac{8.5lb}{gal\ of\ V-MAR\ 3} = 8.5\ \frac{lb}{yd^3}$$

Water from Eclipse 4500:

$$w_{Eclipse\ 4500} = dosage\ (fl\ oz) \times cwt\ of\ cm \times water\ content(\%) \times \frac{1gal}{128\ fl\ oz} \times \frac{lb}{gal\ of\ Eclipse\ 4500}$$
$$= \frac{8.2\ fl\ oz}{cwt} \times 4.38\ cwt\ of\ cm \times 0.4418 \times \frac{1gal}{128\ fl\ oz} \times \frac{7.7lb}{gal\ of\ Eclipse\ 4500} = 0.95\ \frac{lb}{yd^3}$$

Total Free Water from Admixture:

$$\Sigma W_{admx} = 5.62\ \frac{lb}{yd^3} + 8.5 + 0.95\ \frac{lb}{yd^3} = 15.07\ \frac{lb}{yd^3}$$

Water

Batch Water:

$$w_{batch} = w - (w_{free} + \Sigma w_{admx}) = 264.5 \frac{lb}{yd^3} - (92.752 \frac{lb}{yd^3} + 15.07 \frac{lb}{yd^3}) = 156.68 ft^3$$

Total Volume of Water:

$$Volume_{water} = \frac{w}{62.4} = \frac{264.5}{62.4} = 4.24 ft^3$$

DENSITY, AIR CONTENT, SLUMP AND RATIOS

Mass of Concrete (M):

$$M = W_{CM} + W_{Fibers} + W_{Aggregates} + W_{Solids} + W_{water}$$
$$= 438\ lbs + 2.52\ lbs + 1089.93\ lbs + 0\ lbs + 264.5\ lbs = 1794.95\ lbs$$

Absolute Volume of Concrete (V):

$$V = V_{CM} + V_{Fibers} + V_{Aggregates} + V_{Solids} + V_{water}$$
$$= 2.384 + 0.032 + 21.82 + 0 + 4.24 = 28.476 ft^3$$

Theoretical Density (T):

$$T = \frac{M}{V} = \frac{1794.95\ lbs}{28.476 ft^3} = 63.03\ lb/ft^3$$

Measured Density (Wet Unit Weight) (D):

$$Mass_{container} = 11.93\ lbs$$
$$Volume_{container} = .2\ ft^3$$
$$Mass_{container+concrete} = 26.20$$
$$D = \frac{Mass_{concrete}}{Volume_{container}} = \frac{(26.20-11.93)}{.2} = 59.7$$

Air Content:

$$Air\ Content = \frac{T-D}{T} \times 100\% = \frac{(63.03-59.7)}{59.7} = \mathbf{5\%}$$
$$Air\ Content = \frac{27-\Sigma V}{27} \times 100\% = \frac{27-26.94}{27} = \mathbf{.22\%}$$

Water-Cement Ratio:

$\frac{264.5}{249.4} = 1.06$
Water Cementitious Material Ratio: $\frac{264.5}{438} = 0.604$
Ratio of Aggregate Volume to Total Volume: $\frac{21.82\ lb}{27\ ft^3} = .808$
C330 + RCA Ratio: $\frac{V_{C330+RCA}}{V\ Aggregate} = \frac{10.92}{21.82} = 0.5004 \geq .50 \rightarrow Okay!$
Theoretical Slump: *Slump = 1.25*

Terms and Formulas

Abs = absorption of an aggregate, whether taken as a whole, the coarse, or the fine aggregate, %.

admx = admixtures

air = gravimetric air content, per ASTM C138, %.

agg = aggregate

c = cement

cm = cementitious materials (including cement)

c/cm = ratio of cement to cementitious materials, by mass, *dimensionless*

cwt = hundred weight of cementitious material (example 750 lb/yd^3 of cm is 7.5 cwt)

f = fibers

ld = liquid dyes

M = mass, *lb*.

MC_{total} = total moisture content referenced to the oven-dried condition of the aggregate, %.

MC_{free} = free moisture content, referenced to the saturated, surface-dry condition (SSD), of the aggregate, %.

mf = mineral fillers (i.e., aggregate-like materials passing the No. 200 sieve (75µm)

D = measured density (wet, plastic) of concrete test cylinders, per ASTM C138, *lb/ft*^{3}.

T = theoretical density of concrete (zero air voids), per ASTM C138, *lb/ft*^{3}.

S_{ld} = solids in liquid dyes

$S_{p\,admx}$ = solids of powdered admixtures

S_{total} = total solids of liquid dyes, powdered admixtures, and mineral fillers, *lb/yd*^{3}.

SG_{SSD} = specific gravity, in the saturated, surface-dry condition, of aggregate, *dimensionless*.

SG_{OD} = specific gravity, in the oven-dried condition, of aggregate, *dimensionless*.

V = volume, *ft*^{3}.

$V_{agg,SSD}$ = volume, in the saturated, surface-dry condition, of aggregate, *ft*^{3}.

W_{SSD} = mass, in the saturated, surface-dry condition, of aggregate per unit volume of concrete, *lb/yd*^{3}.

W_{OD} = mass, in the oven-dried condition, of aggregate per unit volume of concrete, *lb/yd*^{3}.

W_{stk} = mass, in the stock moisture condition, of the aggregate per unit volume of concrete, *lb/yd*^{3}.

w_{admx} = the mass of water in the admixtures, per unit volume of concrete, *lb/yd*^{3}.

w_{batch} = the mass of water to be batched per unit volume of concrete when the aggregates are in a stock moisture condition, *lb/yd*^{3}.

w_{free} = free water carried into the batch by a wet per unit volume of concrete, *lb/yd*^{3}.

w/c = water to cement ratio, by mass, *dimensionless*.

w/cm = water to cementitious material ratio, by mass, *dimensionless*.

Terms and Formulas

Each one of these formulas should be applied to each aggregate source:

Note that w_{free} can be a negative number indicating a dry and absorptive aggregate.

$$W_{stk} = W_{SSD} + w_{free}$$

Then, for the mixture as a whole:

The following formula should be applied to all admixtures in liquid form:

$$w_{admx} = \text{dosage (fl oz/cwt)} * \text{cwt of cm} * \text{water content (\%)} * \text{1 gal/128 fl oz} * \text{lb/gal of admixture}$$

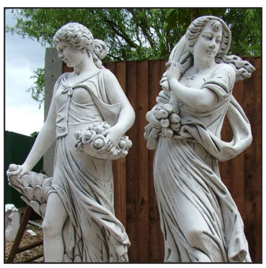
The following formula should be applied to liquid dyes only:

$$S = \text{dosage (fl oz/cwt)} * \text{cwt of cm} * \text{solid content (\%)} * \text{1 gal/128 fl oz} * \text{lb/gal of admixture}$$

NYCON-PVA RECS100

PVA (Polyvinyl Alcohol), Medium Denier, Superior Bond

NYCON
OVER 25 YEARS OF REINFORCING FIBERS



ULTRA-HIGH PERFORMANCE FIBERS

PVA fibers are unique in their ability to create a fully-engaged molecular bond with mortar and concrete that is 300% greater than other fibers.

NYCON-PVA RECS100 Physical Properties

Filament Diameter	20 Denier (100 Microns)
Fiber Length	0.5" (13 mm)
Specific Gravity	1.3
Tensile Strength	180 ksi (1200 MPa)
Flexural Strength	3600 ksi (25 GPa)
Melting Point	435° F (225° C)
Color	White
Water Absorption	<1% by Weight
Alkali Resistance	Excellent
Concrete Surface	Not Fuzzy
Corrosion Resistance	Excellent

Description

NYCON-PVA RECS100 fiber products are 20 denier, monofilament PVA fibers for use in fiber reinforced concrete, stucco, shotcrete and precast. NYCON-PVA RECS100 is specifically designed for use in concrete products for the purpose of controlling plastic shrinkage, thermal cracking and improving abrasion resistance.

NYCON-PVA RECS100 meets the requirements of ASTM C-1116, Section 4.1.3 and AC-32 at 1.0 lb (0.45 kg) per CY.

Applications

NYCON-PVA utilizes the mixing activity to disperse the fibers into the mix. NYCON-PVA acts with a molecular bond in the concrete with a multi-dimensional fiber network. NYCON-PVA does not affect curing process chemically.

NYCON-PVA can be used in all types of concrete. Synthetic fibers help the concrete at early ages, which is especially beneficial where stripping time and handling is important.

800-456-9266 | **www.nycon.com** | **sales@nycon.com**

NYCON-PVA RECS100

PVA (Polyvinyl Alcohol), Medium Denier, Superior Bond

NYCON
OVER 25 YEARS OF REINFORCING FIBERS

Advantages/Benefits

- Molecular bond with the concrete
- Reduces the formation of plastic shrinkage cracking in concrete.
- Provides multi-dimensional reinforcement.
- Improves impact, shatter and abrasion resistance of concrete.
- Enhances durability and toughness of concrete.
- Excellent, "no fuzz" finishability

Mixing

NYCON-PVA RECS100 can be added directly to the mixing system during or after the batching of the ingredients and mixed at high speed for a minimum of five minutes. Additional mixing does not adversely affect the distribution or overall performance of NYCON-PVA. The addition of NYCON-PVA at the normal or high dosage rate does not require any mix design or application changes. A water reducer or super-plasticizer is recommended in concrete products where improved workability and finishability are desired.

Tooling & Finishing

Fiber reinforced concrete can be finished by most finishing techniques. NYCON-PVA does not affect the finishing characteristics of concrete. NYCON-PVA can be used in power/hand troweled concrete, colored and broom finished concrete.

NYCON-PVA can be pumped and placed using conventional equipment. Hand screeds can be used, but vibratory and laser screeds are recommended to provide added compaction and bury surface fibers.

Packaging

(30) 1 lb (0.45 kg) paper beater bags per box, 600 lbs per pallet
(30) 1 lb (0.45 kg) water soluble bags per box, 600 lbs per pallet
(21) 40 lb (18 kg) paper bulk bags, 840 lbs per pallet

NYCON-PVA Fibers are packaged in pre-measured 1 lb (0.45kg) degradable "toss-in" paper beater bags, water soluble bags or bulk bags.

Storage and Shelf Life

NYCON-PVA should be stored in dry warehouse. Protect product from the rain.

800-456-9266 | **www.nycon.com** | **sales@nycon.com**

Nycon Corp. | 300 Ben Fairless Drive | Fairless Hills, PA 19030 | P: 800-456-9266 | P: 215-310-2139 | F: 215-736-2652

ADVA® Cast 530

High-range water-reducing admixture -- ASTM C494 Type A and F and ASTM C1017 Type I

Product Description

ADVA® Cast 530 is a high efficiency polycarboxylate-based superplasticizer. ADVA® Cast 530 has been formulated to impart extreme workability without segregation to concrete and to achieve high early compressive strength as required by the precast industry. ADVA® Cast 530 is optimized for the production of Self-Consolidating Concrete (SCC) in precast applications. ADVA® Cast 530 is formulated to comply with ASTM C494 as a Type A and F and ASTM C1017 Type I.

ADVA® Cast 530 is supplied as a ready-to-use brown liquid, one gallon weighs approximately 8.90 lbs (one liter weighs approximately 1.07 kg). ADVA® Cast 530 contains no intentionally added chlorides.

Product Advantages

- Imparts excellent stability to high flow concrete
- Excellent surface finish

Uses

ADVA® Cast 530 is recommended for use in precast and prestressed production in conventional and Self-Consolidating Concrete applications.

Conventional Concrete Applications of ADVA® Cast 530:

- Can produce concrete with extremely high levels of workability without segregation.
- May be used to produce concrete with very low water/cement ratios while maintaining normal levels of workability.
- Ideal for use in precast and prestressed applications where concrete needs to achieve high early strength along with high levels of workability.
- Provides superior concrete surface finish characteristics with reduced bugholing.

Self-Consolidating Concrete Applications:

SCC produced with ADVA® Cast 530 has unique advantages over conventional flowing concrete.

- **Self placement** - vibration can be eliminated because SCC is highly flowable and will change shape under its own weight to self level and self consolidate within formwork.
- **No segregation** - SCC is a flowable yet highly cohesive material that will not segregate and has significantly reduced bleeding.
- **No blocking** - SCC can pass freely through narrow openings and congested reinforcement without aggregate “blocking” behind obstructions that stop the flow of concrete.

Addition Rates

ADVA® Cast 530 is an easy to dispense liquid admixture. Dosage rates can be adjusted to meet a wide spectrum of concrete performance requirements. Addition rates for ADVA® Cast 530 can vary with the type of application, but will normally range from 3 to 10 fl oz/100 lbs (200 to 650 mL/100 kg) of cement. Should conditions require using more than the recommended addition rate, please consult your GCP representative.

For SCC applications, pre-placement testing is recommended to determine the optimum admixture addition rate and mix design. Factors that influence optimum addition rate include other concrete mix components, aggregate gradations, form geometry and reinforcement configurations. Please consult your local GCP Applied Technologies representative for assistance with developing mix designs for Self-Consolidating Concrete.

Compatibility with Other Admixtures and Batch Sequencing

ADVA® Cast 530 is compatible with most GCP admixtures as long as they are added separately to the concrete mix. However, ADVA® products are not recommended for use in concrete containing naphthalene-based admixtures including DARACEM® 19 and DARACEM® 100 and melamine-based admixtures including DARACEM® 65. In general, it is recommended that ADVA® Cast 530 be added to the concrete mix near the end of the batch sequence for optimum performance. Different sequencing may be used if local testing shows better performance. Please see GCP Technical Bulletin TB-0110, *Admixture Dispenser Discharge Line Location and Sequencing for Concrete Batching Operations* for further recommendations.

Pretesting of the concrete mix should be performed before use and as conditions and materials change in order to assure compatibility with other admixtures, and to optimize dosage rates, addition times in the batch sequencing and concrete performance. For concrete that requires air entrainment, the use of an ASTM C260 air-entraining agent (such as DARAVAIR® or DAREX® product lines) is recommended to provide suitable air void parameters for freeze-thaw resistance. Please consult your GCP Applied Technologies representative for guidance.

Packaging & Handling

ADVA® Cast 530 is available in bulk, delivered by metered trucks, in totes and drums. ADVA® Cast 530 will freeze at approximately 32°F (0°C) but will return to full functionality after thawing and thorough mechanical agitation.

Dispensing Equipment

A complete line of accurate, automatic dispensing equipment is available.

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 consideration, investigation and verification by the user, but we do not warrant the results to be obtained. Please read all statements, recommendations, and 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 that would infringe any patent, copyright, or other third party right.

This document is only current as of the last updated date stated below and is valid only for use in the United States. It is important that you always refer to the currently available information at the URL below to provide the most current product information at the time of use. Additional literature such as Contractor Manuals, Technical Bulletins, Detail Drawings and detailing recommendations and other relevant documents are also available on www.gcpat.com. Information found on other websites must not be relied upon, as they may not be up-to-date or applicable to the conditions in your location and we do not accept any responsibility for their content. If there are any conflicts or if you need more information, please contact GCP Customer Service.

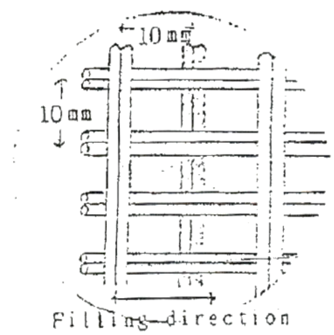
Last Updated: 2018-08-24
gcpat.com/solutions/products/adva-cast-high-range-water-reducers/adva-cast-530

gcp applied technologies

Nippon Electric Glass America, Inc.
ARG DIVISION
GFRC Products and Services

ARG NET SPECIFICATION

1. Product Designation:	TD 10X10 (AN 62 W 1010)
2. Recommended Use:	Lay-up
3. Product Specification:	
Type of Glass	ARG (Alkali Resistant Glass)
Filament diameter (μm)	13.5 ± 2 (0.00053 inches)
Filament diameter code letter	K
Weight (g/m^2)	80 (2.36 oz/yd^2)
Net Construction	
End count per bundle	
Warp (end/bundle)	2 (double)
Filling (end/bundle)	2 (double)
Spacing	
Warp (mm)	10 (0.39 inches)
Filling (mm)	10 (0.39 inches)
Roll width (mm)	914.4 $^{+100}_{-0}$ (36 inches)
Roll length (m)	50 $^{+5}_{-0}$ (1800 feet)
4. Package : Covered with wrapping paper	



Properties of NEG's ARG Fiber

ZrO^2	(wt%)	min. 19
Density	(g/cm^3)	2.7 (0.0975 lbs/in^3)
Tensile strength	(kPa)	1,270-2,450 (185-355 x 10^3 psi)
	(kgf/mm^2)	130-250
Young's modulus	(kPa)	78,400 (11,400 x 10^3 psi)
	(kgf/mm^2)	8,000
Elongation at break (%)		1.5 -- 2.5

2604 West Marshall Drive, Suite 102, Grand Prarie, TX 75050 TEL: 972/602-1740 FAX: 972/602-1760

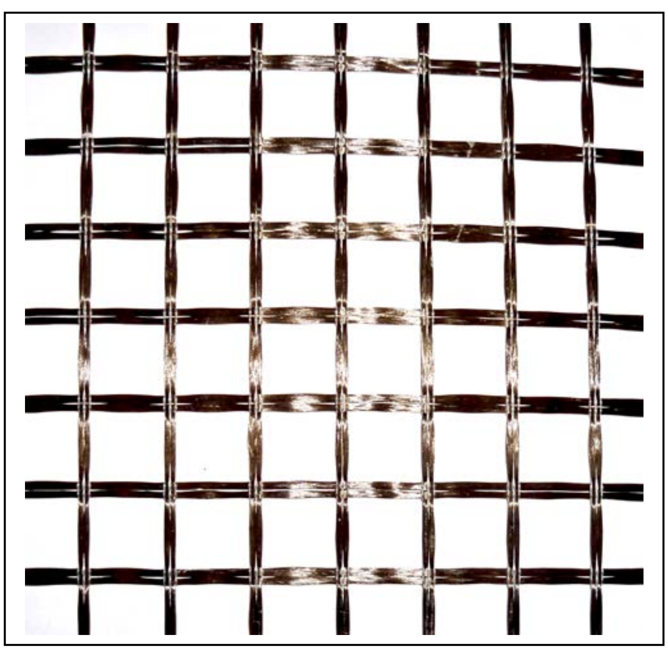
Advanced Filament Technologies L.L.C.
14520 Memorial Drive Suite M137
Houston TX 77079
Phone 281 496-5427 Fax 281 496-4233
Web www.sudaglass.com email Sudaglass@sudaglass.com

Technical Data Sheet
Basalt Geomesh 25mm x 25mm
Part No. Mesh-25-100

Raw Material Properties		
Density of unsized filament material	2.7Grams/cu. centimeter	Tolerance +/- 5%
Moisture content of basalt rock	0.1 %	Tolerance +/- 0.05%
Melting point	1350 C (2462F)	Tolerance +/- 100C

Finished Mesh Properties			
Property	**Metric Units**	**US units**	**Tolerance**
Mesh size	25mm	1 in.	+/- 5%
Area weight	350 grams/sq. meter	10.26 oz./sq. yard	+/- 5%
Thickness	.08-.09mm	0.0032-0.0035 in.	
Width	1 meter	39.4”	+/- 3%
Coating used		Styrene-acrylic latex	
Coating content by weight--%		10.4%	

Testing Results			
Property	**Metric-N/meter**	**US Units -Lb. Force/foot**	**Tolerance**
Maximum Load	Warp 80,780 Weft 78,900	Warp 5,483 Weft 5,415	+/- 5% +/- 5%
Elongation at break		Warp 6.67% Weft 3.53 %	+/- 5% +/- 5%
Breaking elongation	Warp 13.34 mm Weft 7.07 mm	0.53” 0.28”	+/- 5% +/- 5%



Product Description

Allcem™ is a ground granulated blast furnace slag (GGBF slag) product conforming to ASTM C989 Grade 120. Allcem is manufactured by Lehigh Cement Company.

Iron Blast Furnaces and Allcem

Iron blast furnaces are continuously charged from the top with layers of iron ore, flux stone, fuel, and other sources of iron oxide, as part of a highly controlled metallurgical process. As more heat and oxygen are forced into the furnace, temperatures approach 2700° F. The molten iron collects at the bottom of the furnace where it is tapped (removed from the furnace). In the furnace, molten slag floats just above the molten iron. The slag is regularly tapped out of the furnace. The unique chemistry of the iron blast furnace slag makes Allcem a consistent product.

Slag Activity Index, min. %

	*7-Day Index	*28-Day Index
Grade 80	—	75
Grade 100	75	95
Grade 120	95	115

***Average of the last five consecutive samples**

The above grade designations correspond to the average compressive strength of ground granulated blast furnace slag standard mortar cubes proportioned at a 50/50 ratio (slag/reference portland cement mixture) when compared to a 100% reference portland cement mixture.

Producing Allcem Granules

Only blast furnace slag coming from iron blast furnaces is used to make Allcem. After being tapped from the furnace, molten slag is immediately water quenched. This converts the molten iron blast furnace slag into hard granules that look like sand, which are composed primarily of glass. After additional processing of selected granules, the finished Allcem is ground into a uniform cementitious material.

Specifications

ASTM C989 standard specification for "Ground Granulated Blast Furnace Slag as a Constituent in Concrete and Mortars" and AASHTO M 302 standard specification for "Ground Iron Blast Furnace Slag for Use in Concrete and Mortars" are the primary documents pertaining to Allcem. These specifications identify three grades of GGBF slag.

Allcem can also be used as a component in the production of blended cements conforming to ASTM C595 "Standard Specification for Blended Hydraulic Cements." The three types of blended cements containing slag are:

Type S - contains over 70% slag by weight

Type IS - contains 25% to 70% slag by weight

Type I(SM) - contains less than 25% slag by weight

Comparison: Allcem and Portland Cement

Both Allcem and portland cements are hydraulic, which means they harden by chemically reacting with water. Mixtures of Allcem with portland cement and water produce calcium-silicate hydrate (CSH) which is the principle binding material produced when portland cement reacts with water.

Allcem also possesses reactive silicon dioxide (SiO_2) in amounts sufficient to provide significant pozzolanic activity and benefits, in addition to the hydraulic properties of the cement. This is largely associated with lowering the calcium hydroxide [$Ca(OH)_2$] content of concrete by converting it into more CSH binder and lowering permeability. In hardened concrete, $Ca(OH)_2$ is weaker than CSH, additional SiO_2 in Allcem reacts with the $Ca(OH)_2$ to produce more CSH binder. This means that correctly proportioned mixtures made with Allcem and portland cement can exhibit higher strength, greatly reduced permeability, and potentially greater durability in many environments when compared to plain portland cement concretes.

TERMINOLOGY

Blast furnace - A furnace that reduces iron ore to iron.

Blast furnace slag - A non-metallic product consisting of silicates and alumino-silicates of calcium that is developed in a molten condition simultaneously with iron in a blast furnace.

Granulated blast furnace slag - The glassy, granular material formed when molten blast furnace slag is rapidly chilled.

Ground granulated blast furnace slag (GGBF slag) - Granulated blast furnace slag that has been finely ground.

Allcem - Selected GGBF slag manufactured and supplied by Lehigh Cement Company.

Fineness, Water Demand, Air and Color

Allcem, although somewhat finer than portland cement, does not typically have a higher water demand compared to portland cement in concrete. This is believed to be true due to its low absorption and denser packing features (smaller particles of Allcem nestling between the portland cement grains). Allcem may require a slightly higher air-entraining admixture dosage rate to achieve a specified air content. This is attributed to its greater surface area. The very low carbon content and minimum variability in chemistry of Allcem improves the load-to-load uniformity of concrete.

Unlike gray portland cements, Allcem is typically an off-white color. This is attributed to a combination of inherent chemical and physical properties of blast furnace slag granules. Generally, higher dosage rates of Allcem in a mix design will yield a lighter, brighter concrete color.

Shipping and Storage

Allcem is shipped, handled and stored similar to portland cement. As with all cementitious materials, Allcem should be stored in a clean, dry place. Allcem is typically shipped in pneumatic trucks. Rail shipments may be arranged if necessary.

Concrete: Proportioning

GGBF slag concretes may be proportioned by the same methods as portland cement concretes. When developing and/or selecting a concrete mixture, make certain that it meets the job requirements and applicable documents. For example, if concrete is exposed to repeated freezing-and-thawing cycles, the air-entraining requirements of ACI 318 or ACI 301 should be followed. Allcem has a specific gravity of 2.90.

The optimum Allcem dosage rate may vary with the application, specific materials, and other placing conditions. Concrete producers find two or three general-purpose mixtures with Allcem usually cover a variety of needs. Sometimes higher dosages are required, especially in marine environments or mass concretes, when reducing either permeability or heat of hydration is important.

ASTM C494 chemical admixtures and ASTM C260 air-entraining admixtures have been used with great success in concretes containing Allcem. Ternary mixtures using combinations of Allcem and portland cement with either microsilica or fly ash have demonstrated several high-performance characteristics.

As with all concretes containing portland cement, fly ash, microsilica, latex and other admixtures, the fresh and hardened properties of Allcem concrete may vary markedly with different materials, placing conditions, and concrete practices. Therefore, trial batches should be made to determine the concrete capabilities for a specific situation. They also help the producer in evaluating and selecting the appropriate Allcem dosage rate needed for the application.

Concrete: Making and Handling

Based upon the comments of finishers who have used the material in concrete flatwork, "superior" is the word that most accurately describes the finishing characteristics of concretes made with Allcem. As with portland cement concrete, it is important to follow good concrete practices. For example, do not put water onto the surface (blessing) while finishing. Also, protect the concrete from premature drying during all stages of finishing and curing. As with all exterior concretes, proper curing and sealing are essential to obtain maximum durability.

The same factors affect the set time of concretes made with Allcem as with plain portland cement. Generally, the higher the GGBF slag dosage, the slower the set time. This provides some advantages during hot weather concreting. Retarding admixtures and cold weather tend to slow set times for GGBF slag concretes.

As with portland cement-based concretes, the best results occur when the concrete has been cured continuously with water for as long as practical. It should also be allowed to dry sufficiently before the first freezing-and-thawing cycle. The most effective curing method is to cover the concrete with wet burlap (either plain or vinyl coated) according to ACI publication "Guide for Concrete Floor and Slab Construction." Wet burlap should be laid over the concrete as soon as possible without damaging the surface. It should be kept continuously wet throughout the entire curing period. If the concrete will be exposed to de-icer chemicals or salts, the use of a quality concrete sealer is encouraged, especially at early ages.

Concrete: Color

Sometimes, concretes made with combinations of GGBF slag and portland cement may turn green or blue-green in color, particularly if proper water curing has been applied. This is usually attributed to either higher GGBF slag dosages, or to the use of a more finely ground GGBF slag product. Once exposed to air for a few days, the concrete surface will usually become light gray or nearly white with most portland cements. Due to this blue-green color phenomenon and concrete practices used in swimming pool construction, concretes containing GGBF slag are not recommended for use in pool construction.

KEY FEATURES/BENEFITS OF ALLCEM

- **Improved uniformity, workability, pumpability, and better consolidation**
- **Reduced bleeding**
- **Better finishing properties**
- **Increased compressive and flexural strength (typically after 7-10 days)**
- **Reduced permeability**
- **Less calcium hydroxide [$Ca(OH)_2$] present (enhanced durability and reduced efflorescence)**
- **Improved sulfate resistance**
- **Minimized alkali-silica reaction**
- **Improved resistance to a variety of chemical environments**
- **Lower heat of hydration and reduced heat release (important considerations for mass concrete)**
- **Concretes exhibit a lighter and brighter color for colored concretes**
- **"Environmentally sensible" use of natural resources**

Contact your nearest Lehigh representative to learn more about the methods and benefits of using Allcem for improving the durability of concretes.

SALES OFFICES: **LEHIGH CEMENT COMPANY**: **Lehigh North:** Evansville, PA (800) 755-6959; Union Bridge, MD (800) 462-9071; Norfolk, VA (800) 544-7156; Indianapolis, IN (800) 468-6211 • **Lehigh South:** Birmingham, AL (800) 955-0015
Lehigh Southwest: Concord, CA (800) 821-9119 • www.lehighcement.com

9/02-5M

MasterLife® SF 100

Densified Silica Fume Mineral Admixture

Formerly Rheomac SF 100*

Description

MasterLife SF 100 dry, densified silica fume admixture is formulated to produce extremely strong, durable concrete. MasterLife SF 100 silica fume admixture meets the requirements of ASTM C 1240, Standard Specification for Silica Fume used in Cementious Mixtures.

Applications

Recommended for use in:

- Steel-reinforced concrete structures or wet shotcrete applications exposed to deicing or airborne salts
- Any construction project requiring the protection provided by highly durable, low permeability concrete
- Projects requiring high-strength/high-performance concrete
- Green Sense® Concrete

Features

- Added cohesiveness
- Reduced bleeding
- Enhanced performance

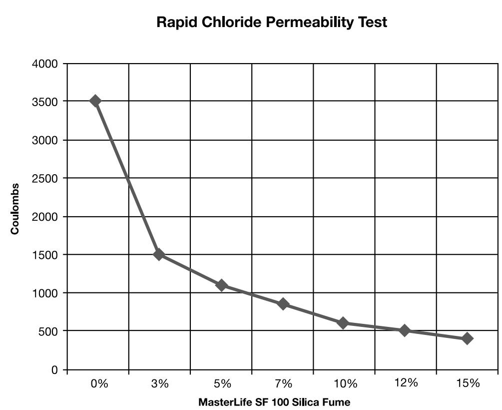
Benefits

- Increased concrete service life
- Increased strength
- Increased modulus of elasticity
- Reduced permeability thereby increasing durability
- Increased resistance to sulfate attack
- Increased resistance to alkali-silica reactivity

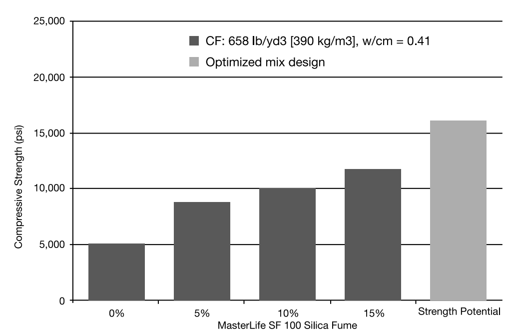
Performance Characteristics

Permeability: MasterLife SF 100 silica fume admixture is a micro-filling material that physically fills the voids between cement particles. MasterLife SF 100 silica fume admixture dramatically lowers permeability and reduces the size and number of capillaries that allow contaminants to enter the matrix.

Rapid Chloride Permeability



Typical Compressive Strengths



MASTER®
» BUILDERS
SOLUTIONS

Compressive Strength: As a pozzolan, MasterLife SF 100 silica fume admixture reacts chemically within a cementitious matrix to increase the amount of calcium silicate hydrate (CSH) gel that is formed. The CSH gel is the bonding agent that holds the matrix of a cementitious mixture together in the hardened state. The additional CSH gel increases strength and decreases permeability.

Specific Gravity: The specific gravity of MasterLife SF 100 silica fume admixture is 2.2.

Guidelines for Use

Dosage: MasterLife SF 100 silica fume admixture is recommended for use in concrete and wet shotcrete applications at an addition dosage of 5-15% by mass of cement.

Dispensing and Mixing: For concrete and wet shotcrete, MasterLife SF 100 silica fume admixture is batched at the concrete production plant in a manner similar to that for cement or other cementitious materials such as fly ash. It may be batched in a central or truck mixer. Follow the procedures outlined in ASTM C 94/C 94M, Standard Specification for Ready-Mixed Concrete or refer to the Silica Fume Association Users Manual for specific batching and mixing instructions.

Product Notes

Corrosivity – Non-Chloride, Non-Corrosive: MasterLife SF 100 silica fume admixture will neither initiate nor promote corrosion of reinforcing or prestressing steel embedded in concrete or of galvanized steel floor and roof systems. Neither calcium chloride nor other chloride-based ingredients are used in the manufacture of this silica fume.

Compatibility: MasterLife SF 100 silica fume admixture can be used with portland cements approved under ASTM, AASHTO or CRD specifications. It is compatible with most concrete admixtures, including all BASF admixtures. MasterLife SF 100 silica fume admixture is recommended for use with high-range water-reducing admixtures, such as the MasterGlenium® series, for maximum workability while maintaining a low water-cementitious materials ratio.

Storage and Handling

MasterLife SF 100 silica fume admixture stores, handles and dispenses similar to cement or fly ash. In bulk, MasterLife SF 100 silica fume admixture may be stored in a silo. Refer to the Silica Fume Association Users Manual for information on the appropriate set up for pumping and handling silica fume into silos. Packaged MasterLife SF 100 silica fume admixture must be stored in a dry area. MasterLife SF 100 silica fume admixture requires no special dispensing equipment.

Shelf Life: MasterLife SF 100 silica fume admixture has a minimum shelf life of 24 months. Depending on storage conditions, the shelf life may be greater than stated. Please contact your local sales representative regarding suitability for use and dosage recommendations if the shelf life of MasterLife SF 100 silica fume admixture has been exceeded.

Packaging

MasterLife SF 100 silica fume admixture is available in 25 lb (11.34 kg) shreddable bags, 2,000 lb (907 kg) bulk bags or by bulk delivery.

Related Documents

Safety Data Sheet: MasterLife SF 100 silica fume admixture, Silica Fume Association Users Manual.

Additional Information

For additional information on MasterLife SF 100 silica fume admixture or its use in developing concrete mixtures with special performance characteristics, contact your local sales representative.

The Admixture Systems business of BASF's Construction Chemicals division is the leading provider of solutions that improve placement, pumping, finishing, appearance and performance characteristics of specialty concrete used in the ready-mixed, precast, manufactured concrete products, underground construction and paving markets. For over 100 years we have offered reliable products and innovative technologies, and through the Master Builders Solutions brand, we are connected globally with experts from many fields to provide sustainable solutions for the construction industry.

Limited Warranty Notice

BASF warrants this product to be free from manufacturing defects and to meet the technical properties on the current Technical Data Guide, if used as directed within shelf life. Satisfactory results depend not only on quality products but also upon many factors beyond our control. BASF MAKES NO OTHER WARRANTY OR GUARANTEE, EXPRESS OR IMPLIED, INCLUDING WARRANTIES OF MERCHANTABILITY OR FITNESS FOR A PARTICULAR PURPOSE WITH RESPECT TO ITS PRODUCTS. The sole and exclusive remedy of Purchaser for any claim concerning this product, including but not limited to, claims alleging breach of warranty, negligence, strict liability or otherwise, is shipment to purchaser of product equal to the amount of product that fails to meet this warranty or refund of the original purchase price of product that fails to meet this warranty, at the sole option of BASF. Any claims concerning this product must be received in writing within one (1) year from the date of shipment and any claims not presented within that period are waived by Purchaser. BASF WILL NOT BE RESPONSIBLE FOR ANY SPECIAL, INCIDENTAL, CONSEQUENTIAL (INCLUDING LOST PROFITS) OR PUNITIVE DAMAGES OF ANY KIND.

Purchaser must determine the suitability of the products for the intended use and assumes all risks and liabilities in connection therewith. This information and all further technical advice are based on BASF's present knowledge and experience. However, BASF assumes no liability for providing such information and advice including the extent to which such information and advice may relate to existing third party intellectual property rights, especially patent rights, nor shall any legal relationship be created by or arise from the provision of such information and advice. BASF reserves the right to make any changes according to technological progress or further developments. The Purchaser of the Product(s) must test the product(s) for suitability for the intended application and purpose before proceeding with a full application of the product(s). Performance of the product described herein should be verified by testing and carried out by qualified experts.

* Rheomac SF 100 became MasterLife SF 100 under the Master Builders Solutions brand, effective January 1, 2014.

BASF Corporation
Admixture Systems
www.master-builders-solutions.basf.us

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Brampton, Ontario L6T 4M7
Tel: 800 387-5862 ■ Fax: 905 792-0651

LEHIGH
HEIDELBERGCEMENTGroup

ASTM Type I-II (AASHTO TYPE I) Portland Cement

1. Product Description

Basic Use: **Lehigh ASTM Type I-II (AASHTO TYPE I),** low alkali, Portland cement is both a general purpose use and a moderate sulfate use hydraulic cement that can be used for most construction projects. Type I-II cement can be used where precaution against moderate sulfate attack is important. Type I-II cement is formulated to be used in grouts, mortars and concrete.

Color: Lehigh Type I-II, low alkali, Portland cement has no artificial colors added and has a normal color of light gray.

Limitations: Lehigh Type I-II, low alkali, Portland cement is designed to be mixed with water. It should be used in an environment that is free of acids and high sulfates.

2. Technical Data

Applicable Standards: Lehigh Type I-II, low alkali, Portland cement is manufactured to conform to **ASTM C150 – Type I** and **Type II** specifications and **AASHTO M85 – Type I** specification.

Physical Properties: *Lehigh* Type I-II, low alkali, Portland Cement is a fine grey powder. ASTM C150 requires that Type I-II Portland Cement have a minimum Blaine fineness of 280 m2/kg.

Strength: According to ASTM C150 and AASHTO M85, mortar cubes made with Type I-II Portland cement will obtain minimum compressive strengths as listed below:

3 days	-	1740 psi
7 days	-	2760 psi

Set Time: According to ASTM C150 and AASHTO M85, a paste made with Type I-II Portland cement will attain an initial set in a minimum of 45 minutes, and a final set in a maximum of 375 minutes when tested by the Vicat test method.

Specific Gravity: Type I-II Portland Cement typically has a specific gravity of 3.15.

3. Safety and Handling

Cement and wet cement mixtures can dry the skin, cause alkali burns and irritate the eyes and upper respiratory tract. Ingestion can cause irritation of the throat. When working with cement and cement mixtures, workers should wear gloves and clothing impervious to moisture. Further safety measures should include; dust masks, safety goggles and barrier cream for exposed skin.

4. Availability

Lehigh Type I-II, low alkali, Portland cement is available in either 94 lb. paper sacks or in bulk. Custom packaging may be available for selected large quantities.

5. Warranty

Lehigh Northwest Cement Company warrants that Lehigh Type I-II, low alkali Portland cement meets the requirements of ASTM C150 (Type I and Type II cement) and AASHTO M85 (Type I cement).

6. Product Storage

All cement must be stored in a dry weather tight enclosure. Bagged material must be stored on pallets that allow air circulation around them.

7. Technical Services

Technical information and services are available from Lehigh Northwest Cement Company.

■ Lehigh Northwest Cement Company■

P.O. BOX 84728, Seattle, WA 98124■ Phone: (206) 763-2525 ■ FAX: (206) 767-2657

ECLIPSE® FLOOR 200

Shrinkage reducing admixture

ASTM C494 Type S

Product Description

Eclipse® Floor 200 is a liquid admixture for concrete that dramatically reduces drying shrinkage and the potential for drying shrinkage-induced cracking and curling. Rather than functioning as an expansive agent, Eclipse Floor 200 acts by reducing the surface tension of pore water. Eclipse Floor 200 is specifically formulated for use in non air-entrained applications only, such as interior slab-on-grade construction. Eclipse Floor 200 is a clear liquid admixture that weighs approximately 7.7 lbs/gal (0.92 kg/L).

Uses

Eclipse Floor 200 may be used in any concrete but provides the most value when used for interior slab-on-grade construction where the potential for cracking and curling due to drying shrinkage is prevalent and undesirable. Other potential Eclipse Floor 200 applications in non air-entrained concrete mixes not subjected to freeze-thaw cycling include bridge decks, parking garages, marine structures and containment structures. Eclipse Floor 200 can be used in ready mix, precast, and prestress non air-entrained concrete, in addition to mortar, grout and wet mix shotcrete.

Product Advantages

- Reduces drying shrinkage up to 80% at 28 days and 50% at 1 year and beyond
- Reduces the potential of cracking due to drying shrinkage in fully and partially restrained concrete
- Reduces curling
- Improves durability, which reduces maintenance and repair costs

Performance

Impact on plastic and hardened concrete properties—
Figure 1 illustrates ASTM C157 drying shrinkage reduction up to 90 days (7 day wet cure) for concrete mixtures containing 0.75 gal/yd³ (3.7 L/m³) and 1.5 gal/yd³ (7.4 L/m³) of Eclipse Floor 200. This data represents typical Eclipse Floor 200 test results for a well proportioned concrete mixture. However, it is recommended that pre-job drying shrinkage testing be conducted to determine actual drying shrinkage reduction for a specific mix proportion and set of materials.

In properly designed low shrinkage concrete mixtures for slab on grade construction, the inclusion of Eclipse Floor 200 may enable joint spacings of up to 50 feet (15 meters) or beyond. The use of Eclipse Floor 200 results in an overall higher value flooring system including:

- Lower joint maintenance cost due to minimum joint openings at a given joint spacing or fewer joints at extended joint spacing.
- Flatter surfaces due to curling reduction
- Longer surface life

Eclipse Floor 200 impacts workability (slump) similarly to an equal volume of water; therefore Eclipse Floor 200 should be used as a replacement for an equal volume of water. Eclipse Floor 200 may have a slight retarding effect on a concrete mix, typically less than one hour. In mixtures containing mid- or high-range water reducers, it is recommended Eclipse Floor 200 be used with near neutral setting polycarboxylate-based admixtures (including the MIRA® and ADVA® product lines). Eclipse Floor 200 may also cause a slight (typically less than 10%) decrease in early and later age compressive strengths. Eclipse Floor 200 is a non-chloride containing, non-corrosive admixture that will not initiate or contribute to the corrosion of reinforcing steel.

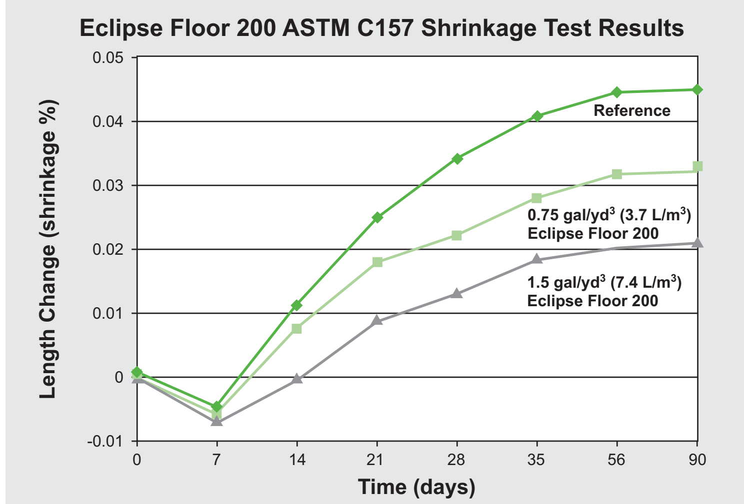

Figure 1

Addition Rates

Typical Eclipse Floor 200 dosage rates are 0.5 to 1.5 gal/yd³ (2.5 to 7.5 L/m³). However, dosage rates ranging from 0.2 to 2.0 gal/yd³ (1.0 to 10 L/m³) can be utilized to meet specific drying shrinkage requirements. Dosage rates as low as 0.2 gal/yd³ (1.0 L/m³) have been successfully used in concrete mixes that are just outside drying shrinkage specifications. Although shrinkage reduction as a function of dosage rate is fairly linear, it is recommended that trial mixtures be evaluated for shrinkage reduction in accordance with ASTM C157 prior to construction.

Compatibility with Other Admixtures and Batch Sequencing

Eclipse Floor 200 is fully compatible with the complete line of Grace Admixtures. In mixtures containing mid- or high-range water reducers, it is recommended that Eclipse Floor 200 be used with polycarboxylate based MIRA mid-range water reducers and ADVA high-range water reducers. In general, Eclipse Floor 200 may be added to the concrete batch sequencing at any time, however preferably after the dry materials and most of the water. Different sequencing may be used if local testing shows better performance. Please see Grace Technical Bulletin TB-0110, *Admixture Dispenser Discharge Line Location and Sequencing for Concrete Batching Operations* for further recommendations. Eclipse Floor 200 should not come in contact with any other admixture before or during the batching process, even if diluted in mix water. Pretesting of the concrete mix should be performed before use, and as conditions and materials change in order to assure compatibility, and to optimize dosage rates, addition times in the batch sequencing and concrete performance Please consult your Grace representative for specific guidance.

Packaging & Handling

Eclipse Floor 200 is currently available in bulk quantities by Grace metered systems, in 275 gal (1,040 L) totes, or in 55 gal (208 L) drums.

Dispensing Equipment

A complete line of automatic dispensing equipment is available through W.R. Grace & Co.–Conn.

Flammability

Eclipse Floor 200 has a flash point of 216°F (102°C). This is substantially above the upper limit of 140°F (60°C) for classification as a flammable material and above the limit of 200°F (93°C) for classification as a combustible material by DOT requirements. Nonetheless, this product must be treated with care and protected from excessive heat, open flame or sparks. For more information, consult the MSDS.

www.graceconstruction.com

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

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Grace Concrete Products

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V-MAR® 3

Concrete rheology-modifying admixture

ASTM C494 Type S

Product Description

V-MAR® 3 is a high efficiency, liquid admixture designed to enable production of Self-Consolidating Concrete (SCC) by modifying the rheology of concrete. V-MAR 3 works by increasing the viscosity of the concrete while still allowing the concrete to flow without segregation. V-MAR 3 is based on a unique, patented biopolymer and is manufactured under closely controlled conditions to provide uniform, predictable performance.

The V-MAR 3 admixture is supplied as a ready-to-use milky white liquid, one gallon weighs approximately 8.5 lbs (one liter weighs approximately 1.02 kg). V-MAR 3 admixture is formulated to meet the requirements of ASTM C494 Type S, specific performance, and does not contain intentionally added chlorides.

Uses

V-MAR 3 is recommended for use in conjunction with ADVA® series superplasticizers to produce SCC.

V-MAR 3 enhances the ability to manufacture SCC by allowing for variations in aggregate gradations and moisture contents. This can greatly reduce the time required to develop SCC mixes, and to update and test new mix designs if raw materials change. In addition, V-MAR 3 allows for the production of SCC in applications where mix designs and materials can not be modified for SCC properties, such as exposed aggregate concrete.

V-MAR 3 can also be used to reduce pump pressures when pumping concrete and for underwater, antiwashout concrete applications.

Product Advantages

- Enables concrete and SCC mix flexibility when using less-than-optimal aggregate gradation and in presence of fluctuation of moisture content
- Modifies concrete rheological properties for improved workability
- Reduces segregation and bleed
- Enhances surface appearance
- Easy to dispense liquid admixture
- Normal set times
- Minimal impact on air entrainment

Advantages

Self-Consolidating Concrete produced with V-MAR 3 and ADVA superplasticizers offers the following advantages:

- Moisture variation — consistent production of SCC even with normal moisture variation from batch to batch.
- Self placement — vibration can be eliminated because SCC is highly flowable and will change shape under its own weight to self level and self consolidate within formwork.
- No segregation — SCC is a flowable yet highly cohesive material that will not segregate, and has significantly reduced bleeding.
- No blocking — SCC can pass freely through narrow openings and congested reinforcement without aggregate "blocking" behind obstructions that stop the flow of concrete.
- Reduced labor and improved productivity through faster and easier concrete placement with no vibration
- Improved labor safety, reduced plant noise levels and improved work environment
- Reduced wear and tear on forms by eliminating vibration
- Achievement of complete consolidation throughout concrete elements, even in thin walled, highly reinforced units

Addition Rates

V-MAR 3 is typically used at an addition rate of 10 to 40 fl oz/yd^3 (390 to 1550 mL/m^3) of concrete.

Dosage requirements are based on water content in the mix. As water content increases, the V-MAR 3 requirement will increase. Typical water contents for SCC mixes are 280 to 320 lbs/yd^3 (166 to 190 kg/m^3). At lower water content, use V-MAR 3 at the lower dosage range, at higher water content, dosage rates will be higher.

V-MAR 3 dosage requirements may also be affected by mix design, cementitious content, aggregate gradations and SCC application.

Use of ADVA series superplasticizers is highly recommended for SCC production. Dosage rate requirements for superplasticizers are typically higher for SCC than for conventional concrete mixes. When producing SCC, admixtures (excluding air entrainers) should be added after the addition of the cementitious material and water.

Pre-placement testing and testing when materials or quantities change are recommended to determine the optimum admixture addition rate. Factors that influence optimum addition rate include other concrete mix components, aggregate gradations, form geometry, and reinforcement configurations. Please consult your local Grace representative for assistance with developing mix designs, admixture combinations and SCC production.

Compatibility with Other Admixtures

V-MAR 3 is intended for use with ADVA series superplasticizers and in combination with all air-entraining agents. All applications should be tested prior to use. Each admixture should be added separately into the concrete mix and not come in contact with each other prior to entering the mix.

Packaging & Handling

V-MAR 3 is available in bulk, in 275 gal (1041 L) totes, 55 gal (210 L) drums, and pails. It will freeze at about 28°F (-2°C) but will return to full functionality after thawing and thorough mechanical agitation.

Dispensing Equipment

A complete line of accurate, automatic dispensing equipment is available.

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GRACE

FOAMED GLASS SPHERES

Typical Properties

Particle size (metric)	**0.1-0.3 mm**	**0.25-0.5 mm**	**0.5-1.0 mm**	**1-2 mm**	**2-4 mm**	**4-8 mm**
Mesh Size	50 x 140	35 x 60	18 x 35	10 x 18	5 x 10	5 x 5/16"
Bulk Density (pcf[1])	25	21	16	14	12	11
Crush Strength (lb/in^2)	350	300	250	230	200	174
Pounds Per Bag	49	38	33	40	32	30
Pounds Per Bulk Bag	1,000	840	640	560	480	554

Product

Agsco Corp provides a complete line of foamed glass spheres made from >90% post-consumer glass. These glass beads act as a lightweight aggregate that additionally provide sound insulation, acoustic dampening, and improve fire resistance. The all-glass composition allows users to go "green" and gain U.S. Green Building Council LEED points in construction projects. Lightweight compositions as low as 25 pcf[1] are possible with good compressive strength.

Applications

Cementitious compositions

- adhesives, grouts, mortars and stucco
- self-leveling underlayment (SLU)
- blocks, bricks and veneer bricks
- sound barrier, concrete tilt-up walls.
- water filtration applications.

Polymeric resin compositions

- cast-and-cure composites
- ready mix mastics

With a variety of product sizes, large and small foamed glass beads can be blended together to provide maximum volume filling in both concrete and polymeric composites.

Packaging

Foamed glass spheres are available in bags (27 per pallet), bulk bags or bulk. The product in bulk bags contains 40 cubic feet. Bulk shipments will be arranged on request. Please ask your AGSCO representative for pricing information.

[1] pcf = pounds/cubic foot

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Revised: 6/18/2014

April 16, 2018

Mr. Jeff Speck
Trinity Expanded Shale & Clay
1112 East Copeland Road, Suite 500
Arlington, TX 76011

Phone: 678-777-6278
E-mail: jeffrey.speck@trin.net

Subject: **Final Report of ASTM C 330-17**
3/8 Structural – Erwinville, LA Plant
TEC Services Project No: 10-0825
TEC Services Sample ID: 17-1290

Dear Mr. Speck:

Testing, Engineering & Consulting Services, Inc. (TEC Services) is an AASHTO R18, ANS/ISO/IEC Standard 17025:2005 and is an Army Corps of Engineers accredited laboratory. TEC Services is pleased to present this final report of our testing on the 3/8-inch Structural lightweight aggregate submitted to our laboratory in December of 2017. The results of this testing pertain only to the samples tested. The aggregate was tested in accordance to ASTM C330-17 *Standard Specification for Lightweight Aggregates for Structural Concrete* as authorized by the service agreement (TEC-PRO-10-0825) dated August 2010.

This specification covers lightweight aggregates intended for use in structural concrete in which prime considerations are reducing the density while maintaining the compressive strength of the concrete. The maximum and minimum requirements for this specification are presented in Section 4 *Chemical Composition* and Section 5 *Physical Properties* of ASTM C330 and are reported in Table 1. Based on our results, the 3/8” Structural lightweight aggregate from the Erwinville, LA Plant submitted to our laboratory meet and/or exceeds the requirements of ASTM C330.

Table 1: Summary of Test Results

Section 4 - Chemical Composition	Test Results	ASTM C330 Requirements
Organic Impurities (Color change)	< 1	3 (max)
Staining (Stain index)	0	60 (max)
Loss on Ignition	3.173	5% (max)
Section 5 – Physical Properties		
Clay Lumps and Friable Particles (Dry mass)	0.2 %	2% (max)
Bulk Density (Loose)	38 lb/ft^3	55 lb/ft^3 (max)
Density Factor (Specific Gravity, Wetted Surface-dry)	1.364	----
72-Hour Absorption	16.8 %	----
Compressive Strength (Requirement based off of Calculated Equilibrium Density)	4,920	3,120 psi (min)
Splitting Tensile (Requirement based off of Calculated Equilibrium Density)	390	312 psi (min)
Drying Shrinkage	-0.015	-0.070 % (max)
Popouts	No Popouts	No Popouts
Grading	See Section 5.1.2 Below	
Resistance to Freezing and Thawing (Relative Dynamic Modulus, %)	99	----

Test Results

<u>Section 4.1.1 Organic Impurities</u>

Requirement – Lightweight aggregate subjected to the test for organic impurities shall not produce darker color than standard.

Result – The lightweight aggregate did not show any color change.

<u>Section 4.1.2 Staining</u>

Requirement – Lightweight aggregate shall have a stain index of less than sixty.

Result – The lightweight aggregate showed no stain, which indicates an index of 0.

<u>Section 4.1.3 Loss on Ignition</u>

Requirement – Lightweight aggregate shall have a loss of ignition not more than five percent.

Result – The lightweight aggregate had a loss on ignition of 3.173 percent.

Section 5.1.1 Clay Lumps and Friable Particles

Requirement – The amount of clay lumps and friable particles shall not exceed two percent by dry mass.

Results – The lightweight aggregate had 0.2 percent clay lumps and friable aggregate.

Section 5.1.2 Grading

The grading shall conform to the requirements in Table 1 of ASTM C330. The Grading and the required grading are reported in Table 2.

Table 2: Grading & Required Grading

Sieve Size	(Intermediates) % Passing	Required % Passing (3/8" to #8)
½ in	100	100
$^3/_8$ in	90.4	80 - 100
#4	23.6	5 - 40
#8	6.4	0 - 20
#16	3.5	0 - 10
#50	1.3	---
#100	1.0	---
#200	0.7	0 - 10

Section 5.1.4 Bulk Density (Loose)

Requirement – The maximum bulk density (loose) for coarse aggregate is 55 lbs/ft^3.

Result – The lightweight aggregate had an average bulk density (loose) of 38 lb/ft^3.

Section 5.1.6 Specific Gravity & Absorption

The density factor was tested in accordance with ASTM C127 - 15 *Standard Test Method for Density, Relative Density (Specific Gravity) & Absorption of Coarse Aggregate*. The sample was dried to a constant mass and soaked for 72 hours. The specific gravity and absorption is reported in Table 3.

Table 3: Specific Gravity & Absorption

Absorption after 72-hour Soak (percent)	Relative Density (Specific Gravity) (Oven-Dry)	Relative Density (Specific Gravity) (Wetted Surface-Dry)
16.8	1.168	1.364

Concrete mixtures containing the lightweight aggregate were batched in order to make test specimens for compressive strength, splitting tensile, drying shrinkage and resistance to freezing and thawing. The material sources and amount of material used in the concrete mix are reported in Table 4. Fresh properties are reported in Table 5.

Concrete Mix Proportions

Table 4: Mix Proportions

Material	Source	Amount
		(pcy)
Cement	Lehigh, Leeds	564
Fine Aggregate – Natural Sand	Lambert, Wiregrass	1,141
Coarse Aggregate - #57 Stone	Vulcan, Lithonia	535
Lightweight Aggregate – (3/8” to #8)	Trinity – Erwinville, LA	675
Air Entrainment	Vinsol Resin	1. 1.5 oz/yd³
Water Reducer	Type F – High Range	9.7 oz/yd³
Water	Lawrenceville City Water	275
	Total	3,190

Table 5: Fresh Properties

Slump (inches)	3.00
Unit Weight (lb/ft^3)	116.0
Air Content (%)	6.75
Concrete Temperature (°F)	72

The oven-dry density of the concrete mixture was calculated by the mixture quantities, aggregate moisture content, and the volume of the concrete batch. The calculated equilibrium density of 110.6 lb/ft³ was calculated by adding 3 lb/ft³ to the calculated oven-dry density. The calculated equilibrium density is used to determine the specification requirements for the compressive and split tensile strengths.

Section 5.2.1 Compressive Strength and Splitting Tensile Strength

Compressive Strength

Requirement – For a concrete with combinations of normal weight and lightweight aggregates and a calculated equilibrium density of 110.6 lb/ft³, the minimum compressive strength is 3,120 psi. This was calculated by interpolation from the values presented in section 5.2.1 and are reported in Table 6. The specimens tested were 4" x 8" cylinders and the results are reported in Table 7.

Table 6: Compressive & Splitting Tensile Strength Requirements

Calculated Equilibrium Density (lbs/ft³)	Splitting Tensile Strength Requirements (psi)	Compressive Strength Requirements (psi)
115	330	4,000
110	310	3,000

Table 7: Compressive Strength Results

Sample ID	Compressive Strength (psi)
17-1290 -A	5,050
17-1290 -B	5,040
17-1290 -C	4,820
17-1290 -D	4,780
Average	**4,920**

Splitting Tensile

Requirement – For a concrete with combinations of normal weight and lightweight aggregates and a calculated equilibrium density of 110.6 lb/ft³, the minimum splitting tensile strength is 312 psi. The specimens tested were 6" x 12" cylinders and the results are reported in Table 8.

Table 8: Splitting Tensile Strength Result

Sample ID	Splitting Tensile Strength (psi)
17-1290 -1	420
17-1290 -2	320
17-1290 -3	450
17-1290 -4	390
17-1290 -5	380
17-1290 -6	325
17-1290 -7	510
17-1290 -8	315
Average	**390**

<u>Section 5.2.3 Drying Shrinkage</u>

Three length change beams (4” x 4” x 11¼”) were moist cured for seven days. Upon the completion of the 7-day moist curing an initial reading was obtained, which was used as the base length for the drying shrinkage calculations. The samples were then placed in a curing cabinet maintained at 100 ± 2°F with a relative humidity of 32 ± 2% for 28 days.

Requirement – The drying shrinkage of the concrete specimens shall not exceed 0.07% at 28days.

Table 9: Drying Shrinkage at 28 Days

Sample ID	Length Change at 28 Days (%)
17-1290 (1)	-0.014
17-1290 (2)	-0.016
17-1290 (3)	-0.015
Average	**-0.015**

<u>Section 5.2.4 Popouts</u>

Requirement – There shall be no popouts observed after test concrete made with the tested lightweight aggregate is subjected to an autoclave in accordance with ASTM C151-16 *Standard Test Method for Autoclave Expansion of Hydraulic Cement.*

Result – No popouts were observed.

<u>Section 5.2.5 Resistance to Freezing and Thawing</u>

The freeze-thaw samples were tested in accordance with ASTM C666-03 (2008) *Resistance of Concrete to Rapid Freezing and Thawing – Procedure A (freezing and thawing in water)* with the curing modifications listed in ASTM C330.

Results – The average relative dynamic modulus after 300 cycles was 99%.

Results are reported in Table 10.

Table 10– Freeze-Thaw Testing – Cast Concrete Samples (3 beams)

Total Cycles Completed	Fundamental Transverse Frequency, khz			Relative Dynamic Modulus (%)			Weight Change (grams)			Length Change (inches)		
	Beam 1	Beam 2	Beam 3	Beam 1	Beam 2	Beam 3	Beam 1	Beam 2	Beam 3	Beam 1	Beam 2	Beam 3
0	1.875	1.875	1.875	100	100	100	0	0	0	0	0	0
35	1.875	1.875	1.836	100	100	96	0	0	0	0	0	0
70	1.855	1.855	1.836	100	100	96	0	0	0	0	0	0
105	1.855	1.855	1.836	100	100	96	0	0	0	0	0	0
135	1.855	1.855	1.836	100	100	96	0	0	0	0	0	0
165	1.855	1.855	1.836	100	100	96	0	0	0	0	0	0
200	1.855	1.855	1.836	100	100	96	0	0	0	0	0	0
235	1.855	1.855	1.836	100	100	96	0	0	0	0	0	0
268	1.855	1.855	1.836	100	100	96	0	0	0	0	0	0
300	1.855	1.855	1.836	100	100	96	0	0	0	0	0	0
Average Relative Dynamic Modulus					**99**			**0**			**0**	

We appreciate the opportunity to provide our services to you on this project. Should you have any questions or comments regarding this report, please feel free to contact us at your convenience

Sincerely,

Testing, Engineering & Consulting Services, Inc.

Steven Maloof
Project Manager

Shawn P. McCormick
Laboratory Principal

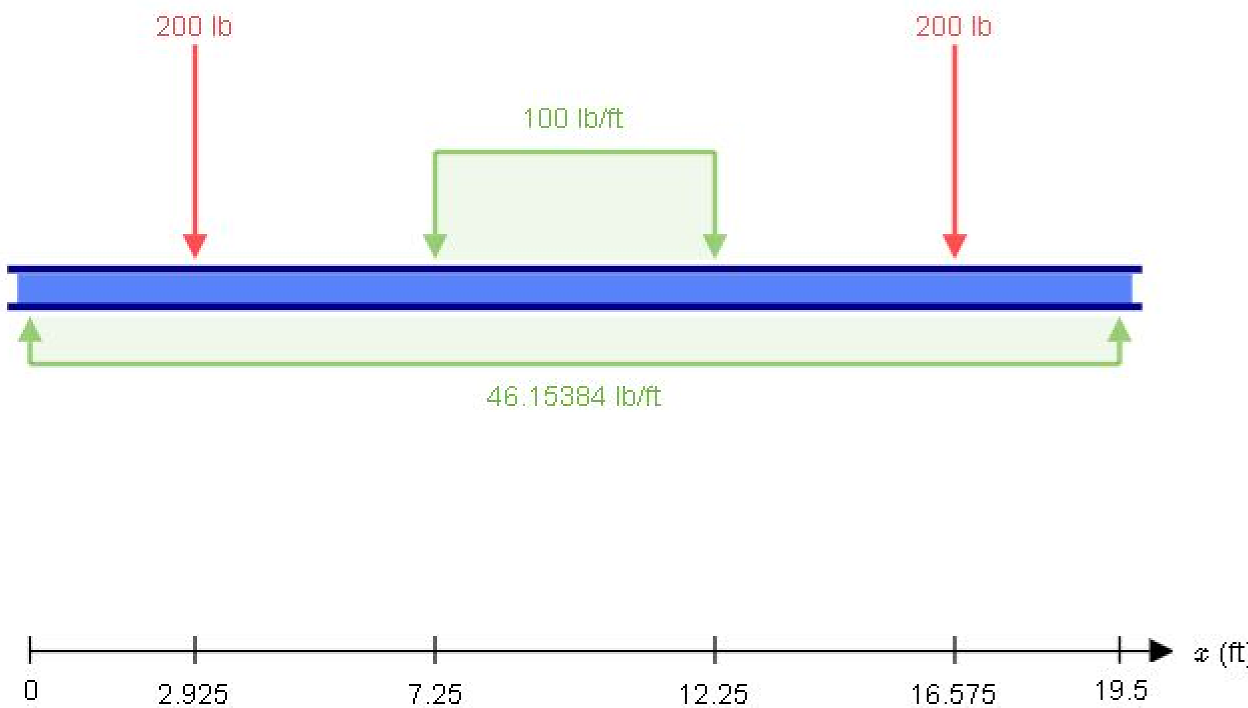
appendix d

structural calculations

I. Cross-Sections Sample Calculation: 100 lb/ft Loaded Canoe with 2 Paddlers

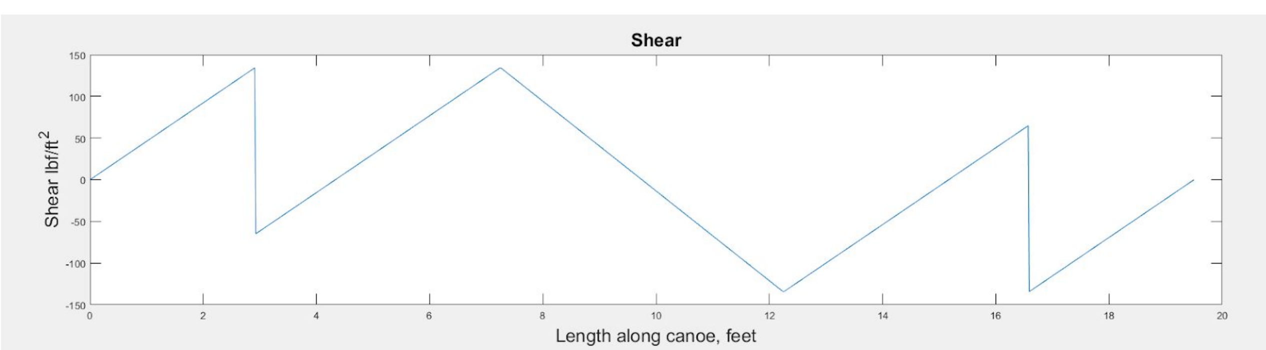
Assumptions:	Predefined Variables:
■ Canoe is treated as simply supported beam with uniformly distributed weight and buoyant force ■ Cross section is evaluated as 3 rectangular sections at right angles ■ No reinforcement is considered ■ Canoe weight is considered to be 200 lbs, factored to 240 lbs with LRFD	■ Canoe weight: 240 lbs ■ Canoe length: 19.5 ft ■ Net force load distribution along canoe: $\frac{100\frac{lb}{ft}\cdot 5\,ft + 2\cdot 200\,lb + 240\,lb}{19.5\,ft} - \frac{240\,lb}{19.5\,ft} = 46.15\ \frac{lb}{ft}$ ■ Paddlers at positions 15% and 85%, 2.925 ft and 16.575 ft

Free Body Diagram:



Singularity Function for Loading Case:

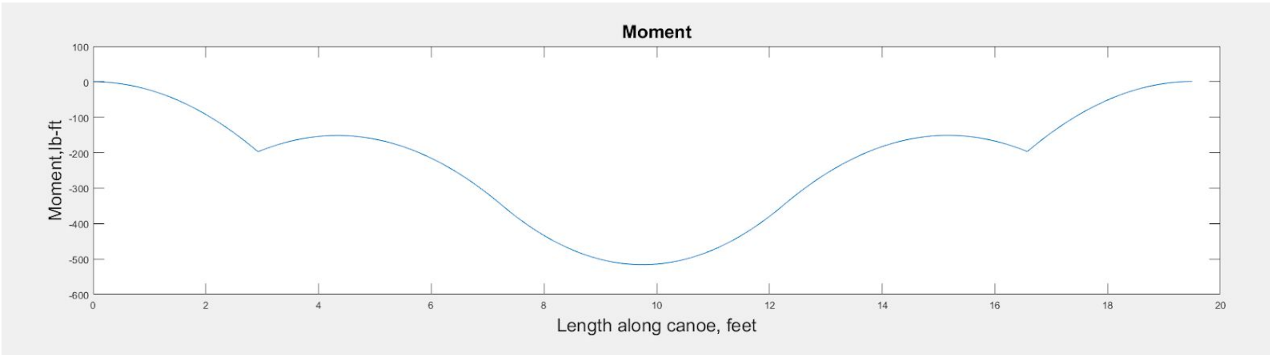
$$V = 46.15 < x >^{1} - 200 < x - 2.925 >^{0} - 100 < x - 7.25 >^{1} + 100 < x - 12.25 >^{1} - 200 < x - 16.575 >^{0}$$



Shear diagram for sample case

Bending Moment Singularity Function Calculation:

$$M = -\int V\,dx = -\left[\frac{46.15}{2} < x >^2 - 200 < x - 2.925 >^1 - 50 < x - 7.25 >^2 + 50 < x - 12.25 >^2 - 200 < x - 16.575 >^1\right]$$



Bending Moment diagram for sample case

Moment of Inertia Calculations:

Hull thickness t_h = 0.7 in.

Gunwale thickness t_g = 0.5 in.

Cross section width w= 24.7 in.

Cross section height h = 14.2 in.

Area base: 16.59 in^2

Area sides: 7.1 in^2

Centroid of Bottom : $y_1 = t_h/2 =$ 0.35 in.

Centroid of Walls: $y_2 = h/2 =$ 7.1 in.

Centroid Axis (Distance from bottom):

$y_c = \Sigma A_i y_i / \Sigma A_i =$ 3.46 in.

Central Axis Moment of Inertia of rectangular segments $= \frac{bh^3}{12}$

$I_{base} =$ 0.7060 in^4

$I_{side} =$ 238.6 in^4

Results:

Maximum Bending Moment:

-516.065 ft-lb, 9.74 ft from bow

Moment of Inertia of Max Moment Cross-Section:

$I = \Sigma(I + A_i d_i)$

= 493.84 in^4

Max Compressive stress σ^-:

My_{top}/I **= 134.6 psi**

Max Tensile stress σ^+ **:**

My_{bottom}/I **= 43.38 psi**

Shear Stress at cross section τ_{max}:

From singularity function:

V, max shear force = 134.30 lbs

A, Cross sectional area =30.79 in^2

$\tau_{max} = \frac{V}{A}$ **= 4.36 psi**

Maximum Bending Moment before concrete cracking (No reinforcement considered):

Concrete Maximum Stresses:

σ^+_{max} = 1470 psi compressive stress

σ^-_{max} = 650 psi tensile stress

Modulus of Rupture: $f_r = 7.5\lambda\sqrt{\sigma^+_{max}}$, $\lambda = 0.75$ for lightweight aggregate concrete

$$f_r = 7.5(0.75)\sqrt{1470\ psi} = 215.66 \text{ psi}$$

$$y_{max} = y_{bottom,\ tensile\ fracture}$$

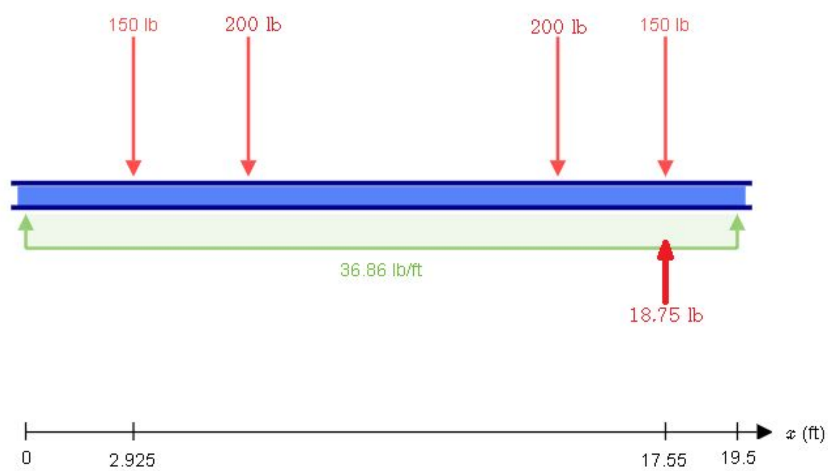
$M_{cracking} = (f_r \cdot I_{Max\ Beam})/(y_{max})$ = **2565.06 lb-ft bending moment**

Maximum Bending Moment before structural failure: Basalt Mesh and ARG reinforcement provide superb tensile strength; total structural failure occurs when maximum compressive strength of concrete is reached, which is unaffected by the reinforcement. $\sigma_{max}^{+} = 1470\ psi$ $M_{ultimate} = (\sigma_{max}^{+} \cdot I_{Max\ Beam})/(y_{max}) =$ **5611.81 ft-lb bending moment**

II. Structural Analysis of Four Person Co-ed Race

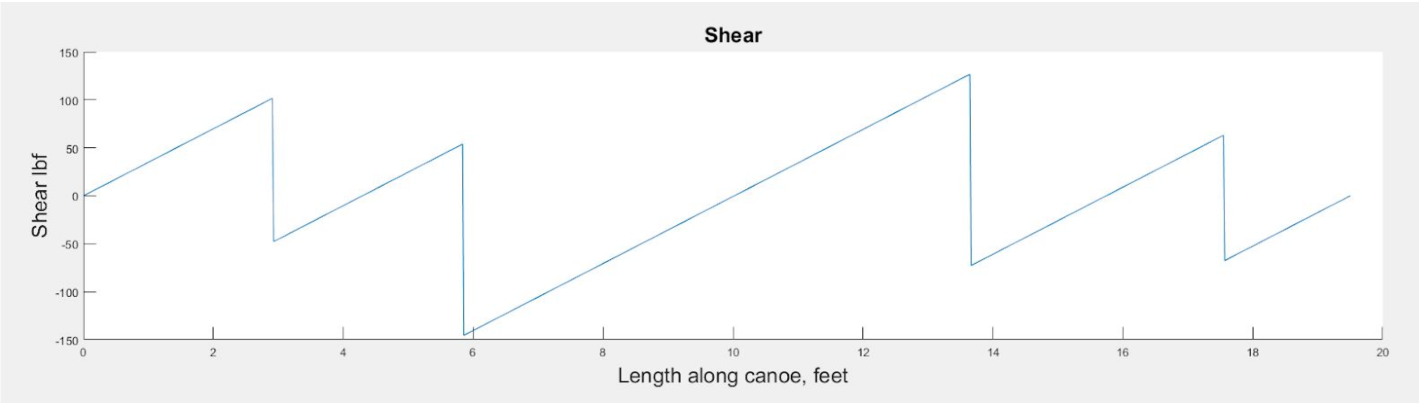
Assumptions:	Predefined Variables:
■ Canoe is treated as simply supported beam with uniformly distributed weight and buoyant force ■ Cross section is evaluated as 3 rectangular sections at right angles ■ No reinforcement is considered ■ Canoe weight is considered to be 200 lbs, factored to 240 lbs with LRFD ■ Additional 18.75 lb buoyant point load at rear paddler for consideration of uneven load distribution	■ Canoe weight: 240 lbs ■ Canoe length: 19.5 ft ■ Net force load distribution along canoe: $\frac{2*150+2\cdot200\ lb+240\ lb}{19.5\ ft} - \frac{240\ lb}{19.5\ ft} = 36.86\ \frac{lb}{ft}$ ■ 150lb Paddlers at positions 15% and 90%, 200lb Paddlers at 30% and 75%

Free Body Diagram:



Singularity Function for Loading Case:

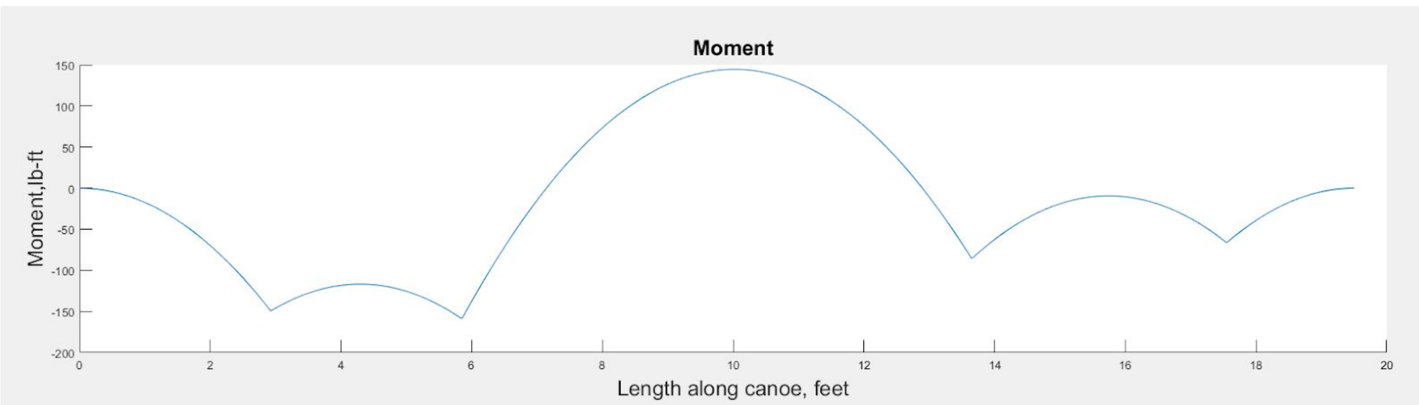
$$V = 36.86 < x >^{1} - 150 < x - 2.925 >^{0} - 150 < x - 17.55 >^{0} - 200 < x - 5.85 >^{0} - 200 < x - 13.65 >^{0} + 18.75 < x - 17.55 >^{0}$$



Shear diagram for Co-ed case

Bending Moment Singularity Function Calculation:

$$M = -\int V\,dx = -[\tfrac{36.86}{2} < x >^{2} - 150 < x - 2.925 >^{1} - 150 < x - 17.55 >^{1} - 200 < x - 5.85 >^{1} - 200 < x - 13.65 >^{1} + 18.75 < x - 17.55 >^{1}]$$



Bending Moment diagram for Co-ed case

Moment of Inertia Calculations:

Hull thickness t_h = 0.7 in.

Gunwale thickness t_g = 0.5 in.

Cross section width w= 20.4 in.

Cross section height h = 14 in.

Area base: 13.58 in^2

Area sides: 7 in^2

Centroid of Bottom : y1 = $t_h/2$ = 0.35 in.

Centroid of Walls: y2 = h/2 = 7 in.

Centroid Axis (Distance from bottom):

$y_c = \Sigma A_i y_i / \Sigma A_i$ = 3.73 in.

Central Axis Moment of Inertia of rectangular segments $= \frac{bh^3}{12}$

I_{base}= 0.5545 in^4

I_{side}= 228.7 in^4

Results:

Maximum Shear:

V=145.42 lbf, 5.86 ft from bow

Moment of Inertia of Max Shear Cross-Section:

$I = \Sigma(I + A_i d_i^2)$

= 458.92 in^4

Moment at Max Shear Cross Section:

M**= -158.1947 ft-lb**

Max Tensile stress σ^-:

My_{top}/I **= 42.52 psi**

Max Compressive stress σ^+ **:**

My_{bottom}/I **= 15.39 psi**

Shear Stress at cross section τ_{max}:

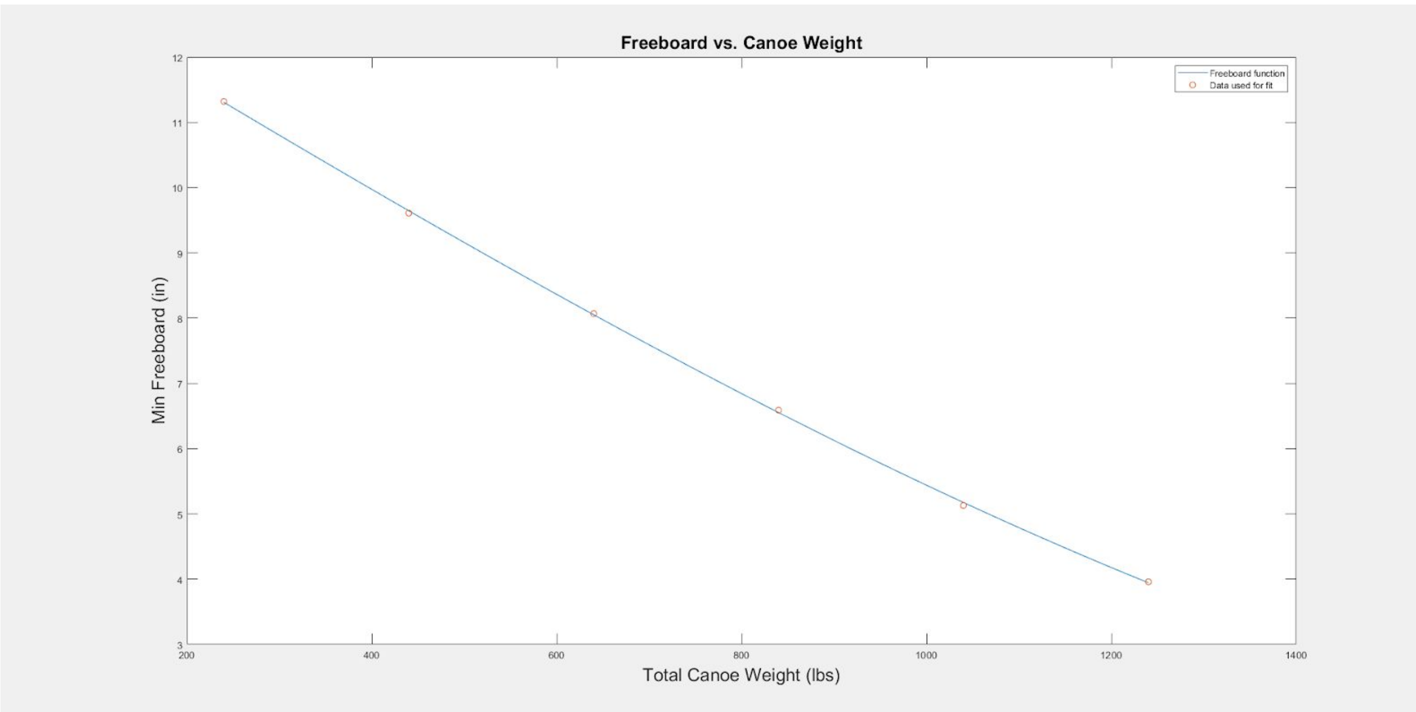
A, Cross sectional area = 27.58 in^2

$\tau_{max} = \frac{V}{A}$ = **5.27 psi**

II. Freeboard Calculations

<u>Assumptions and Method:</u>

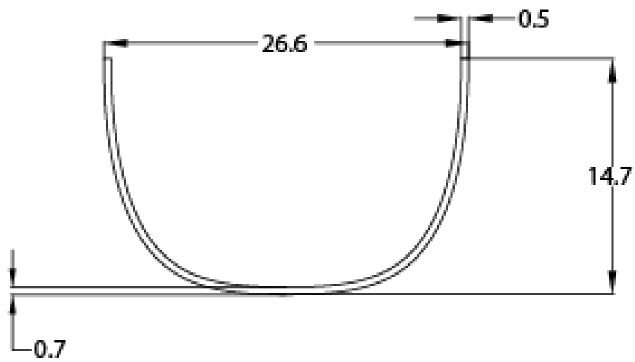
- Canoe weight is 240 lbs
- Freeboard values manually calculated via CAD software values for several load cases between the canoe weight and max load case (240 lbs, 1240 lbs)
- Data is fit to a polynomial curve for freeboard as a function of weight



appendix e

hull/reinforcement & percent open area calculations

I. Hull Thickness Calculations



Variables:

t_g : thickness of canoe gunwale = $0.5\ in.$

t_h : thickness of canoe hull = $0.7\ in.$

t_r : thickness of reinforcement mesh, Basalt and ARG
= $0.05\ in.$, (2 layers of reinforcement)

At Gunwales:

Percent thickness of reinforcement = $\frac{2t_r}{t_g}(100\%) = \frac{2(0.05\ in)}{0.5\ in}(100\%) = 20.0\%$ ($< 50\%$ *maximum*) **Compliant**

At Hull bottom:

Percent thickness of reinforcement = $\frac{2t_r}{t_g}(100\%) = \frac{2(0.05\ in)}{0.7\ in}(100\%) = 14.3\%$ ($< 50\%$ *maximum*) **Compliant**

II. Percent Open Area Calculations

Variables:

d_1 : spacing of reinforcement (center-to-center) along sample length

d_2 : spacing of reinforcement (center-to-center) along sample width

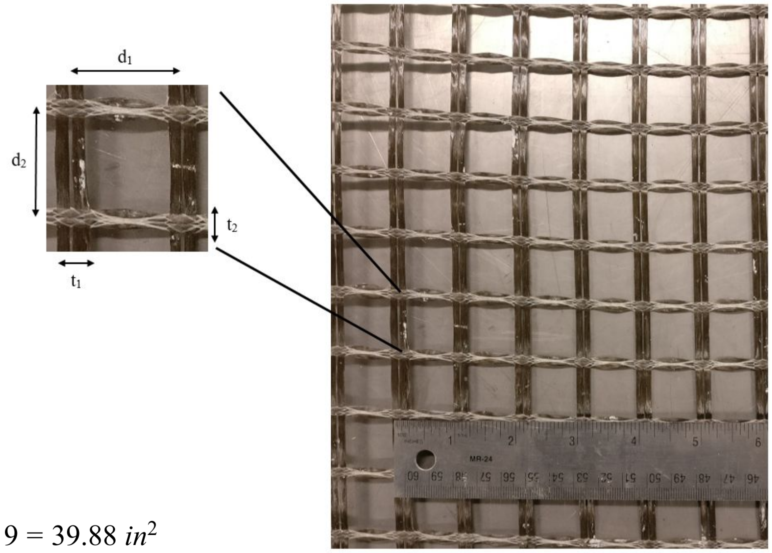
t_1 : thickness of reinforcement along sample length

t_2 : thickness of reinforcement along sample width

n_1 : number of apertures along sample length

n_2 : number of apertures along sample width

Basalt Mesh:
Given 7in x 9in sample



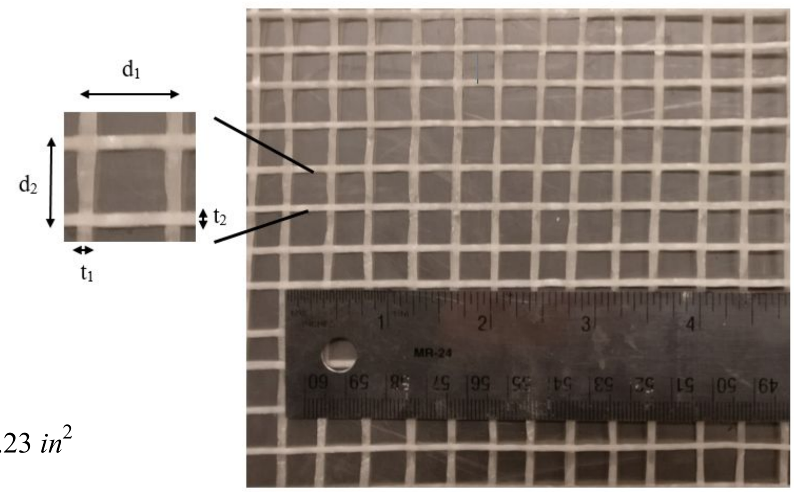
$d_1 = 1.0\ in.$
$d_2 = 1.0\ in.$
$t_1 = 0.25\ in.$
$t_2 = 0.156\ in.$
$n_1 = 7$
$n_2 = 9$

$$Area_{open} = (d_1 - t_1)(d_2 - t_2) \cdot n_1 \cdot n_2$$
$$= (1.0\ in. - 0.25\ in.)(1.0\ in. - 0.156\ in.) \cdot 7 \cdot 9 = 39.88\ in^2$$

Total area = $(7.0\ in.)(9.0\ in.) = 63\ in^2$

POA = $\frac{\sum Area_{open}}{Area_{total}}(100\%) = \frac{39.88\ in^2}{63\ in^2}(100\%) = 63.3\%$ (>40% minimum) **Compliant**

Alkali Resistant Glass (ARG) Mesh:
Given 4.875 in. x 4.5 in. sample



$d_1 = 0.375\ in.$
$d_2 = 0.375\ in.$
$t_1 = 0.0625\ in.$
$t_2 = 0.0625\ in.$
$n_1 = 13$
$n_2 = 12$

$$Area_{open} = (d_1 - t_1)(d_2 - t_2) \cdot n_1 \cdot n_2$$
$$= (0.375\ in. - 0.0625\ in.)^2 \cdot 12 \cdot 13 = 15.23\ in^2$$

Total area = $(4.875\ in.)(4.5\ in.) = 21.94\ in^2$

POA = $\frac{\sum Area_{open}}{Area_{total}}(100\%) = \frac{15.23\ in^2}{21.94\ in^2}(100\%) = 69.4\%$
(>40% minimum) **Compliant**

detailed fee estimate

materials

position	hourly rate	hours
2 project design engineers	$35	36
6 technicians	$25	36

$7,920

hull design & structural

position	hourly rate	hours
2 principle design engineers	$50	28
4 technicians	$25	28

$5,600

graphics

position	hourly rate	hours
2 project design engineers	$35	33
6 technicians	$25	33

$7,260

officer meetings

position	hourly rate	hours
2 project constuction managers	$40	46
design manager	$45	46
quality manager	$35	23
construction superintendent	$40	11
2 principle design engineers	$50	12
4 project design engineers	$35	14
office administrator	$15	11

$10,320

construction

position	hourly rate	hours
construction superintendent	$40	72
6 laborers	$25	72

$13,680

casting day

position	hourly rate	hours
2 project construction managers	$35	6
design manager	$45	6
quality manager	$35	6
28 technicians	$25	6

$5,310

team meetings

position	hourly rate	hours
2 project construction managers	$35	10
design manager	$45	10
20 technicians	$25	10

$620

direct labor

after employee costs and project multiplier

$7,920

detailed fee estimate

mold construction

resource	cost
maker pass	$100
wood, nails, wax, sandpaper, 3D printing	$200
	$300

materials expenses

item	cost/lb	total
styrofoam	$25.00	$67.50
basalt mesh	$1.60	$256.00
fiberglass	$0.12	$7.20
concrete sealers	$0.50	$30.33
consultant - monteiro	$200 /hr	$1,200
		$1,561.03

shipping costs

driving canoe in a tailer to Platteville, WI	2076 mile distance
typical u-haul truck with 10 miles per gallon specification	$2.61 average nation-wide price per gallon
	$541.84

WAN SHI TONG

matieral	classification	weights (lbs)	cost per pound
OPC	cement	69.286	$0.03
Slag	slag	40.736	$0.02
Silica Fume	silica fume	11.641	$0.44
Foamed Glass 2-4		36.313	$0.98
Riverlite 3/8 SSD		257.575	$0.00
13mm Fibers PVA	pva fibers	0.7	$1.05
ADVA 530	superplasticizer	2.25	$8.79
VMAR-3	rheology modifying	2.383	$8.50
ECLIPSE 2500	shrinkage reducer	0.594	$6.16
Water	Non Carbonated	43.525	$0.03

with 25 batches: $2,233.54

Pre-Qualification Form (Page 1 of X)

University of California, Berkeley

(school name)

We acknowledge that we have read the 2021 ASCE Concrete Canoe Competition Request for Proposal and understand the following (*initialed by team captain and ASCE Faculty Advisor*):

The requirements of all teams to qualify as a participant in the Conference and Society-wide Final Competitions as outlined in Section 2.0 and Exhibit 3. TT CPO

The requirements for teams to qualify as a potential Wildcard team including scoring in the top 1/3 of all Annual Reports, submitting a Statement of Interest, and finish within the top 1/2 of our Conference Concrete Canoe Competition (Exhibit 3) TT CPO

The eligibility requirements of registered participants (Section 2.0 and Exhibit 3) TT CPO

The deadline for the submission of *Letter of Intent* and *Pre-Qualification Form* (uploaded to ASCE server) is October 22, 2020. TT CPO

The last day to submit *ASCE Student Chapter Annual Reports* to be eligible for qualifying (so that they may be graded) is February 1, 2021. TT CPO

The last day to submit *Request for Information* (RFI) to the C4 is January 22, 2021. TT CPO

Teams are responsible for all information provided in this *Request for Proposal*, any subsequent RFP addendums, and general questions and answers posted to the ASCE Concrete Canoe Facebook Page, from the date of the release of the information. TT CPO

The submission date of *Technical Proposal* and *Enhanced Focus Area Report* for Conference Competition (uploading of digital copies to ASCE server) is Friday, February 19, 2021. TT CPO

The submission date of *R. John Craig Presentation* for Conference Competition (uploading of presentation to ASCE server) is Friday, February 19, 2021. TT CPO

The submission date of *three (3) Peer Reviews* to the respective teams' folders (uploading of digital copies to ASCE server) is Friday, March 12, 2021. TT CPO

The submission date of *Technical Proposal* and *Enhanced Focus Area Report* for Society-wide Final Competition (uploading of digital copies to ASCE server and mailed hard copies to ASCE Headquarters) is Thursday, May 20, 2021. TT CPO

Tracy Tanusi	10/5/2020	Claudia P. Ostertag	10/8/2020
Team Captain	*(date)*	*ASCE Student Chapter Faculty Advisor*	*(date)*

(signature) *(signature)*

As of the date of issuance of this Request for Proposal, what is the status of your school / university's 2020-21 classroom instruction (in-person, remote, hybrid)? What is anticipated after Thanksgiving break? If in-person or hybrid, do you have access to laboratory space or other facilities outside of classes?

As of the date of issuance of this Request for Proposal, the status of the University of California, Berkeley's classroom instruction is remote. After Thanksgiving break it will continue to be remote. This will further apply towards the spring semester. Our team is focusing on getting on access to the laboratory space on campus, however it is unclear whether it will be allowed by the department.

In 250 words or less, provide a high-level overview of the team's Health & Safety (H&S) Program. If there is currently not one in place, what does the team envision their H&S program will entail? Include a discussion on the impact of COVID-19 on the team's ability to perform work and what plans would be implemented assuming work could be performed.

Our pre-COVID Health and Safety Program was in-person. Before any work on the canoe began, all members were required to take an online health and safety course. The online course discussed general emergency response practices, along with environmental sustainability, general workplace safety, hazardous materials,laboratory safety, safety management, and equipment safety. After passing the online course and receiving a certificate of approval, the team attended an in-person lab training with the lab manager. This training covered the basic principles of where to go and who to contact during an emergency, and it familiarized the team with the layout of the lab, including the location of first aid kits, landline phones, emergency staircases, and fire alarms. Once divisions started, prior to any work being done, the division officers would give overviews of the division-specific safety measures.

Due to COVID-19 and our inability to meet in person, these physical safety measures are no longer relevant. Instead, we are practicing safety by hosting virtual events and meetings enabling us to remain socially distant so as not to spread the virus.

In 150 words or less, provide a high-level overview of the team's current QA/QC Program. If there is currently not one in place, what does the team envision their QA/QC program will entail?

Without an in-person canoe to inspect, this year's QA/QC focuses on interpreting the new rules and ensuring we adapt accordingly. They have read the new guidelines and worked with our project management to devise our virtual submission. They have also been in charge of submitting Requests for Information (RFI's) which given the profound changes this year has been extremely important. Though we are not building a physical canoe, it is as important as ever that the deliverables being worked on by our divisions are in accordance with the new rules and guidelines of the virtual competition.

Has the team reviewed the Department and/or University safety policies regarding material research, material lab testing, construction, or other applicable areas for the project?

Yes

The anticipated canoe name and overall theme is *"The Last Bearbender*," a play on "The Last Airbender" cartoon that was popular over the summer. The theme will include references from the series.

Has this theme been discussed with the team's faculty advisor about potential Trademark of Copyright issues?

Yes

The core project team is made up of <u>15</u> people.

UC Berkeley Concrete Canoe Team

750 Davis Hall
Berkeley, CA, 94720
(415) 589-0477
pm@concretecanoe.berkeley.edu

October 10, 2020

ASCE Student Services
1801 Alexander Bell Drive
Reston, VA, 20191
Attn: ASCE Concrete Canoe Competition Committee

To whom it may concern,

We are UC Berkeley's Concrete Canoe team. We strive to engineer canoes that excel both in the water and in design. In the past we have utilized a myriad of innovative strategies to improve our canoe's mix, construction process, and overall performance. We have implemented everything from 3D printing to pre-fabricated cross section design. We have divided our project into six divisions and have had over 70 members from six different majors. Our canoe competes in the MidPac competition, placing third in the 2019 MidPac Competition.

This year due to COVID-19 and the efforts of our team as well as our school to stay safe, we do not have access to our usual facilities and are following ASCE's guidelines for a virtual competition. In response to our fully online semesters, we have generated a fully online professional development curriculum to supplement our regular meetings, along with regular division meetings for the divisions that can perform online work - Graphics, Hull Design and Structural Analysis, Quality Assurance and Quality Control, and Materials divisions.

Following the guidelines of the virtual competition, we have focused our efforts in two deliverables. In addition to creating a theoretical mix, we have also worked on completing a comprehensive website including a video of our process. Both these elements have been opportunities to teach members valuable skills in these fields.

We look forward to confronting the challenges presented by COVID-19 and maintaining a valuable experience in concrete canoe while remaining safe and healthy.

Sincerely,
UC Berkeley Concrete Canoe Team

Tracy Tanusi
(818) 331-0927
ttanusi@berkeley.edu

Claudia Ostertag, PhD
(510) 642-0184
ostertag@berkeley.edu

RFP Addendum No.1
Correction to Submission Date

4.2.1 Letter of Intent & Pre-Qualification Forms

Teams shall submit a *Letter of Intent* along with their *Pre-Qualification Forms* which acknowledges receipt of the Request for Proposal solicitation and shall provide a synopsis of their understating of the project. The letter must be signed by at least one (1) team captain and ASCE Student Chapter Faculty Advisor. The phone number and email address for both the team captain and faculty advisor shall be provided.

The Pre-Qualification Forms (see ***Exhibit 4***) are required to be completed and signed off by each team including initialing off on each line item and providing signatures from the team's team captain and the ASCE Student Chapter Faculty Advisor. Adobe PDF versions of the *Letter of Intent* and *Pre-Qualification Forms* are to be uploaded to the team's respective folder **no later than 5:00 pm [Eastern] Friday, October 16, 2020.** ***Late submissions and documents missing any of the required signatures, initials, and email addresses will be considered non-responsive and subject to deduction.***

Correction

Pursuant to RFI No. 6, Subject: Conflicting Submission Dates, issued 9/16/20

Adobe PDF versions of the *Letter of Intent* and *Pre-Qualification Forms* are to be uploaded to the team's respective folder **no later than 5:00 pm [Eastern] Thursday, October 22, 2020.**

We acknowledge that we are in receipt of ***Addendum No. 1 – Change to Submission Date*** *to the 2021 ASCE Concrete Canoe Competition Request for Proposal. We also acknowledge that this form shall be submitted under Appendix G – Supporting Documentation (Section 6.4.9.7 of the RFP).*

Tracy Tanusi — 01/04/2021

Team Captain (print name) — *(date)*

(signature)

Professor Claudia Ostertag — 01/07/2021

ASCE Student Chapter Faculty Advisor (print name) — *(date)*

(signature)

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