CALAXY

2020

Cal Concrete Canoe

University of California, Berkeley

University of California, Berkeley
Concrete Canoe: *Calaxy*

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

From: **UC Berkeley Concrete Canoe**

Date: **February 17, 2020**

Re: ***2020 ASCE National Concrete Canoe Competition™ Request for Proposals***

Enclosed please find our *Technical Proposal* for the 2020 Mid-Pacific Conference Concrete Canoe Competition containing the approach to our concrete canoe prototype, *Calaxy*. 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 2020 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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Executive Summary

The universe has always fascinated humankind. From the stars, planets and galactic systems, humankind has been infinitely creative in expressing their curiosity towards the solar system and beyond. They tell tales of the gods and goddesses, they inspire stories of extraterrestrial life and they influence some of our most common expressions about innovation and ambition, such as "reach for the stars" and "the sky's the limit." The stars inspire hope—for space as we know it is infinitely vast with unlimited potential for exploration and discovery.

In the winter of 1995, the director of the Space Telescope Science Institute, Robert Williams, led the Hubble Deep Field Team in a risky experiment. He wanted to point the Hubble Space Telescope at an empty patch of sky to test the limits of what the telescope could detect. At that time, the telescope had a negative public image, so Williams' colleagues protested that his mission would be a waste of time and prove to be even more detrimental to the telescope's public relations. Despite their doubts, Williams was determined and proceeded to spend 100 hours over a 10 day period pointing the telescope at "nothing." Early the following year, the photographs were processed and released to the public (Figure 1). The seemingly empty space turned out to be filled with over 3,000 galaxies (National Geographic).

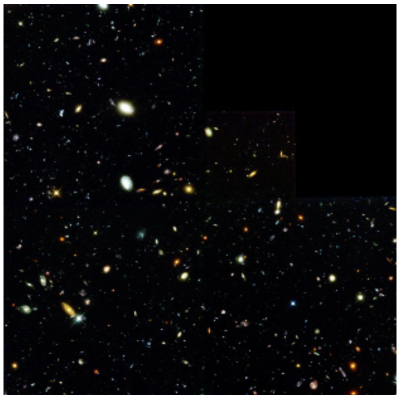

Figure 1: Hubble Deep Field image

During that same winter, UC Berkeley's Concrete Canoe team was working on their canoe, *NautiCal*. The following summer of 1996, the team brought *NautiCal* to the national competition held at the University of Wisconsin–Madison and returned home with the 3rd place award. Inspired by Williams's dedication to discovery and willingness to take calculated risks, this year's team set out to build its *Calaxy* prototype and develop new procedures and designs based on literature and rigorous testing. Ultimately, from 32 years of competing in the National Concrete Canoe Competition, with 21 total Nationals qualifications, 5 championships, and 15 Top-5 finishes, UC Berkeley's team aims to return to Madison, Wisconsin once again and be awarded a contract to provide the standard canoe design for future ASCE competitions.

The UC Berkeley Concrete Canoe team is the best candidate to be awarded a contract to provide the standard canoe design for future ASCE competitions. Calaxy features a sustainable and innovative design that minimizes manufacturing waste and maximizes complete resource usage. With a special focus on constructability and ease of quality assurance and quality control, the team's prototype design produces repeatable 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.

Table 1: ***Calaxy*** **Specifications**

Name	*Calaxy*
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	

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 straightline speed and maneuverability for ideal race performance. *Calaxy*'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 (ARG) scrim, supplemented by polyvinyl alcohol (PVA) fibers in the concrete mix.

Calaxy'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 Williams explored the night sky. Further like Williams, they took the calculated risk of drastically changing the structural mix in order to remove expanded polystyrene (EPS), which had previously composed half the volume of the structural mix. Such a monumental task was daunting. Even so, the endlessly innovative team pushed through by creating new optimization methods 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 succeed in removing EPS and replacing it with sustainable materials, such as recycled rubber chips. With the newfound optimization techniques, the team further improved upon the mix. The structural mix APOLLO produces a medium-weight sturdy canoe that can weather extended use while also being light enough to effectively command. The patch mix ORION generates a tough and smooth finish that is easy to sand, but hard to crack. The graphics mix ARTEMIS further boasts easy application and brilliant, clean colors. All mixes feature exceptional workability, which helps ensure the quality and structural integrity of the canoe.

Table 2: Material Properties

Mix	Apollo (Structural)	Orion (Patch)	Artemis* (Finishing)
Plastic Unit Weight (pcf)	71.4	81.2	92.4
Oven-Dried Unit Weight (pcf)	61	70	84
28-Day Compressive Strength (psi)	1450	3640	4730
28-day Tensile Strength (psi)	290	1550	2010
28-Day Composite Flexural Strength (psi)	290	770	910
Slump (in.)	1/2	5	25
Air Content (%)	1.5	0.93	0.71
* Anticpated properties			

Calaxy was built using a female mold which significantly decreases the amount of concrete wasted during the casting process (*Bearneath the Sea*). The mold construction process has also been tailor made for easy manufacturing. All parts of the mold are precut and labelled for quick assembly. Specialized skill was only necessary for the development of the design files; assembly could be facilitated by new members with basic training. Furthermore, the interlocking structure of the mold allows it to be put together with incredibly precise tolerance and minimal on-site layout work. This structure is easy to check for quality, as it automatically guarantees the accurate location and plumbness of the pieces. These testaments to reliability are highlighted by the time saved in the construction process (Table 3). In terms of sustainability, *Calaxy* excels with its compostable wooden mold, coated with an eco-friendly sealer and biodegradable demolding agent. Additionally, it features many compact-sized pieces that can be cut from scrap wood.

Table 3: Schedule Variances

Milestone	Variance Between Baseline and Reality (Days)	Reason for variance
Canoe Formwork Completion	-10	Prefabrication of formwork pieces
Casting Canoe	-56	Early casting before winter break
Sanding Completion	-7	Accelerated casting allowed more time to sand
Graphics Completion	-2	Shifted all other division members to apply graphics

From a project management standpoint, the design choices made by the team facilitated flexible scheduling, which allowed for additional time savings. Since much of the work could be done with only basic training, the project management team was able to easily shift the workforce between tasks to account for variations in workload. The project managers paid special attention to accurately documenting work hours using the When I Work® software. By analyzing this data and taking into account officer reports on productivity, inefficiencies were identified and mitigated.

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

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 our constituent institutions and students.

Officers

President: Amber Chau
Joint Fundraising Committee Chair: Parson Galicia
Vice President: Amanda Lee
Chair of Staff and Secretary: Sarah Chen
Faculty Advisor: Nick Sitar
Practicioner Advisor: Madeline Ziser

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242 Total number of chapter members

125 Number of members with Junior and Senior status

10 Total number of associated student organizations

88 Total number of ASCE National-Society members

78% Percent of eligible Juniors and Seniors that are members

8 Number of competition teams

Core Team Members

Katrina Yap

Angel Bravo

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

Tracy Tanusi

Jr. Project Manager
Assisted project managers and worked with division officers to ensure deadlines were consistently met

Sonia Martin

QA/QC
Oversaw project progression to guarantee quality, improve efficiency, and minimize delays

Jiu Chang

Webmaster
Built and maintained website for online presence

Shaan Jagani

Hull Design and Structural Analysis
Analyzed past designs and developed new, optimized hull design in addition to analyzing critical loading cases and resulting material requirements

Uma Krishnaswamy

Treasurer
Responsible for fund-raising, budget-allocation and reimbursement

Geraldine Fabro

Social Media
Publicized events and helped with community engagement/awareness

Jason Park

Zachary Wu

Graphics
Designed graphical elements of canoe, stands, product display, and paper

Matthew Michalek

Karen Lee

Materials
Developed and tested sustainable, compliant concrete mixes

Marcus D'Avignon

Austin Chen

Construction
Directed construction of canoe mold, casting, sanding and cross-section

Paddling
Oversaw paddler training sessions and instructed new paddlers

Brandon Wong

John Cadiz

Social Events
Recruited new members and planned social events to boost morale during year

Organization Chart

Quality Assurance and Quality Control

- Katrina Yap (Sr & Team Captain)
- Tracy Tanusi (So & Team Captain)
- Sonia Martin (Jr & QA/QC Officer)
- Angel Bravo (Sr)
- John Cadiz (Jr)
- Austin Chen (So)
- Marcus D'Avignon (So)
- Shaan Jagani (So)
- Uma Krishnaswamy (So)
- Brandon Wong (So)
- Zachary Wu (So)

Graphics

- Jason Park (So & Officer)
- Zachary Wu (So & Officer)
- Russo Hernandez (Fr)
- Emily Ma (So)
- Ingrid Shan (Fr)
- Ethan Chen (So)
- Tracy Tanusi (So)
- Andrew Ting (Fr)
- Emily Zhao (Fr)

Construction

- Marcus D'Avignon (So & Officer)
- Brooke Chang (So)
- Amber Chau (Sr)
- Maggie Chen (Sr)
- Melody Chen (Fr)
- Emma Drake (Fr)
- Desmond Fung (Jr)
- Cindy Ke (Jr)
- Jessica Lee (Fr)
- Oswaldo Pastor (Fr)
- Aaron Soll (Fr)
- Tracy Tanusi (So)
- Brandon Wong (So)
- Katrina Yap (Sr)
- Alan Zhu (Fr)

Hull Design and Structural Analysis

- Shaan Jagani (So & Officer)
- Jeffrey Cheng (So)
- Kevin Cheng (Fr)
- Daniel Gonzalez (Fr)
- Cindy Ke (Jr)
- Emily Ma (So)
- Yusaku Nakano (Fr)
- Oswaldo Pastor (Fr)
- Aaron Soll (Fr)
- Jennifer Terada (Fr)
- Eric Wang (Sr)

Materials

- Matthew Michalek (So & Officer)
- Karen Lee (So & Officer)
- John Cadiz (Jr)
- Brooke Chang (So)
- Ben Clifner (Fr)
- Julian Falagan (Fr)
- James Holcombe (Fr)
- Thomas Le (Fr)
- Hana Meroth (Fr)
- William Lin (Fr)
- Andrea Pelayo (Sr)
- Emmanuel Rodriguez-Marquez (So)
- Ellis Spickermann (So)
- Emily Zhao (Fr)

Paddling

- Austin Chen (So & Officer)
- Amber Chau (Sr)
- Jessica Lee (Fr)
- William Lin (Fr)
- Ethan Chen (So)
- Tracy Tanusi (So)
- Eric Wang (Sr)
- Edward Yam (Jr)
- Katrina Yap (Sr)
- Emily Zhao (Fr)
- Alan Zhu (Fr)

Technical Approach to the Overall Project

Hull Design

Calaxy's primary hull design principle revolves 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 ensures that *Calaxy* overcomes previous design hurdles and continues UC Berkeley Concrete Canoe's legacy of improvement and innovation.

Table 4: Hull Characteristics		
	Bearneath the Sea (2019)	**Calaxy (2020)**
Max Depth (in.)	16.0	14.8
Length to Beam Ratio	9.4	8.8
Bow and Stern Angles (from the vertical)	35° and 30°	35° and 30°
Bow and Stern Rockers (in.)	2.0 and 4.0	2.9 and 4.7
Minimum Hull Thickness (in.)	0.50	0.50
Average Hull Thickness (in.)	0.60	0.60

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. *Calaxy* 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 would no longer push into the secondary stability regime of the canoe. The reduction of over 1.2" of wall height from *Bearneath the Sea* makes *Calaxy* one of the shallowest canoes the team has produced. This allows for weight reduction of the canoe and subsequently greater straightline speed, along with increased maneuverability. Furthermore, a heavy rocker was introduced for both the bow and stern to reduce the wetted area of the canoe. Given the competition's focus on slalom performance, the associated loss of tracking ability with an increased rocker was deemed viable.

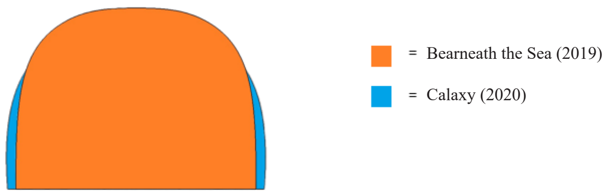


Figure 2. Differences in hull shape between 2019 and 2020

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 and 30 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 is critical in maintaining sufficient turning ability in *Calaxy*.

A model for *Calaxy* 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, *Calaxy*'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 *Calaxy*.

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 weights of the paddlers and canoe. The initial values of 125 and 167 lbs for female and male paddlers, respectively, were multiplied by 1.6 to reach the actionable values of 200 and 267 lbs, respectively. Given the Material Division's estimate of 61.8 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.

Five loading cases for the canoe were analyzed: the male and female races, with each paddler positioned at 15% and 85% of the length of the canoe, the co-ed race, with male paddlers at 15% and 85%, female at 30% and 70%, the transport case, with 20 team members carrying the canoe, and the display case, with supports positioned 3 ft from either end of the canoe.

The maximum bending moment experienced under all conditions was during the male race, with a moment of 520.67 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 are linearly distributed along the height of the cross section. Therefore, the maximum compressive stress was 20.51 psi at the gunwale and the maximum tensile stress was 34.97 psi at the keel.

Shear stress along the sides of the canoe was modeled via analysis of the canoe walls as cantilever beams experiencing pressure from the weight of water under a loading case where the canoe was submerged to the gunwale. This produced a maximum value of 13.5 psi. Deflection under this condition was determined to be negligible.

Given a similar reinforcement scheme and calculated stresses as last year's canoe, the previous safety factor of 4 was deemed adequate for *Calaxy* 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) scrim at the bow and stern. Multiple layers provide adequate tensile reinforcement while maintaining compliant Percent Open Area and construction feasibility.

Development and Testing

To explore the farthest reaches of the *Calaxy*, a vessel's core materials must be lighter, stronger, and more sustainable than its predecessors. This challenge to become the standard, along with the new aggregate ruling, presented a hefty task. Because of this, the Materials Division focused on innovation through ideas not seen or attempted by the team in years 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 in last year's canoe, *Bearneath the Sea*, was used as the baseline for this year's mix. One of key alterations this year was the removal of expanded polystyrene (EPS) (ASTM C578) from the mix. The team agreed that the inclusion of EPS into any mix would be environmentally detrimental, as its industrial byproducts pollute ecosystems, despite it being a lighter alternative to other aggregates. Keeping the concrete lighter than water without EPS proved to be one of the greatest design challenges for the Materials Division.

In previous years, the team included aggregates without consideration for gradation or optimal grading, but this year the officers developed a more complex gradation to maximize aggregate volume, thereby decreasing the cement paste necessary to fill gaps.
However, manually creating optimal gradations that fit curves such as the Fuller Curve or Andreasen & Andersen Curve through trial and error is inefficient. In response, a MATLAB® program was developed to optimize the grading. The two function inputs were the optimal weight percent of sieve sizes and the percent

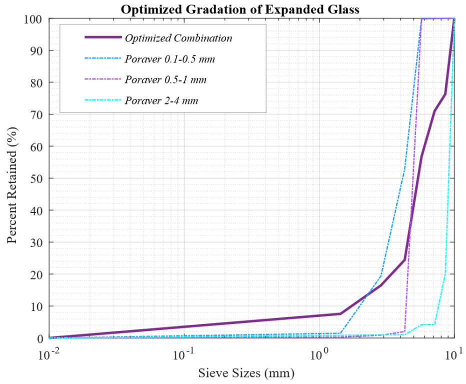


Figure 3. Optimized gradation of expanded glass as calculated by MATLAB program

retained of all aggregates for the given sieve sizes. Through least squares regression, the function was used to approximate the weight percent of each aggregate, which could then be converted to volume percent. These optimal percent values best fit the Andersen & Andreasen Curve given the aggregates in the mix.

Once the MATLAB® program was written, the team chose a set of aggregates and filler to best replace the EPS. The first tests included a large range of expanded glass Poraver® (ASTM D1483) and K1 (SG = 0.15) Series glass microbubbles (ASTM C1774) along with Utelite expanded shale (ASTM C330). Over a month and a half timeframe, the team rigorously phased out the EPS (SG = .03) by slowly decreasing the percent volume in increments of 5-10%. While one of the challenges faced in this period was a decrease in strength, within a month the team had created a mix that met the team's lower bound of 800 psi compressive strength without EPS.

This new mix definitively proved that the team could make mixes which are lighter than water without EPS, a concept not achieved in several years by UC Berkeley. The next task was purchasing the remaining materials, specifically S22 microbubbles (ASTM D281-84), for the finishing mix. The smaller-sized S22 Series (SG=0.22) microbubbles contained in the S22 Series entirely pass the No. 200 sieve. For the K1, there was no reliable cutoff size, as the minimum and maximum sizes straddled the No. 200 sieve size. Therefore, buying the S22 Series ensured that all microbubbles would go into the filler category. This made the canoe lighter without having to either sieve out large parts of the filler or making unreliable calculations on how many microbubbles specifically passed through in every mix.

In order to fulfill the requirement of 30% of aggregate being anything but expanded glass bubbles or cenospheres, the team decided that a proper solution was to supplement the 25% lightweight structural aggregate concept from previous years rulesets with 5% rubber chips (SG = 1.04) (ASTM F3012). A literature review on rubber chips showed that 5% was the highest amount that did not drastically decrease strength while also maximizing the usage of a lower density and environmentally-friendly alternative (Eldin). These recycled rubber chips come from used tires from the automobile industry, which has not found a proper method to recycle this rubber. The addition of rubber chips into the concrete mix effectively provides a solution for used tires while also beneficially impacting the lightweight structural base mix by decreasing the density and weight of the canoe.

As the team continued to innovate, the mix strength progressed. Initially, the overall baseline mix had an average 28-day strength of 1170 psi. The new mixes faced a serious dilemma in the large amount of segregation that occurred due to varying material densities over the 7-day curing time. When the test samples were taken out of their reusable plastic cylinder molds, they immediately fell apart. However, this problem was solved by the addition of the viscosity-modifying admixture VMAR-3 (ASTM C494). Once the VMAR-3 was added to the next iteration, one batch still fell apart, but the other batch did not. While the strength of this new mix was lower, with an average value of 870 psi, progress was being made. To compensate for the segregation problems still at hand, the next iteration included more VMAR-3, as well as a modified gradation mix in order to be a more optimized fit to the Andersen & Andreasen curve. After 7 days, this mix had a strength that was slightly lower than the baseline mix. By the next week the mix had achieved 7-day strengths of 1470 psi and 28-day strengths of 1700 psi max. However, this mix had some downfalls, which is why it ended up not being the final base mix. The fresh mix dried out very quickly and had trouble sticking to surfaces, which made it difficult to work with while molding the canoe by hand. The next mix intended to increase adhesion by adding more water and decreasing the use of aggregate. Eventually, this method was successful, and came to be an effective mix in all design specifications with a 7-day strength of 1250 psi and a 28-day strength of 1450 psi. However, the team wanted to continue to innovate. The final mix that was created included the addition of DAREX AEA (air entraining admixture) (ASTM C260). This mix was very light and stuck to almost any surface; however, it had a very low strength compared with the others, averaging only about 1170 at 14 days. In the end, the prior mix, with a 28-day strength of 1450 psi, good adhesion, and low density, was chosen as the final base mix: APOLLO.

Figure 4: Options to choose between during mix design

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.

Calaxy's patch mix, RION, was inspired by the work of older iterations of the base mix. One reason for this was that the smooth finish and adhesive properties from the base mix are desirable patch mix properties. During the early stages of testing, base mixes were grainy, compact, and very adhesive. These optimal properties allowed the new patch mix to stick well to the base mix and other areas that were missing concrete. Additionally, the patch mix was stronger than the base mix, which decreased the chance of new crack propagation. It also was easier to sand, as the grains jutting out on the surface produced a sandable surface with a smooth finish below.

However, testing after the initial result showed that the mix was too flaky. As a result, although the canoe could be sanded easily, there was no harder concrete below the surface and after enough sanding, and the entire layer of concrete could be sanded off. The division adapted the mix by adding more water. This improved the problem of flakiness; however the adhesiveness decreased and the concrete mix was no longer able to stick to walls. The third iteration proved to be the first patch mix with the desired properties. For the third iteration, more OPC (ASTM C150) and slag (ASTM C989) were added in order to increase the cement paste within the mix. This increased the adhesiveness such that the patch mix could stick to walls.

The final mix applied to *Calaxy*, the graphics mix, ARTEMIS, was inspired by the team's 2016 canoe, *RadiCal*. This decision was made in part because of the sprayability of the *RadiCal*'s graphics mix that was crafted in order to create a "tye-dye" aesthetic. The feasibility of this mix, however, relied heavily on the use of styrene-butadiene (SBR) latex as an admixture, so the recent ban on latex pushed the Materials Division to innovate towards alternatives that would increase workability and slump to almost liquid proportions. This was solved with an increase to maximum dosage of both a high-range (ADVA) and medium-range (ZYLA) water reducer. This provided a smooth and liquid mix able to effectively hold pigment and adhere to a surface cleanly. The concrete mix needed to be as bright as possible, so a mixture of white Portland cement along with slag and vitrified calcium alumino-silicate (VCAS) included as supplementary cementitious materials was proposed. However, as the VCAS was not adequately tested to show a quantifiable difference—the concept was then left for future tests and innovations. Even so, the graphics mix, along with the patch and structural were able to surpass the construction and hull design teams specifications, allowing them to focus on their own advances and goals.

Construction

Future tests and innovations inspired the Construction Division this year, as the division's goal was to streamline and further improve upon the techniques pioneered by last year's team, *Bearneath the Sea*. The team opted again for a female mold due to its ease of construction and use. The division's history of emphasizing environmental sustainability continued to play a prominent role in *Calaxy*'s construction practices. The division chose 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 was collected from local scrap sources to further minimize the mold's environmental impact; for example, donations from McLeod Design, a local contractor, provided a large supply of reusable wood. The remaining cross-sections were constructed from ½"-thick oriented strand board due to its multidirectional strength and resistance to splitting. ⅛"-thick birch plywood was used for interior paneling for its flexibility and ease of use.

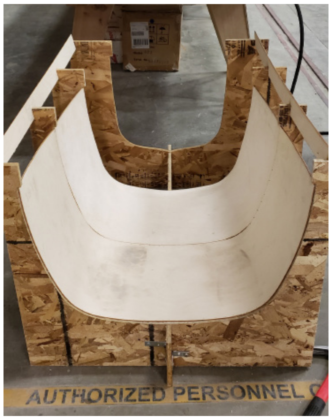


Figure 5: Mockup completed using plywood panels

Before working on the full canoe mold, two full-scale mockups were constructed in order to test techniques, troubleshoot potential problems, and train new members. The first mockup featured two sections, one of which was covered with ½”-wide mahogany strips, while the second was paneled with ⅛”-thick birch. The second mockup was completely paneled and filled with an early version of the concrete structural mix to test its adhesion, while later providing a finished material to test various sanding techniques. Members were versed in lab safety and were given the chance to practice using the tools required for the final build.

Similar to the year prior, an interlocking system of U-shaped cross-sections inserted into a central spine formed the backbone of the mold (Figure 6). 22 cross-sections were inserted into the 3-section spine at 10” intervals. An extra ⅛” of tolerance was given to the spine slots to allow the cross-sections to fit with ease. The cross-sections were designed in SOLIDWORKS® and then exported to AutoDesk® Fusion 360™ software where they were prepared for Computer Numerical Control (CNC) milling. Parts were then milled out of ½”-thick wood from donated scrap. L-brackets were inserted at intersections between the cross-sections and spine to restrict rotational movement. Plywood spacers made of ¼”-thick birch were temporarily inserted at the top of the cross-sections to maintain even spacing for paneling.

Figure 6: Interlocking skeleton with spacers being used during panel installation

Panels to line the mold were designed in SOLIDWORKS® and formatted in Adobe™ Illustrator®. These panels were laser-cut from ⅛”-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 were designed with living hinges, a series of perforations enhancing flexibility, to precisely fit the contours and create a pointed stern keel (Figure 7). Panels were also cut to be ¼” shorter than the designed cross section to allow room for expansion and proper fitment. Nail guns were used to secure the panels to the cross-sections at ½” intervals. Unlike wood glue, the nails enabled the panel to be instantly fastened to the cross-section despite resistance from the curved contours of the hull. The nails could also be easily removed upon demolding to enable the wood to be composted. To prevent horizontal bowing between cross-sections, laminated strips of ½”-wide plywood were inserted perpendicularly for added rigidity (Figure 8).

Figure 7: Panels with living hinges extending from the chine to the bottom of the canoe

Figure 8: Installed braces to prevent bulging in panels

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

The team lined the top of the mold with ½”-wide plywood strips to form the top edge for the gunwales of the canoe. Two strips were 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 were secured to the cross-sections with nails.

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

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

After casting, the canoe was enclosed in a polyvinyl chloride (PVC) frame which was then covered in tarps to maintain a controlled curing environment. Moisture from four humidifiers maintained constant humidity during the 44-day curing period over the team's winter break. Measures were taken to eliminate collection of water, such as sloping the roof of the enclosure so water could drain down one side. The interior was covered with burlap to trap moisture on the concrete itself. The outside of the canoe was draped with plastic sheets, and the humidifiers were set on sloped surfaces so as to prevent water collection in the canoe. The canoe was then set to cure for the entirety of winter break.

Upon returning, the curing chamber was disassembled and replaced with a larger enclosure for sanding. Sanding consisted 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 were all equipped with gloves, N-95 masks, and safety goggles. Laser scans that had been taken before sanding were used to locate thicker areas that required machine sanding. This enabled the team to more strategically focus on what sections of the canoe needed more sanding. The bow and stern were then filled with styrofoam and covered in concrete to create bulkheads.

Afterwards, the canoe will be demolded and sanding on the outside will begin. Demolding will be easier with the female mold, as it can be set on the ground and removed section by section. The canoe will then be flipped over and set back on the work table for exterior sanding. Once initial sanding is complete, gaps will be filled in with patch mix and resanded. Dyed graphics mix will then be applied over vinyl stencils. To polish, the team plans to use a handheld rotary sander with a buffing fitting. To finish, the entire canoe will be waterproofed to ensure maximum seaworthiness and preserve the vividness of the graphics.

Ultimately, the innovations made within the year serve as a testament to the hard work and resilience of the team behind *Calaxy*. An improved hull design focusing on creating a smaller turning radius and a lightweight reinforcement scheme set the canoe up for success on race day. The team designed lightweight structural concrete mixes without EPS and created algorithms and programs optimizing the design process and saving labor hours and material resources. They improved on past techniques as well as pioneered new sanding and polishing strategies that decreased environmental impact, thus improving efficiency without compromising the factors that have made past canoes successful. The team has finished a true concrete racing canoe and has just begun to standardize the quintessence of a concrete canoe.

Approach to Scope, Schedule, and Fee

This year, UC Berkeley's team of 48 people designed and built *Calaxy*, the concrete canoe prototype. To implement this, the team's project management scheme focused on the optimization of manpower usage and investment in thorough training of the large proportion of new members. Through the implementation of these lean construction practices, the *Calaxy* prototype surpassed its goals of quality, innovation, and sustainability.

To ensure that sufficient time was dedicated to all critical activities, the project management team created a schedule that detailed the project timeline. 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 have historically caused delays, activities that have inherent risk or uncertainty, and other activities on the critical path. For example, tasks involving material procurement handled by third parties are subject to possible unforeseen delays during order processing and delivery. Since these kinds of delays cannot be controlled by the team, they pose a considerable amount of risk to the critical path activities. To counteract this, free float was added to the duration of these activities.

In addition, the research portion of the mix design process also 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. In order to mitigate this, a more efficient branched research structure was developed that allowed for the simultaneous development of different potential mixes (Figure 9). This was made possible by analyzing the available manpower and redirecting additional people to help with labor-intensive subtasks.

The optimization of manpower usage, demonstrated in the example above, was facilitated by the introduction of the When I Work® employee scheduling software (Figure 10). All team members were required to create accounts and clock in and out when they worked on the project, as well as document the role they were performing during each shift. 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. The canoe was casted during the fall semester of the school year and cured over winter break, allowing more float time to be allocated to subsequent tasks, such as sanding and application of graphics.

This year's team had the benefit of a large labor force due to the successful recruitment of many new members. To ensure they produced quality work during this year and in future years, the officers invested time to thoroughly train the large proportion of new members. This was reflected by an increase in labor hours spent at the beginning of the project. On the other hand, this large trained force allowed for more flexibility in the project schedule, as labor was 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. This weekly meeting 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.

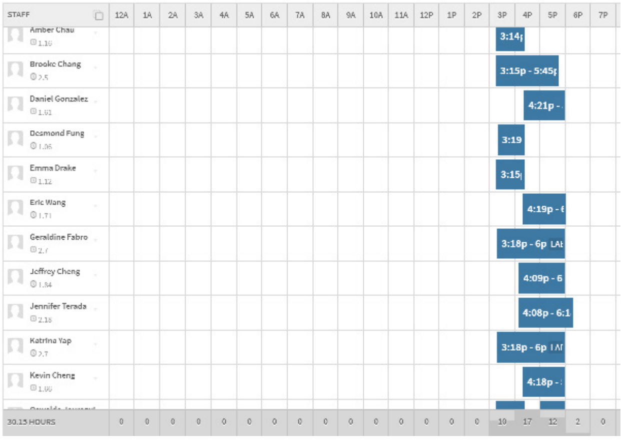


Figure 10: Sample of recorded hours from When I Work®

From the team's funding, a budget of $2600 was allocated to concrete material costs, an increase of $1000 from last year's concrete materials costs. Since this year's structural mix uses strikingly different materials than last year's mix, the team had to invest in many new aggregates, which is reflected by the increased costs. A budget of $600 was allocated to construction materials and finishing tools, a decrease of $250 from last 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 following page details the calculated costs for the production of this year's canoe prototype specifically based on standardized costs provided in the *Request for Proposals*.

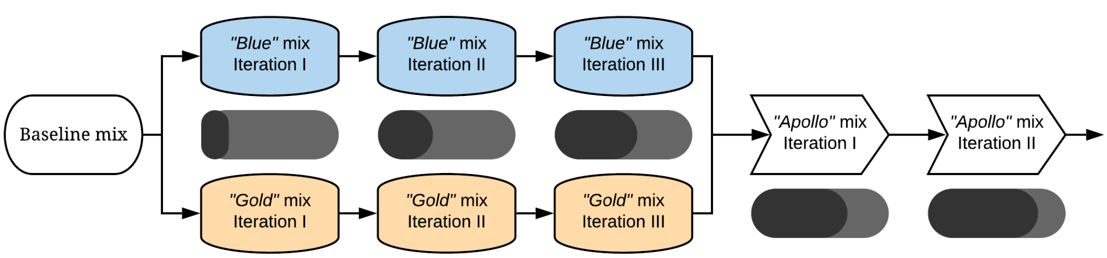


Figure 9: Branching structure used to work on mix design research in parallel

Itemized Fee Summary

Hull Design and Structural Analysis

Position	Hourly Rate	Hours
Project Design Engineer	$50	32
6 Laborers	$25	32

$6,400

Mold and Canoe Construction

Position	Hourly Rate	Hours
Construction Superintendent	$40	72
6 Laborers	$25	72

$13,680

Mixture Design Development

Position	Hourly Rate	Hours
Profject Design Engineer	$35	72
6 Technicians	$25	72

$15,840

Officer Meetings

Position	Hourly Rate	Hours
2 Project Construction Managers	$40	28
Design Manager	$45	28
Quality Manger	$35	28
Construction Superintendent	$40	28
4 Project Design Engineers	$35	28
Principle Design Engineer	$50	28
3 Office Admins	$15	28

$10,560

Proposal, Presentation, and Display

Position	Hourly Rate	Hours
Project Design Engineer	$35	48
6 Technicians	$25	48

$10,560

Casting Day

Position	Hourly Rate	Hours
3 Project Construction Managers	$40	6
2 Project Design Engineers	$35	6
Quality Manager	$35	6
28 Laborersv	$25	6

$5,500

Team Meetings

Position	Hourly Rate	Hours
2 Project Construction Managers	$40	10
Design Manger	$45	10
25 Laborers	$25	10

$7,500

Direct Labor

$228,207.28

as averaged by When I Work® and after employee costs and profit multiplier

Apollo Mix

Materials	Classification	Weights (lbs)	Cost / lb	Total Cost
OPC	Cement	2.89	$0.03	$0.09
Slag	Slag	2.39	$0.02	$0.05
Silica Fume	Silica Fume	0.46	$0.44	$0.20
Poraver .1-.5	Cenospheres	1.02	$0.18	$0.18
Poraver .5-1	Cenospheres	0.83	$0.18	$0.15
Poraver 2-4	Cenospheres	1.15	$0.18	$0.21
S22	Expanded Glass	0.49	$0.25	$0.12
Utelite Crushed	Lightweight Agg	4.91	$0.05	$0.25
Rubber Chips	Rubber	0.56	$0.60	$0.34
13mm Fibers PVA	PVA Fibers	0.03	$1.05	$0.03
ADVA 530	Superplasticizer	0.02	$8.79	$0.18
VMAR-3	Rheology Modifying	0.15	$8.50	$1.28
ECLIPSE 2500	Shrinkage Reducers	0.02	$6.16	$0.12
Water	Non Carbonated	3.5	$0.03	$0.11
	1.3 cu. ft. per batch	16 batches	$3.29	$52.64

Orion Mix

Materials	Classification	Weights (lbs)	Cost / lb	Total Cost
OPC	Cement	2.36	$0.03	$0.07
Slag	Slag	2.44	$0.02	$0.05
Silica Fume	Silica Fume	0.82	$0.44	$0.36
Poraver .1-.5	Cenospheres	0.74	$0.18	$0.13
Poraver .5-1	Cenospheres	3.14	$0.18	$0.57
Utelite Crushed	Cenospheres	5.13	$0.05	$0.26
S22	Expanded Glass	0.56	$0.25	$0.14
13mm Fibers PVA	PVA Fibers	0.03	$1.05	$0.03
ADVA 530	Superplasticizer	0.02	$8.79	$0.18
VMAR-3	Viscosity Modfiying	0.15	$9.25	$1.39
ECLPISE 2500	Shrinkage Reducers	0.09	$6.16	$0.55
Water	Non Carbonated	2.56	$0.03	$0.08
				$3.80
	1.3 cu. ft. per batch	1.5 batches		$5.70

Artemis Mix

Materials	Classification	Weights (lbs)	Cost / lb	Total Cost
OPC	Cement	4	$0.03	$0.12
Slag	Slag	1.98	$0.02	$0.04
VCAS	VCAS	1.15	$0.32	$0.37
Pumice Sand	Lightweight Agg	2.98	$0.05	$0.15
K1	Expanded Glass	0.11	$0.25	$0.03
ADVA	Superplasticizer	0.01	$8.79	$0.09
VMAR	Viscosity Modfiying	0.08	$9.25	$0.74
ECLIPSE	Shrinkage Reducers	0.06	$6.16	$0.37
Pigments	Powder	0.21	$5.00	$1.05
Water	Non Carbonated	2.47	$0.03	$0.07
	1.3 cu. ft. per batch	2 batches	$3.03	$6.06

Item	Cost / lb	Total Cost
Styrofoam	$25.00	$67.5
Basalt Mesh	$1.60	$256
Fiberglass	$0.12	$7.20
Concrete Sealers	$0.50	$30.33
Outside Consultant - Monteiro		$1200

$1,561.03

Mold Construction

Resource	Cost
Maker Pass	$100
Wood, Nails, Wax, Sandpaper, 3D Printing	$200

$300

Shipping Calculation

Details	Hourly Rate
Driving the canoe in a trailer to Madison, Wisconsin	2076 mile distance
Typical U-Haul Truck with 10 miles per gallon specification	$2.61 average nation-wide price per gallon

$6,400

Material Expenses

$1,425.36

after applying markup multiplier

Approach to Health & Safety

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.

Over the next few weeks, division officers trained members for any tools and equipment relevant to their roles. Prior to beginning each new work task, the officers briefed members on relevant safety protocol, necessary personal protective equipment (PPE), and potential hazards or emergency situations. Members were only allowed to work under the supervision of an officer, and officers were responsible for upholding safe practices during their shifts. PPE was consistently worn throughout the process of building the canoe, and division officers ensured that safety precautions were taken at all times.

Quality Assurance and Quality Control

Calaxy's Quality Assurance and Quality Control Division faced the challenge of maintaining strong quality standards while adapting to the new task of designing and constructing a canoe prototype. Before beginning 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 were pre-batched before final casting to ensure a consistent mix. Each batch was 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 was further monitored to avoid cold joints while casting. The depth of each concrete layer placed on the mold was also measured using custom-made depth checkers, thus maintaining uniformity across all three layers. Furthermore, before being allowed to participate in casting, each member was required to pass a practice casting assessment on one of the mold mockups.

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

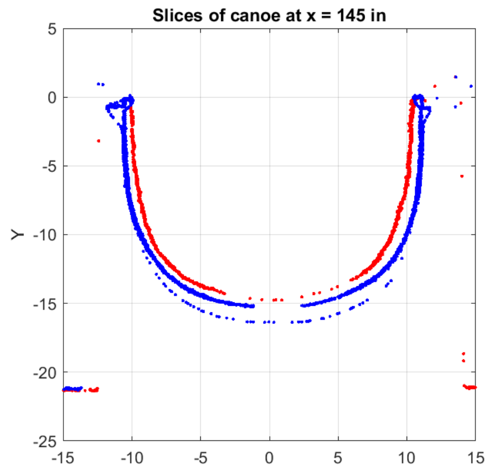


Figure 11: Laser scan slice of the canoe used to determine concrete thickness after casting

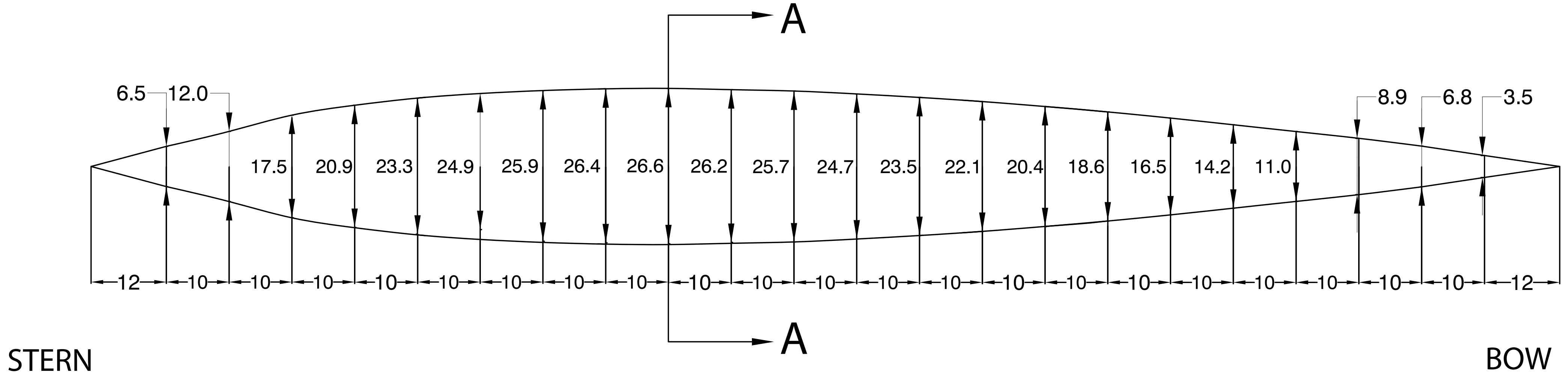
For non-construction aspects of the canoe prototype, the QA/QC Division worked closely with theproject managers to develop a system to help with adherence to the new set of guidelines for the prototype. Division officers read thoroughly over their sections within the *Request for Proposals* documentand 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 future teams can adopt.

Approach to Sustainability

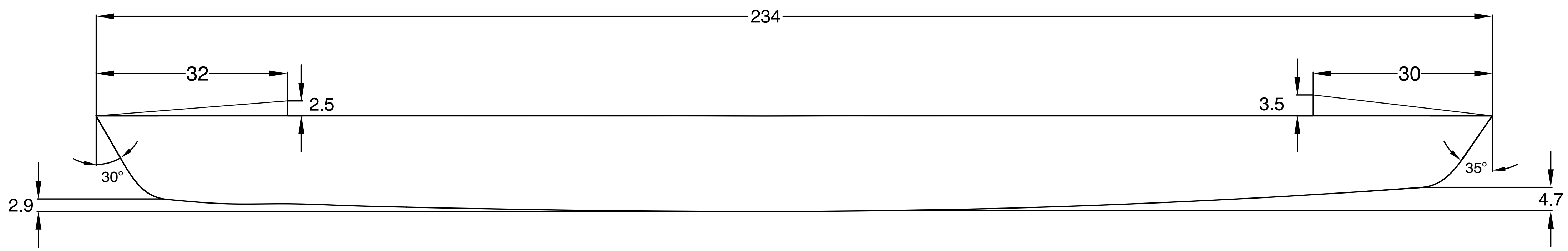
This year's team created the most sustainable canoe yet, reusing materials from local sources, reducing costs, and making environmentally friendly choices. Throughout the drafting, planning, and building process, the team utilized computer softwares to minimize paper waste, as well as facilitate collaboration and file sharing efficiently. The Paddling Division reused unwanted boats from a local boathouse for team paddling practices and upcycled old yoga mats and foam rollers to create seats for paddlers. By optimizing the mix design process through optimal regression methods, the Materials Division reduced the concrete needed for testing to half the amount of last year while also reusing cylinder molds. Furthermore, the Materials Division incorporated industrial byproducts, such as ground-granulated blast furnace slag (GGBFS) and silica fume, into the concrete mixes. By replacing half of the Ordinary Portland Cement (OPC) in the structural mix with these mineral admixtures, the team reduced its carbon footprint by 46% (U.S. Concrete). Finally, the Construction Division worked 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 was substantially lower. After demolding the canoe and removing all hardware and nails, this wooden mold was composted, because it was built with eco-friendly wax and sealer.

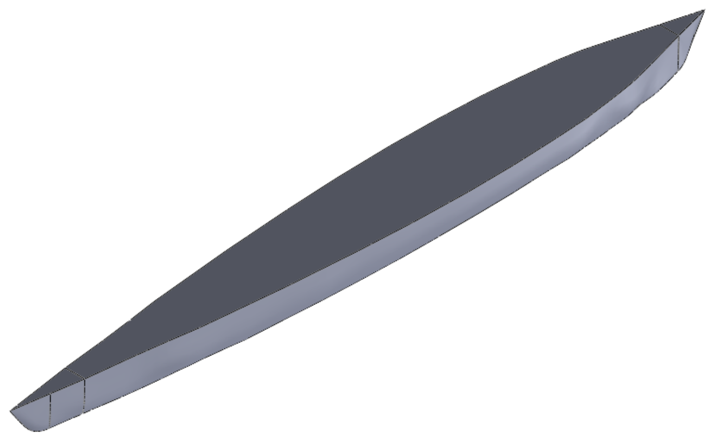
Figure 12: Exhausted but exuberant team after casting!

PLAN VIEW

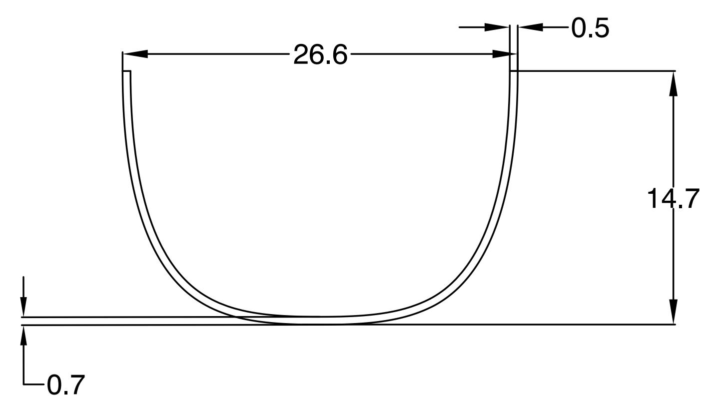


ELEVATION VIEW

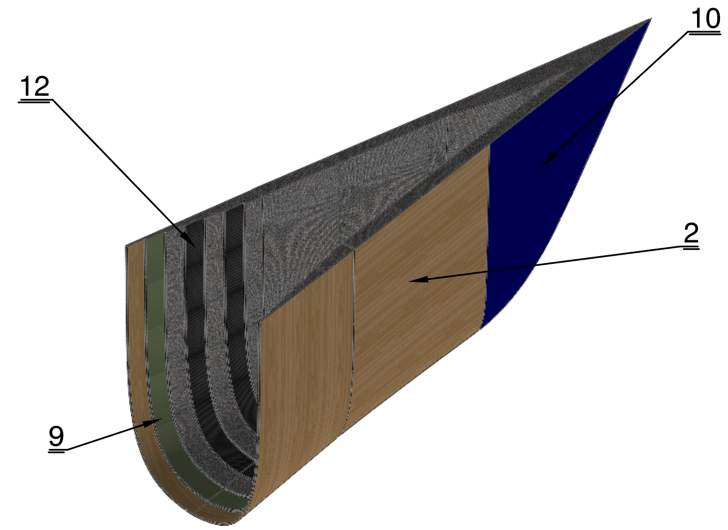




ISOMETRIC VIEW



SECTION A-A



CUTAWAY SECTION

CALIFORNIA CONCRETE CANOE

Bill of Materials

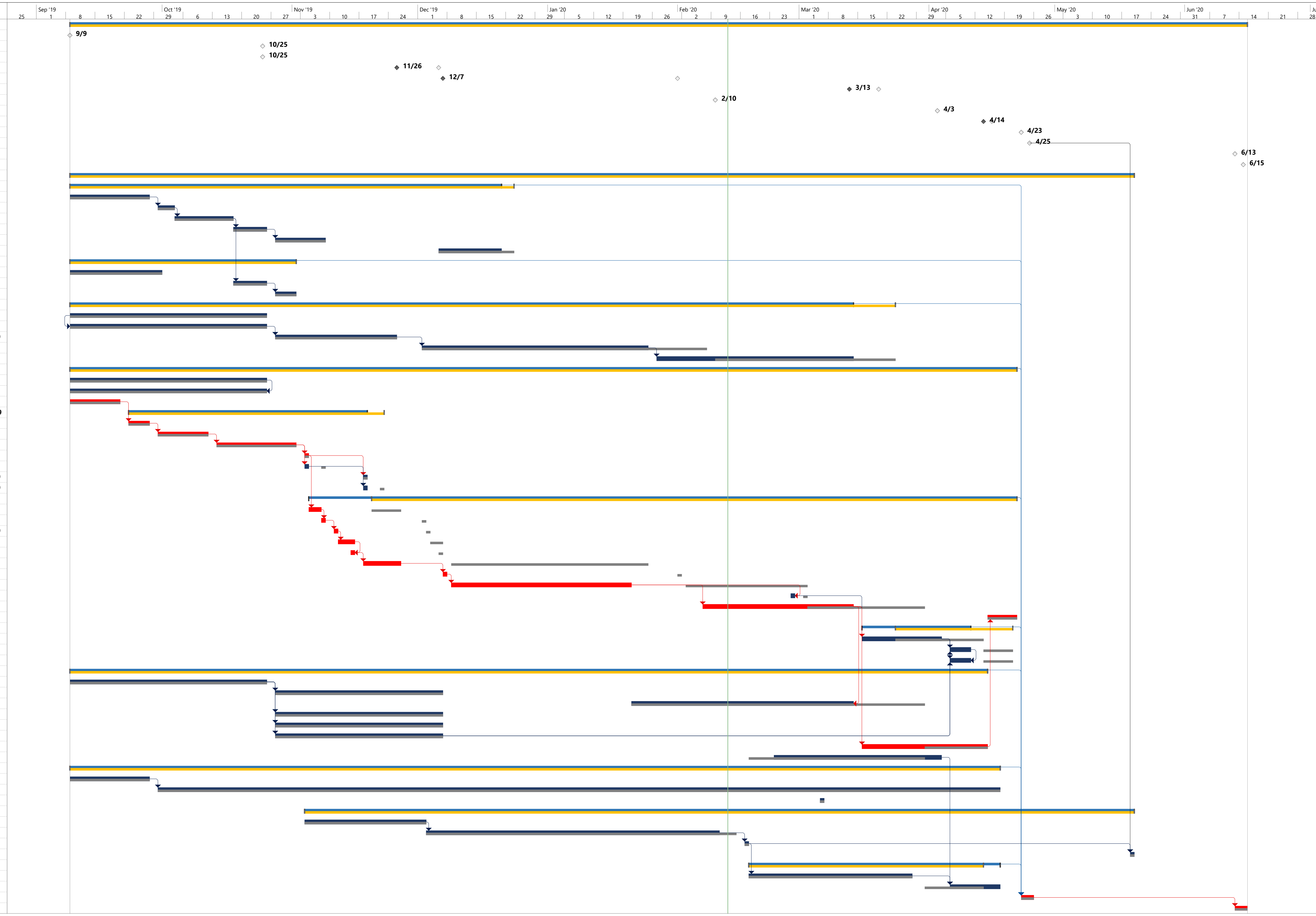
NO.	DESCRIPTION	QTY
1	Plywood 3/16"	1-4'x4'
2	Plywood 1/8"	16-2'x4'
3	Oriented Strand Board 1/2"	4-4'x8'
4	Metal Screws 1/2"	~170
5	Corner Braces	80-2"x2"
6	Galvanized Steel Strap	4-6"x0.13"
7	Brad Nails 1/2"	~750
8	Brad Nails 5/8"	~500
9	Wax	0.88 lbs.
10	Polylactic Acid (PLA)	4.79 lbs.
11	Duct Tape	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		

Calaxy
DESIGN DRAWING

All dimensions are in inches.

DRAWN BY:	DATE:
Sonia Martin Shaan Jagani	02/13/2020

ID	Task Name	Duration	Start	Finish
1	**Project Milestones**	**205 days**	**Mon 9/9/19**	**Mon 6/15/20**
2	Project Start	0 days	Mon 9/9/19	Mon 9/9/19
3	Hull Design Completion	0 days	Fri 10/25/19	Fri 10/25/19
4	Research of Construction Methods Completion	0 days	Fri 10/25/19	Fri 10/25/19
5	Canoe Formwork Completion	0 days	Tue 11/26/19	Tue 11/26/19
6	Casting Canoe	0 days	Sat 12/7/19	Sat 12/7/19
7	Sanding Completion	0 days	Fri 3/13/20	Fri 3/13/20
8	Technical Paper Completion	0 days	Mon 2/10/20	Mon 2/10/20
9	Presentation Slides Completion	0 days	Fri 4/3/20	Fri 4/3/20
10	Graphics Completion	0 days	Tue 4/14/20	Tue 4/14/20
11	MidPac Start	0 days	Thu 4/23/20	Thu 4/23/20
12	MidPac End	0 days	Sat 4/25/20	Sat 4/25/20
13	National Concrete Canoe Competition Start	0 days	Sat 6/13/20	Sat 6/13/20
14	National Concrete Canoe Competition End	0 days	Mon 6/15/20	Mon 6/15/20
15	**Functional Activities**	**184 days**	**Mon 9/9/19**	**Tue 5/19/20**
16	**Hull Design**	**76 days**	**Mon 9/9/19**	**Fri 12/20/19**
17	Research of Preliminary Hull Design	15 days	Mon 9/9/19	Fri 9/27/19
18	Flume Test	4 days	Mon 9/30/19	Thu 10/3/19
19	Hull Design Revisions	10 days	Fri 10/4/19	Thu 10/17/19
20	SolidWorks Modeling	6 days	Fri 10/18/19	Fri 10/25/19
21	Panel Drawing Extrapolation	10 days	Mon 10/28/19	Fri 11/8/19
22	Construction Drawing	12 days	Fri 12/6/19	Fri 12/20/19
23	**Structural Analysis**	**40 days**	**Mon 9/9/19**	**Fri 11/1/19**
24	Analysis Classes and Research	16 days	Mon 9/9/19	Mon 9/30/19
25	Loading Case Analysis	6 days	Fri 10/18/19	Fri 10/25/19
26	Sample Calculations	5 days	Mon 10/28/19	Fri 11/1/19
27	**Materials & Mix Design**	**136 days**	**Mon 9/9/19**	**Fri 3/13/20**
28	Material Procurement	35 days	Mon 9/9/19	Fri 10/25/19
29	Research of Preliminary Mix Design	35 days	Mon 9/9/19	Fri 10/25/19
30	Trial Batching and Testing Base Mix	21 days	Mon 10/28/19	Mon 11/25/19
31	Trial Batching and Testing Patch Mix	41 days	Mon 12/2/19	Fri 1/24/20
32	Trial Batching and Testing Finishing Mixes	35 days	Mon 1/27/20	Fri 3/13/20
33	**Construction**	**163 days**	**Mon 9/9/19**	**Tue 4/21/20**
34	Material Procurement	35 days	Mon 9/9/19	Fri 10/25/19
35	Research of Construction Methods	35 days	Mon 9/9/19	Fri 10/25/19
36	Machine Equipment Training	10 days	Mon 9/9/19	Fri 9/20/19
37	**Mock Ups**	**41 days**	**Mon 9/23/19**	**Mon 11/18/19**
38	CNC Cross Sections	5 days	Mon 9/23/19	Fri 9/27/19
39	Install Cross Sections	10 days	Mon 9/30/19	Fri 10/11/19
40	Stripping and Paneling	15 days	Mon 10/14/19	Fri 11/1/19
41	Casting Mock Up 1	1 day	Mon 11/4/19	Mon 11/4/19
42	Casting Mock Up 2	1 day	Mon 11/4/19	Mon 11/4/19
43	Demold Mock Up 1	1 day	Mon 11/18/19	Mon 11/18/19
44	Demold Mock Up 2	1 day	Mon 11/18/19	Mon 11/18/19
45	**Calaxy**	**122 days**	**Tue 11/5/19**	**Tue 4/21/20**
46	CNC Cross Sections	3 days	Tue 11/5/19	Thu 11/7/19
47	Install Spine	1 day	Fri 11/8/19	Fri 11/8/19
48	Waterproofing Table and Spine	1 day	Mon 11/11/19	Mon 11/11/19
49	Install Cross Sections	4 days	Tue 11/12/19	Fri 11/15/19
50	Waterproofing Cross Sections	1 day	Fri 11/15/19	Fri 11/15/19
51	Paneling	7 days	Mon 11/18/19	Tue 11/26/19
52	Casting	1 day	Sat 12/7/19	Sat 12/7/19
53	Curing	31 days	Mon 12/9/19	Mon 1/20/20
54	Demolding	1 day	Fri 2/28/20	Fri 2/28/20
55	Sanding	26 days	Fri 2/7/20	Fri 3/13/20
56	Sealing	5 days	Wed 4/15/20	Tue 4/21/20
57	**Final Product Deliverables**	**20 days**	**Mon 3/16/20**	**Fri 4/10/20**
58	Cutaway Cross Section	15 days	Mon 3/16/20	Fri 4/3/20
59	Canoe Stand Construction	5 days	Mon 4/6/20	Fri 4/10/20
60	Display Table Construction	5 days	Mon 4/6/20	Fri 4/10/20
61	**Graphics**	**158 days**	**Mon 9/9/19**	**Tue 4/14/20**
62	Theme Research and Development	35 days	Mon 9/9/19	Fri 10/25/19
63	Canoe Graphics Application Research	30 days	Mon 10/28/19	Fri 12/6/19
64	Canoe Graphics Design	39 days	Tue 1/21/20	Fri 3/13/20
65	Canoe Paper Design	30 days	Mon 10/28/19	Fri 12/6/19
66	Display Design	30 days	Mon 10/28/19	Fri 12/6/19
67	Stand Design	30 days	Mon 10/28/19	Fri 12/6/19
68	Canoe Graphics Application	22 days	Mon 3/16/20	Tue 4/14/20
69	Presentation Design	30 days	Mon 2/24/20	Fri 4/3/20
70	**Paddling**	**161 days**	**Mon 9/9/19**	**Fri 4/17/20**
71	Padding Recruitment	15 days	Mon 9/9/19	Fri 9/27/19
72	Paddling Training	146 days	Mon 9/30/19	Fri 4/17/20
73	Time Trials	1 day	Fri 3/6/20	Fri 3/6/20
74	**Technical Paper**	**144 days**	**Mon 11/4/19**	**Tue 5/19/20**
75	Draft Paper	21 days	Mon 11/4/19	Mon 12/2/19
76	Paper Editing	51 days	Tue 12/3/19	Mon 2/10/20
77	Paper Submission	1 day	Mon 2/17/20	Mon 2/17/20
78	National Paper Submission	1 day	Tue 5/19/20	Tue 5/19/20
79	**Presentation**	**44 days**	**Tue 2/18/20**	**Fri 4/17/20**
80	Script Writing	29 days	Tue 2/18/20	Fri 3/27/20
81	Presentation Rehearsal	10 days	Mon 4/6/20	Fri 4/17/20
82	MidPac Competition	3 days	Thu 4/23/20	Sat 4/25/20
83	National Concrete Canoe Competition	3 days	Sat 6/13/20	Mon 6/15/20



Project: Canoe final schedule_b
Date: Thu 2/13/20

Task | Milestone | Summary | Critical | Baseline | Baseline Milestone | Baseline Summary

Page 1

Appendix A: Mixture Proportions and Primary Mixture Calculations

MIXTURE: Apollo - Structural Mix

Cementitious Materials

Component	Specific Gravity	Volume	Amount of CM	
White Cement Type 1	3.15	*1.32 ft^3*	260.0 lb/yd^3	Total cm (includes c) ____**516.9**___ lb/yd^3 c/cm ratio, by mass __**0.50**_____
Slag Cement	2.90	*1.19 ft^3*	215.2 lb/yd^3	
Silica Fume	*2.20*	*0.30 ft^3*	*41.7 lb/yd^3*	

Fibers

Component	Specific Gravity	Volume	Amount of Fibers	
13 mm PVA Fibers	1.30	*0.032 ft^3*	*2.52 lb/yd^3*	Total Amount of Fibers ____2.52___ lb/yd^3

Aggregates (Excluding Mineral Fillers Passing No. 200 Sieve)

Aggregates	Expanded Glass (EG) or Cenosphere (C)[1]	Abs (%)	SG_{OD}	SG_{SSD}	Base Quantity, W		Volume, $V_{agg,\,SSD}$
					W_{OD}	W_{SSD}	
Poraver 0.1-0.5	Yes	*34%*	*0.435*	*0.583*	*84.7 lb/yd^3*	*113.4 lb/yd^3*	*3.12 ft^3*
Poraver 0.5-1	Yes	*18%*	*0.373*	*0.441*	*59.7 lb/yd^3*	*70.5 lb/yd^3*	*2.56 ft^3*
Poraver 2-4	Yes	*14%*	*0.261*	*0.298*	*86.3 lb/yd^3*	*98.4 lb/yd^3*	*5.29 ft^3*
Utelite Crushed Lightweight Structural Aggregate	No	*31.4%*	*1.301*	*1.71*	*339.4 lb/ yd^3*	*445.9 lb/yd^3*	*4.18 ft^3*
reRubber Ambient Crumb Rubber 6-14 Mesh	No	*0%*	*1.000*	*1.000*	*56.7 lb/yd^3*	*56.7 lb/yd^3*	*0.91 ft^3*

Liquid Admixtures

Admixture	lb/ US gal	Dosage (fl. oz / cwt)	% Solids	Amount of Water in Admixture	
ADVA 530	*8.9*	*35.1*	*30.6%*	*8.78 lb/yd^3*	Total Water from Liquid Admixtures, $\sum w_{admx}$ ____**22.7**___ lb/yd^3
V-MAR 3	*8.5*	*38.9*	*0.69%*	*13.0 lb/yd^3*	
Eclipse 4500	*7.7*	*6.91*	*55.82%*	*0.95 lb/yd^3*	

Solids (dyes, powdered admixtures, and mineral fillers)

Component	Specific Gravity	Volume (ft^3)	Amount (lb/yd^3)	
S22 Glass Bubbles - Mineral Filler (Passing No. 200 sieve)	**0.22**	*3.216 ft^3*	*44.15 lb/yd^3*	Total Solids. S_{total} ___**57.33**____ lb/yd^3
Poraver 0.1-0.5 - Mineral Filler (Passing No. 200 sieve)	**0.583**	*0.0477 ft^3*	*1.74 lb/yd^3*	
Poraver 0.5-1 - Mineral Filler (Passing No. 200 sieve)	**0.441**	*0.0077 ft^3*	*0.212 lb/yd^3*	
Poraver 2-4 - Mineral Filler (Passing No. 200 sieve)	**0.298**	*0.0465 ft^3*	*0.865 lb/yd^3*	
Utelite Crushed Lightweight Structural Aggregate - Mineral Filler (Passing No. 200 sieve)	**1.71**	*0.0971 ft^3*	*10.36 lb/yd^3*	

Water

	Amount		Volume
Water, w, $[=\sum (w_{free} + w_{admx} + w_{batch})]$	w/c ratio, by mass ___**1.099**____ w/cm ratio, by mass ___**0.553**____	*285.7 lb/yd^3*	*4.58 ft^3*
Total Free Water from All Aggregates, $\sum w_{free}$		*-51.63 lb/yd^3*	
Total Water from All Admixtures, $\sum w_{admx}$		*22.7 lb/yd^3*	
Batch Water, w_{batch}		*314.63 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	*516.9 lb*	*2.52 lb*	*784.9 lb*	*57.33 lb*	*285.7 lb*	*$\sum$M:1647.35lb*

***Absolute Volume,** V*	*2.82 ft^3*	*0.032 ft^3*	*16.06 ft^3*	*3.41 ft^3*	*4.58 ft^3*	*∑V: 26.88 ft^3*
***Theoretical Density,** T, (=∑M / ∑V)*	*62.28 lb/ft^3*		***Air Content, Air,** [= (T – D)/T x 100%]*			*-16.5 %*
***Measured Density,** D*	*71.35 lb/ft^3*		***Air Content, Air,** [= (27 – ∑V))/27 x 100%]*			*0.37 %*
***Total Aggregate Ratio**[2] (=$V_{agg,SSD}$ / 27)*	*59.48 %*		***Slump***			*0.5 in.*
***EG+C Ratio**[3] (=V_{EG+C} / $V_{agg,SSD}$)*	*68.31 %*					

1. *Indicate if aggregate is expanded glass (EG)(i.e., Poraver™ or similar product) and/or cenospheres (C).*
2. *Ratio of total aggregate volume (in percent) compared to the total volume of concrete (min. allowable is 30%)*
3. *Ratio of combined volume of expanded glass (EG) and cenospheres (C) (V_{EG+C} (in percent)) compared to the total aggregate volume of aggregate in SSD condition ($V_{agg,SSD}$); (max. allowable is 70%)*

MIXTURE: ORION – PATCH MIX

CEMENTITIOUS MATERIALS				
Component	*Specific Gravity*	*Volume*	*Amount of CM*	
White Cement Type 1	3.15	1.863 ft^3	366.2 lb/yd^3	Total cm (includes c) ___772.8___ lb/yd^3 c/cm ratio, by mass __0.474____
Slag Cement	2.90	1.836 ft^3	332.4 lb/yd^3	
Silica Fume	2.20	0.54 ft^3	74.2 lb/yd^3	

FIBERS				
Component	*Specific Gravity*	*Volume*	*Amount of Fibers*	
13 mm PVA Fibers	1.30	0.035 ft^3	2.76 lb/yd^3	Total Amount of Fibers ___2.76___ lb/yd^3

AGGREGATES (EXCLUDING MINERAL FILLERS PASSING NO. 200 SIEVE)							
Aggregates	*Expanded Glass (EG) or Cenosphere (C)*[1]	*Abs (%)*	*SG_{OD}*	*SG_{SSD}*	*Base Quantity, W*		*Volume, $V_{agg,\ SSD}$*
					W_{OD}	*W_{SSD}*	
Poraver 0.1-0.5	Yes	34%	0.435	0.583	59.367 lb/yd^3	79.55 lb/yd^3	2.19 ft^3
Poraver 0.5-1	Yes	18%	0.373	0.441	200.3 lb/yd^3	236.4 lb/yd^3	8.60 ft^3
Hess Grade 2 Pumice Sand	No	14.8%	1.490	1.71	428.0 lb/yd^3	491.3 lb/yd^3	4.60 ft^3

LIQUID ADMIXTURES					
Admixture	*lb/ US gal*	*Dosage (fl. oz / cwt)*	*% Solids*	*Amount of Water in Admixture*	
ADVA 530	8.9	15.01	30.6%	5.61 lb/yd^3	Total Water from Liquid Admixtures, $\sum w_{admx}$ ____17.22___ lb/yd^3
V-MAR 3	8.5	17.04	0.69%	8.52 lb/yd^3	
Eclipse 4500	7.7	7.05	55.82%	1.44 lb/yd^3	
ZYLA 625	9.1	5.02	40.2%	1.65 lb/yd^3	

SOLIDS (DYES, POWDERED ADMIXTURES, AND MINERAL FILLERS)				
Component	*Specific Gravity*	*Volume (ft^3)*	*Amount (lb/yd^3)*	
S22 Glass Bubbles - Mineral Filler (Passing No. 200 sieve)	**0.22**	2.163 ft^3	29.7 lb/yd^3	Total Solids. S_{total} ___31.60___ lb/yd^3
Poraver 0.1-0.5 - Mineral Filler (Passing No. 200 sieve)	**0.583**	0.033 ft^3	1.19 lb/yd^3	
Poraver 0.5-1 - Mineral Filler (Passing No. 200 sieve)	**0.441**	0.026 ft^3	0.71 lb/yd^3	

WATER			
	Amount		*Volume*
Water, w, [$=\sum (w_{free} + w_{admx} + w_{batch})$]	w/c ratio, by mass ___0.829___ w/cm ratio, by mass ___0.393___	303.7 lb/yd^3	4.87 ft^3
Total Free Water from All Aggregates, $\sum w_{free}$		-119.6 lb/yd^3	
Total Water from All Admixtures, $\sum w_{admx}$		17.2 lb/yd^3	
Batch Water, w_{batch}		406.0 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	772.8 lb	2.76 lb	807.2 lb	31.60 lb	303.7 lb	$\sum$M:1918.0 lb
Absolute Volume, V	4.24 ft^3	0.035 ft^3	15.4 ft^3	2.22 ft^3	4.87 ft^3	$\sum$V:26.75 ft^3
Theoretical Density, T, ($=\sum M / \sum V$)	71.71 lb/ft^3		*Air Content, Air, [= (T – D)/T x 100%]*			-13.2%
Measured Density, D	81.2 lb/ft^3		*Air Content, Air, [= (27 – $\sum$V))/27 x 100%]*			0.93 %

***Total Aggregate Ratio*[2]** *(=$V_{agg,SSD}$ / 27)*	*57.0 %*	***Slump***	*5 in.*
***EG+C Ratio*[3]** *(=V_{EG+C} / $V_{agg,SSD}$)*	*70.0 %*		

1. *Indicate if aggregate is expanded glass (EG)(i.e., Poraver™ or similar product) and/or cenospheres (C).*
2. *Ratio of total aggregate volume (in percent) compared to the total volume of concrete (min. allowable is 30%)*
3. *Ratio of combined volume of expanded glass (EG) and cenospheres (C) (V_{EG+C} (in percent)) compared to the total aggregate volume of aggregate in SSD condition ($V_{agg,SSD}$); (max. allowable is 70%)*

MIXTURE: ARTEMIS – FINISHING MIX

CEMENTITIOUS MATERIALS				
Component	*Specific Gravity*	*Volume*	*Amount of CM*	
White Cement Type 1	3.15	2.673 ft³	525.4 lb/yd³	Total cm (includes c) **1152.8** lb/yd³ c/cm ratio, by mass **0.4558**
Slag Cement	2.90	2.646 ft³	479.1 lb/yd³	
Silica Fume	2.20	1.08 ft³	148.3 lb/yd³	

FIBERS				
Component	*Specific Gravity*	*Volume*	*Amount of Fibers*	
13 mm PVA Fibers	1.30	0.035 ft³	2.757 lb/yd³	Total Amount of Fibers **2.757** lb/yd³

AGGREGATES (EXCLUDING MINERAL FILLERS PASSING NO. 200 SIEVE)							
Aggregates	*Expanded Glass (EG) or Cenosphere (C)*[1]	*Abs (%)*	*SG_{OD}*	*SG_{SSD}*	*Base Quantity, W*		*Volume, $V_{agg,\,SSD}$*
					W_{OD}	*W_{SSD}*	
Poraver 0.1-0.3	Yes	39%	0.436	0.606	200.4 lb/yd³	278.5 lb/yd³	7.365 ft³
Poraver 0.25-0.5	Yes	33.26%	0.400	0.533	56.62 lb/yd³	75.46 lb/yd³	2.269 ft³
Hess Grade 2 Pumice Sand	No	14.8%	1.490	1.71	383.4 lb/yd³	440.5 lb/yd³	4.128 ft³

LIQUID ADMIXTURES					
Admixture	*lb/ US gal*	*Dosage (fl. oz / cwt)*	*% Solids*	*Amount of Water in Admixture*	
ADVA 530	8.9	10.06	30.6%	5.614 lb/yd³	Total Water from Liquid Admixtures, $\sum w_{admx}$ **17.23** lb/yd³
V-MAR 3	8.5	11.43	0.69%	8.524 lb/yd³	
Eclipse 4500	7.7	4.727	55.82%	1.443 lb/yd³	
ZYLA 625	9.1	3.354	40.2%	1.649 lb/yd³	

SOLIDS (DYES, POWDERED ADMIXTURES, AND MINERAL FILLERS)				
Component	*Specific Gravity*	*Volume (ft³)*	*Amount (lb/yd³)*	
S22 Glass Bubbles – Mineral Filler (Passing No. 200 sieve)	**0.22**	1.97 ft³	27.00 lb/yd³	Total Solids. S_{total} **66.47** lb/yd³
Poraver 0.1-0.3 – Mineral Filler (Passing No. 200 sieve)	**37.81**	0.057 ft³	0.076 lb/yd³	
Poraver 0.25-0.5 – Mineral Filler (Passing No. 200 sieve)	**33.26**	0.0023 ft³	2.139 lb/yd³	
Pigment (varies by color)	**1.99**	0.30	37.25 lb/yd³	

WATER			
	Amount		*Volume*
Water, w, [=$\sum$ ($w_{free} + w_{admx} + w_{batch}$)]	w/c ratio, by mass **0.509** w/cm ratio, by mass **0.232**	404.35 lb/yd³	4.29 ft³
Total Free Water from All Aggregates, $\sum w_{free}$		-154.10 lb/yd³	
Total Water from All Admixtures, $\sum w_{admx}$		17.23 lb/yd³	
Batch Water, w_{batch}		267.5 lb/yd³	

DENSITIES, AIR CONTENT, RATIOS, AND SLUMP						
Values for 1 cy of concrete	cm	Fibers	Aggregate (SSD)	Solids, S_{total}	Water, w	Total
Mass, M	1152.8 lb	2.757 lb	794.49 lb	66.47 lb	267.48 lb	∑M: 2284.0 lb
Absolute Volume, V	6.399 ft³	0.0348 ft³	13.762 ft³	2.32 ft³	4.29 ft³	∑V: 26.81 ft³
Theoretical Density, T, (=∑M / ∑V)	85.20 lb/ft³		*Air Content, Air, [= (T – D)/T x 100%]*			-8.45%
Measured Density, D	92.4 lb/ft³		*Air Content, Air, [= (27 – ∑V))/27 x 100%]*			0.71%

Total Aggregate Ratio[2] *(=$V_{agg,SSD}$ / 27)*	*50.97%*	***Spread***	*25.0 in.*
EG+C Ratio[3] *(=V_{EG+C} / $V_{agg,SSD}$)*	*70.0%*		

1. *Indicate if aggregate is expanded glass (EG)(i.e., Poraver™ or similar product) and/or cenospheres (C).*
2. *Ratio of total aggregate volume (in percent) compared to the total volume of concrete (min. allowable is 30%)*
3. *Ratio of combined volume of expanded glass (EG) and cenospheres (C) (V_{EG+C} (in percent)) compared to the total aggregate volume of aggregate in SSD condition ($V_{agg,SSD}$); (max. allowable is 70%)*

Apollo - Structural Mix Calculations

CEMENTITIOUS MATERIALS

Volume of White Portland Cement:

$$Volume_{White\ Portland\ Cement} = \frac{Weight_{White\ Portland\ Cement}}{SG_{White\ Portland\ Cement} \times 62.4} = \frac{260.0}{3.15 \times 62.4} = 1.32\ ft^3$$

Volume of Ground Granulated Blasted Furnace Slag:

$$Volume_{Slag\ Cement} = \frac{Weight_{Slag\ Cement}}{SG_{Slag\ Cement} \times 62.4} = \frac{215.2}{2.90 \times 62.4} = 1.19\ ft^3$$

Volume of Silica Fume:

$$Volume_{Silica\ Fume} = \frac{Weight_{Silica\ Fume}}{SG_{Silica\ Fume} \times 62.4} = \frac{41.7}{2.20 \times 62.4} = 0.30\ ft^3$$

Total Weight Cementitious Materials:

$$\sum W_{cm} = 260\frac{lb}{yd^3} + 215.2\frac{lb}{yd^3} + 41.7\frac{lb}{yd^3} = 516.9\ lb/yd^3$$

FIBERS

Volume of 13mm PVA Fibers:

$$Volume_{Fibers} = \frac{Weight_{Fibers}}{SG_{Fibers} \times 62.4} = \frac{2.52}{1.30 \times 62.4} = 0.032\ ft^3$$

AGGREGATES

Poraver 0.1-0.5 (Stock was at OD):

$$Abs = \frac{W_{SSD} - W_{OD}}{W_{OD}} \times 100\% = \frac{113.4 - 84.7}{84.7} = 34\%$$

$$MC_{total} = \frac{W_{STK} - W_{OD}}{W_{OD}} \times 100\% = \frac{84.7 - 84.7}{84.7} = 0\%$$

$$MC_{free} = MC_{total} - Abs = 0\% - 34\% = -34\%$$

$$W_{SSD} = \left(1 + \frac{Abs}{100\%}\right) \times W_{OD} = \left(1 + \frac{34\%}{100\%}\right) \times 84.7 = 113.4\ lbs$$

$$w_{free} = W_{OD} \times \left(\frac{MC_{free}}{100\%}\right) = 84.7 \times \left(\frac{-34\%}{100\%}\right) = -28.8\ lbs$$

$$W_{STK} = W_{SSD} + w_{free} = 113.4 - 28.8 = 84.7\ lbs$$

$$Volume_{Poraver\ 0.1-0.5} = \frac{Weight_{Poraver\ 0.1-0.5}}{SG_{Poraver\ 0.1-0.5} \times 62.4} = \frac{113.4}{0.583 \times 62.4} = 3.12\ ft^3$$

**Amount passing 200 sieve has been subtracted and is accounted for in the Mineral Filler Section*

Poraver 0.5-1 (Stock was at OD):

$$Abs = \frac{W_{SSD} - W_{OD}}{W_{OD}} \times 100\% = \frac{70.5 - 59.7}{59.7} = 18\%$$

$$MC_{total} = \frac{W_{STK} - W_{OD}}{W_{OD}} \times 100\% = \frac{59.7 - 59.7}{59.7} = 0\%$$

$$MC_{free} = MC_{total} - Abs = 0\% - 18\% = -18\%$$

$$W_{SSD} = \left(1 + \frac{Abs}{100\%}\right) \times W_{OD} = \left(1 + \frac{18\%}{100\%}\right) \times 59.7 = 70.5\ lbs$$

$$w_{free} = W_{OD} \times \left(\frac{MC_{free}}{100\%}\right) = 59.7 \times \left(\frac{-18\%}{100\%}\right) = -10.8\ lbs$$

$$W_{STK} = W_{SSD} + w_{free} = 70.5 - 10.8 = 59.7\ lbs$$

$$Volume_{Poraver\ 0.5-1} = \frac{Weight_{Poraver\ 0.5-1}}{SG_{Poraver\ 0.5-1} \times 62.4} = \frac{70.5}{0.441 \times 62.4} = 2.56\ ft^3$$

**Amount passing 200 sieve has been subtracted and is accounted for in the Mineral Filler Section*

Poraver 2-4 (Stock was at OD):

$$Abs = \frac{W_{SSD} - W_{OD}}{W_{OD}} \times 100\% = \frac{98.4 - 86.3}{86.3} = 14\%$$

$$MC_{total} = \frac{W_{STK} - W_{OD}}{W_{OD}} \times 100\% = \frac{86.3 - 86.3}{86.3} = 0\%$$

$$MC_{free} = MC_{total} - Abs = 0\% - 14\% = -14\%$$

$$W_{SSD} = \left(1 + \frac{Abs}{100\%}\right) \times W_{OD} = \left(1 + \frac{14\%}{100\%}\right) \times 86.3 = 98.4\ lbs$$

$$w_{free} = W_{OD} \times \left(\frac{MC_{free}}{100\%}\right) = 86.3 \times \left(\frac{-14\%}{100\%}\right) = -12.1\ lbs$$

$$W_{STK} = W_{SSD} + w_{free} = 98.4 - 12.1 = 86.3\ lbs$$

$$Volume_{Poraver\ 2-4} = \frac{Weight_{Poraver\ 2-4}}{SG_{Poraver\ 2-4} \times 62.4} = \frac{98.4}{0.298 \times 62.4} = 5.29\ ft^3$$

**Amount passing 200 sieve has been subtracted and is accounted for in the Mineral Filler Section*

Utelite Crushed Lightweight Structural Aggregate (Stock was at SSD):

$$Abs = \frac{W_{SSD} - W_{OD}}{W_{OD}} \times 100\% = \frac{445.9 - 339.4}{339.4} = 31.4\%$$

$$MC_{total} = \frac{W_{STK} - W_{OD}}{W_{OD}} \times 100\% = \frac{445.9 - 339.4}{339.4} = 31.4\%$$

$$MC_{free} = MC_{total} - Abs = 31.4\% - 31.4\% = 0\%$$

$$W_{SSD} = \left(1 + \frac{Abs}{100\%}\right) \times W_{OD} = \left(1 + \frac{31.4\%}{100\%}\right) \times 339.4 = 445.9\ lbs$$

$$w_{free} = W_{OD} \times \left(\frac{MC_{free}}{100\%}\right) = 445.9 \times \left(\frac{0\%}{100\%}\right) = 0\ lbs$$

$$W_{STK} = W_{SSD} + w_{free} = 445.9 + 0 = 445.9\ lbs$$

$$Volume_{Utelite} = \frac{Weight_{Utelite}}{SG_{Utelite} \times 62.4} = \frac{445.9}{1.71 \times 62.4} = 4.18\ ft^3$$

**Amount passing 200 sieve has been subtracted and is accounted for in the Mineral Filler Section*

reRubber Ambient Crumb Rubber 6-14 Mesh:

$$Abs = \frac{W_{SSD} - W_{OD}}{W_{OD}} \times 100\% = \frac{56.7 - 56.7}{56.7} = 0\%$$

$$MC_{total} = \frac{W_{STK} - W_{OD}}{W_{OD}} \times 100\% = \frac{56.7 - 56.7}{56.7} = 0\%$$

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

$$W_{SSD} = \left(1 + \frac{Abs}{100\%}\right) \times W_{OD} = \left(1 + \frac{0\%}{100\%}\right) \times 56.7 = 56.7\ lbs$$

$$w_{free} = W_{OD} \times \left(\frac{MC_{free}}{100\%}\right) = 59.7 \times \left(\frac{0\%}{100\%}\right) = 0\ lbs$$

$$W_{STK} = W_{SSD} + w_{free} = 56.7 + 0 = 56.7\ lbs$$

$$Volume_{Poraver\ 0.5-1} = \frac{Weight_{Poraver\ 0.5-1}}{SG_{Poraver\ 0.5-1} \times 62.4} = \frac{56.7}{1.0 \times 62.4} = 0.91\ ft^3$$

**Amount passing 200 sieve has been subtracted and is accounted for in the Mineral Filler Section*

Total Weight Aggregates:

$$\sum W_{aggregates} = 113.4 \frac{lbs}{yd^3} + 70.5 \frac{lb}{yd^3} + 98.4 \frac{lb}{yd^3} + 445.9 \frac{lbs}{yd^3} + 56.7 \frac{lbs}{yd^3} = 784.9\ lb/yd^3$$

LIQUID ADMIXTURES

Water from ADVA 530:

$$w_{ADVA\ 530} = dosage\ (fl\ oz) \times cwt\ of\ cm \times water\ content\ (\%) \times \frac{1gal}{128 fl\ oz} \times \frac{lb}{gal\ of\ ADVA\ 530}$$

$$= \frac{35.1\ fl\ oz}{cwt} \times 5.169\ cwt\ of\ cm \times 0.694 \times \frac{1gal}{128 fl\ oz} \times \frac{8.9\ lb}{gal\ of\ ADVA\ 530} = 8.78\ lb/yd^3$$

Water from V-MAR 3:

$$w_{VMAR\,3} = dosage\ (fl\ oz) \times cwt\ of\ cm \times water\ content\ (\%) \times \frac{1gal}{128fl\ oz} \times \frac{lb}{gal\ of\ VMAR\ 3}$$
$$= \frac{38.9\ fl\ oz}{cwt} \times 5.169\ cwt\ of\ cm \times 0.611 \times \frac{1gal}{128fl\ oz} \times \frac{8.5\ lb}{gal\ of\ VMAR\ 3} = 13.0\ lb/yd^3$$

Water from Eclipse 4500:

$$w_{Eclipse\ 4500} = dosage\ (fl\ oz) \times cwt\ of\ cm \times water\ content\ (\%) \times \frac{1gal}{128fl\ oz} \times \frac{lb}{gal\ of\ Eclipse\ 4500}$$
$$= \frac{6.91\ fl\ oz}{cwt} \times 5.169\ cwt\ of\ cm \times 0.4418 \times \frac{1gal}{128fl\ oz} \times \frac{7.7\ lb}{gal\ of\ VMAR\ 3} = 0.95\ lb/yd^3$$

Total Free Water from Admixtures:

$$\sum w_{admx} = 8.78\frac{lb}{yd^3} + 13.0\frac{lb}{yd^3} + 0.95\frac{lb}{yd^3} = 22.7\ lb/yd^3$$

SOLIDS

Poraver 0.1-0.5 - Mineral Filler (Passing 200 Sieve):

$$Volume_{Mineral\ Filler} = \frac{Percent\ Passing\ No.200\ Sieve \times Total\ SSD\ Volume\ Poraver\ 0.1-0.5}{100\%}$$
$$= \frac{1.5\% \times 3.18\ ft^3}{100\%} = 0.0477\ ft^3$$
$$W_{Mineral\ Filler} = Volume_{Mineral\ Filler} \times SG_{Poraver\ 0.1-0.5} \times 62.4 = 0.0477ft^3 \times 0.583 \times 62.4 = 1.74\ lbs$$

Poraver 0.5-1 - Mineral Filler (Passing 200 Sieve):

$$Volume_{Mineral\ Filler} = \frac{Percent\ Passing\ No.200\ Sieve \times Total\ SSD\ Volume\ Poraver\ 0.5-1}{100\%}$$
$$= \frac{0.3\% \times 2.57\ ft^3}{100\%} = 0.0077\ ft^3$$
$$W_{Mineral\ Filler} = Volume_{Mineral\ Filler} \times SG_{Poraver\ 0.5-1} \times 62.4 = 0.0077ft^3 \times 0.441 \times 62.4 = 0.212\ lbs$$

Poraver 2-4 - Mineral Filler (Passing 200 Sieve):

$$Volume_{Mineral\ Filler} = \frac{Percent\ Passing\ No.200\ Sieve \times Total\ SSD\ Volume\ Poraver\ 2-4}{100\%}$$
$$= \frac{0.87\% \times 5.35\ ft^3}{100\%} = 0.0465\ ft^3$$
$$W_{Mineral\ Filler} = Volume_{Mineral\ Filler} \times SG_{Poraver\ 2-4} \times 62.4 = 0.0465ft^3 \times 0.298 \times 62.4 = 0.865\ lbs$$

Utelite Crushed Lightweight Structural Aggregate - Mineral Filler (Passing 200 Sieve):

$$Volume_{Mineral\ Filler} = \frac{Percent\ Passing\ No.200\ Sieve \times Total\ SSD\ Volume\ Utelite}{100\%} = \frac{2.27\% \times 4.28\ ft^3}{100\%}$$
$$= 0.0971\ ft^3$$
$$W_{Mineral\ Filler} = Volume_{Mineral\ Filler} \times SG_{Utelite} \times 62.4 = 0.0971ft^3 \times 1.71 \times 62.4 = 10.36\ lbs$$

Glass Bubbles S22:

$$Volume_{Mineral\ Filler} = \frac{Percent\ Passing\ No.200\ Sieve \times Total\ SSD\ Volume\ S22}{100\%} = \frac{100\% \times 3.216\ ft^3}{100\%}$$
$$= 3.216\ ft^3$$
$$W_{Mineral\ Filler} = Volume_{Mineral\ Filler} \times SG_{S22} \times 62.4 = 3.216\ ft^3 \times 0.22 \times 62.4 = 44.15\ lbs$$

Total Weight Solids:

$$\sum W_{solids} = 1.74\frac{lbs}{yd^3} + 0.212\frac{lb}{yd^3} + 0.865\frac{lb}{yd^3} + 10.36\frac{lbs}{yd^3} + 44.15\frac{lbs}{yd^3} = 57.33\ lb/yd^3$$

WATER
Batch Water: $$w_{batch} = w - \left(w_{free} + \sum w_{admx}\right) = 285.7\frac{lb}{yd^3} - \left(-51.63\frac{lb}{yd^3} + 22.7\frac{lb}{yd^3}\right) = 314.63\ lb/yd^3$$
Total Volume of Water: $$Volume_{Water} = \frac{w}{62.4} = \frac{285.7}{62.4} = 4.58\ ft^3$$

DENSITIES, AIR CONTENT, SLUMPS, AND RATIOS
Mass of Concrete (M): $$M = W_{CM} + W_{Fibers} + W_{Aggregates} + W_{Solids} + W_{water} = 516.9\ lbs + 2.52\ lbs + 784.9\ lbs + 57.33\ lbs + 285.7\ lbs = 1647.35\ lbs$$
Absolute Volume of Concrete (V): $$V = V_{CM} + V_{Fibers} + V_{Aggregates} + V_{Solids} + V_{water} = 2.82\ ft^3 + 0.032\ ft^3 + 16.06\ ft^3 + 3.41\ ft^3 + 4.58\ ft^3 = 26.88\ ft^3$$
Theoretical Density (T): $$T = \frac{M}{V} = \frac{1647.35\ lbs}{26.88\ ft^3} = 62.28\ lb/ft^3$$
Measured Density (Wet Unit Weight) (D): $$Mass_{Container} = 16.13\ lbs$$ $$Volume_{Container} = 0.2\ ft^3$$ $$Mass_{Container+Concrete} = 30.399\ lbs$$ $$D = \frac{Mass_{Concrete}}{Volume_{Container}} = \frac{30.399\ lbs - 16.13\ lbs}{0.2\ ft^3} = 71.35\ lb/ft^3$$
Air Content: $$Air\ Content = \frac{T-D}{D} \times 100\% = \frac{62.28\frac{lb}{ft^3} - 71.35\ lb/ft^3}{62.28\ lb/ft^3} \times 100\% = -16.5\%$$ $$Air\ Content = \frac{27 - \Sigma V}{27} \times 100\% = \frac{27 - 26.88}{27} \times 100\% = 0.37\%$$
Water-Cement Ratio: $$\frac{285.7\ lbs\ water}{260.0\ lbs\ cement} = 1.099$$
Water-Cementitious Material Ratio: $$\frac{285.7\ lbs\ water}{516.9\ lbs\ cementitious\ material} = 0.553$$
Ratio of Aggregate Volume to Total Volume: $$\frac{V_{agg.SSD}}{27} = \frac{16.06\ ft^3}{27\ ft^3} = 0.5948 > 0.3\ \rightarrow Okay!$$
Ratio of Expanded Glass and Cenospheres to Total Aggregates $$\frac{V_{EG+C}}{V_{agg.SSD}} = \frac{10.97\ ft^3}{16.06\ ft^3} = 0.6831 < 0.7 \rightarrow Okay!$$
Measured Slump: $$Slump = 0.5\ in$$

Appendix B: Structural Calculations

I. Cross-Sections Sample Calculation: 80 lb/ft Loaded Canoe with 2 Paddlers

Assumptions:

- 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

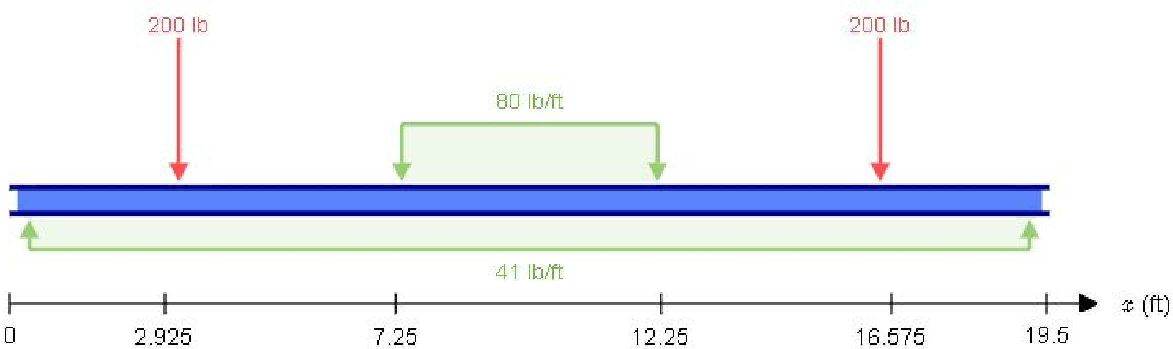
Predefined Variables:

- Canoe weight: 240 lbs
- Canoe length: 19.5 ft
- Net force load distribution along canoe:

$$\frac{80\,\frac{lb}{ft}\cdot 5\,ft + 2\cdot 200\,lb + 240\,lb}{19.5\,ft} - \frac{240\,lb}{19.5\,ft} = 41\,\frac{lb}{ft}$$

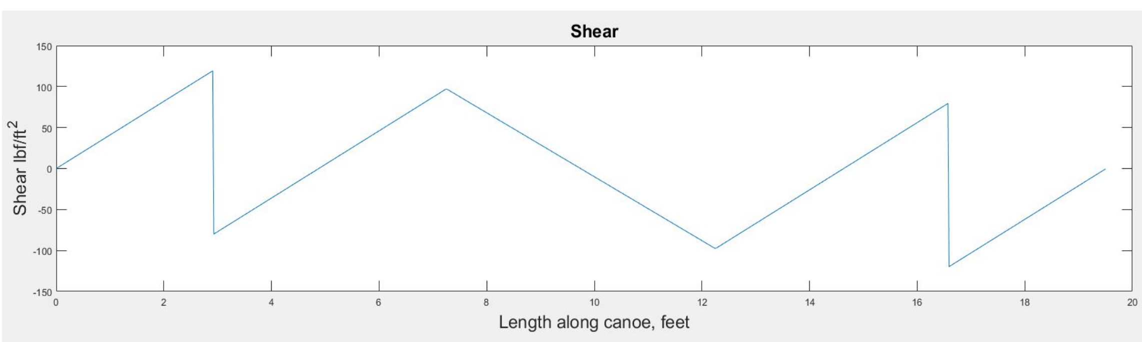
- Paddlers at positions 15% and 85%, 2.925 ft and 16.575 ft

Free Body Diagram:



Singularity Function for Loading Case:

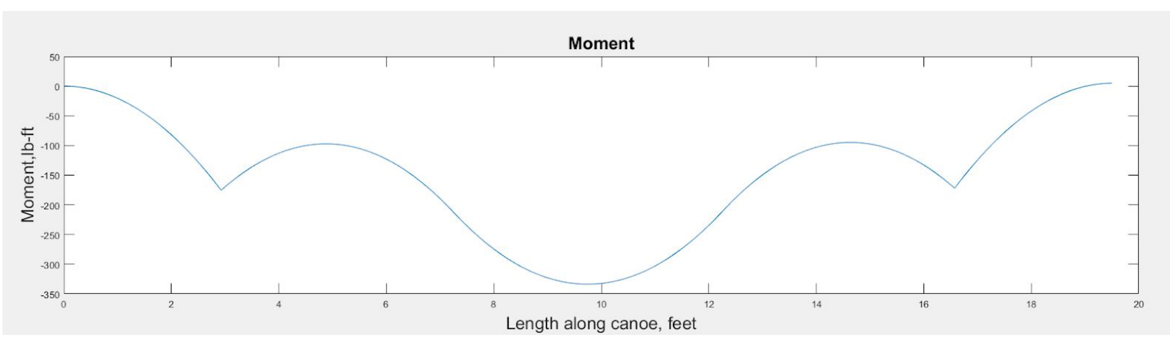
$$V = 41 < x >^1 - 200 < x - 2.925 >^0 - 80 < x - 7.25 >^1 + 80 < x - 12.25 >^1 - 200 < x - 16.575 >^0$$



Shear diagram for sample case

Bending Moment Singularity Function Calculation:

$$M = -\int V\,dx = \frac{41}{2} < x >^2 - 200 < x - 2.925 >^1 - 40 < x - 7.25 >^2 + 40 < x - 12.25 >^2 - 200 < x - 16.575 >^0$$



Bending Moment diagram for sample case

Moment of Inertia Calculations:	Results:
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: 16.5900 in^2 Area sides: 7.1 in^2 Centroid of Bottom : $y1 = t_h/2 = 0.35$ in. Centroid of Walls: $y2 = h/2 = 7.1$ in. Centroid Axis (Distance from bottom): $y_c = \Sigma A_i y_i / \Sigma A_i = 9.0809$ in. Central Axis Moment of Inertia of rectangular segments $= \frac{bh^3}{12}$ $I_{base} = 0.7060\ in^4$ $I_{side} = 238.6\ in^4$	Maximum Bending Moment: **-333.78 ft-lb**, **9.74 ft from bow** Moment of Inertia of Cross-Section: $I = \Sigma(I + A_i d_i)$ **= 1559.66** in^4 **Max Tensile stress** σ^-: My_{top}/I **= 13.15 psi** **Max Compressive stress** σ^+**:** My_{bottom}/I **= 23.32 psi** **Maximum Shear Stress** τ_{max}: From singularity function: V, max shear force = 119.75 lbs A, Cross sectional area =30.79 in^2 $\tau_{max} = \frac{V}{A}$ **=3.89 psi**

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

Concrete Maximum Stresses:

$\sigma_{max}^{+} = 1470$ psi compressive stress

$\sigma_{max}^{-} = 650$ psi tensile stress

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

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

$y_{max} = y_{bottom}$

$M_{cracking} = (f_r \cdot I)/(y_{max}) =$ **3086.75 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.

$\sigma_{max}^{+} = 1470\ psi$

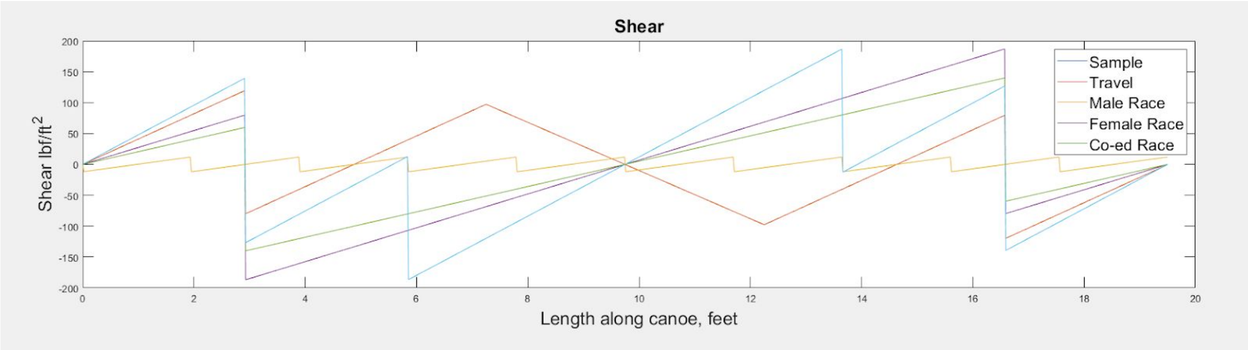
$M_{ultimate} = (\sigma_{max}^{+} \cdot I)/(y_{max}) =$ **21039.58 ft-lb bending moment**

II. Structural Analysis of Additional Loading Cases

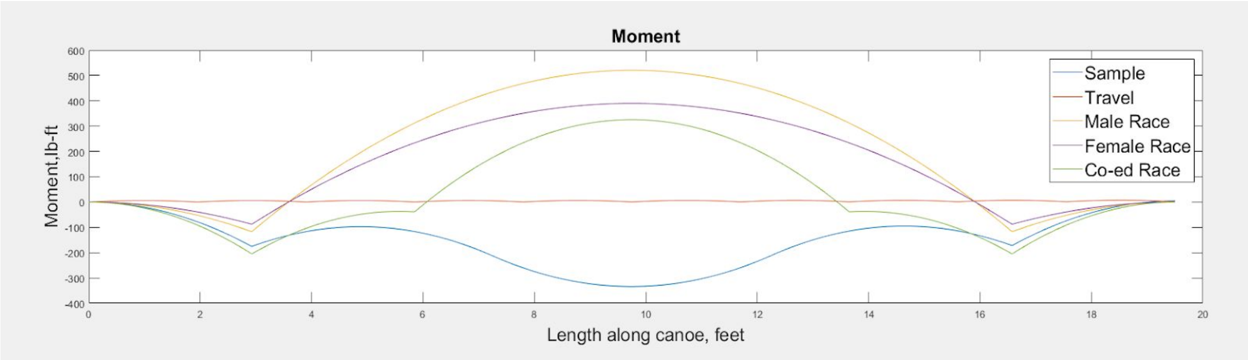
Maximum Moment = 520 ft-lb during Male Race
Location: 9.74 ft from bow

	Estimated Weight (lbs.)	Factored Weight (lbs.)
Canoe	200	240
Paddler (M)	167	267
Paddler (F)	125	200

Max compressive stress $\sigma^- = My_{top}/I = 20.51$ psi
Max tensile stress $\sigma^+ = My_{bottom}/I = 34.97$ psi



Shear diagram for all loading cases



Bending moment diagram for all loading cases

<u>Shear Stress in Chines:</u>

Assumptions:

- Canoe walls are modeled as cantilever beams, supported from the hull bottom
- Canoe side walls are vertical
- Canoe is submerged to gunwale in water for sake of analysis
- Density of water ~63 pcf
- Untransformed hull considered (no reinforcement)

Stress Calculations:

Maximum Canoe Wall height = 14.8 in.

Stress multiplied by a factor of 1.3 to account for wave impact forces

$P_{max} = 1.3\rho gL = (1.3)(63 \text{ pcf})(14.8 \text{ in.}) = (1.3)(.036563 \text{ lbs/in}^3)(14.8 \text{ in.}) = 0.702 \text{ psi}$

Assuming 1 inch length for analysis

$$V_{max} = \frac{PbL}{2} = \frac{(0.702\ psi)(1\ in.)(15.4\ in.)}{2} = 5.4\ lbs$$

Maximum Shear Stress τ_{max}

$$\tau_{max} = \frac{3V}{2A} = \frac{(3)(5.4\ lbs.)}{(2)(1\ in.)(0.6\ in.)} = \mathbf{13.5\ psi}$$

Maximum Deflection:

$$I = bt^3/12 = (1/12)(1\ in.)(0.6\ in.)^3 = .018\ in^3$$

$$Density,\ w_c = 61.8 \text{ pcf}$$

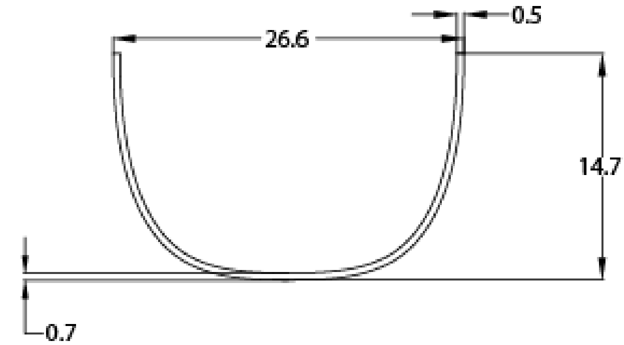
$$E = w_c^{1.5} 33\lambda\sqrt{(f'c)} = (67^{1.5})(33)(0.75)\sqrt{(1470)} = 461,016\ psi$$

$\lambda = 0.75$ for lightweight aggregate concrete

$$\delta_{max} = \frac{wd^4}{30EI} = \frac{(0.702psi * 1in.)(15.4\ in.)^4}{(30)(461{,}016\ psi)(0.018\ in^3)} = \mathbf{0.159\ in.}$$

Appendix C: Hull Thickness/Reinforcement and POA 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

$d_1 = 1.0\ in$

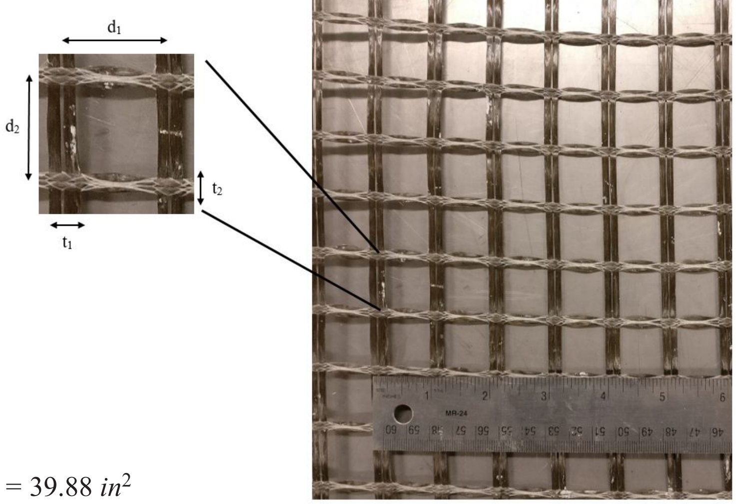
$d_2 = 1.0\ in$

$t_1 = 0.25\ in$

$t_2 = 0.156\ in$

$n_1 = 7$

$n_2 = 9$



$Area_{open} = (d_1 - t_1)(d_2 - t_2) * n_1 * n_2$

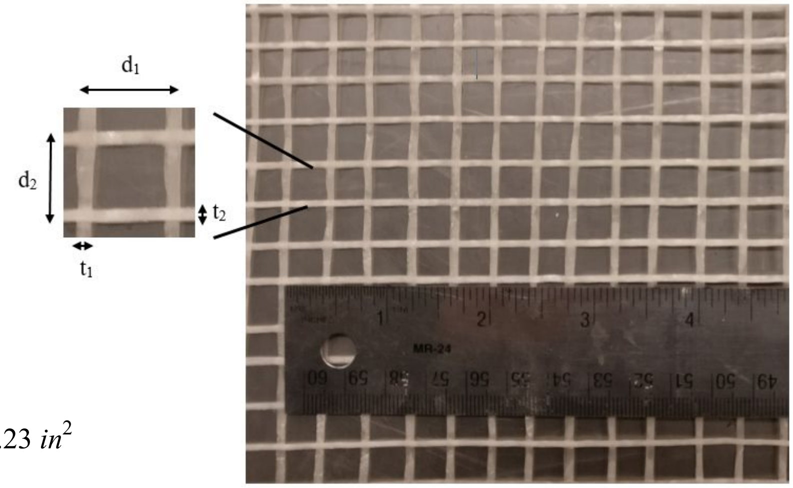
$= (1.0\ in - 0.25\ in)(1.0\ in - 0.156\ in) * 7 * 9 = 39.88\ in^2$

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 4.875in x 4.5in sample



$d_1 = 0.375\ in$

$d_2 = 0.375\ in$

$t_1 = 0.0625\ in$

$t_2 = 0.0625\ in$

$n_1 = 13$

$n_2 = 12$

$$Area_{open} = (d_1 - t_1)(d_2 - t_2) * n_1 * n_2$$

$$= (0.375\ in - 0.0625\ in)^2 * 12 * 13 = 15.23\ in^2$$

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**

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Appendix E: Supporting Documentation

Pre-Qualification Form (Page 1 of 3)

UC Berkeley
(school name)

We acknowledge that we have read the 2020 ASCE National Concrete Canoe Competition Request for Proposal and understand the following (*initialed by team project manager* and *ASCE Faculty Advisor*):

The requirements of all teams to qualify as a participant in the Conference and National Competitions as outlined in Section 2.0 and Attachment 1. KY N.S.

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 (Attachment 1) KY N.S.

The eligibility requirements of registered participants (Section 2.0 and Attachment 1) KY N.S.

The deadline for the submission of *Preliminary Project Delivery Schedule* and *Pre-Qualification Form* (uploaded to ASCE server) is November 1, 2019; 11:59 p.m. Eastern KY N.S.

The last day to submit *ASCE Student Chapter Annual Reports* to be eligible for qualifying (so that they may be graded) is February 1, 2020 KY N.S.

The last day to submit *Request for Information* (RFI) to the CNCCC is January 15, 2020 KY N.S.

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. KY N.S.

The submission date of *Technical Proposal* and *MTDS Addendum* for Conference Competition (hard copies to Host School and uploading of electronic copies to ASCE server) is Monday, February 17, 2020. KY N.S.

The submission date of *Technical Proposal* and *MTDS Addendum* for National Competition (hard copies to ASCE and uploading of uploading of electronic copies to ASCE server) is May 19, 2020; 5:00 p.m. Eastern. KY N.S.

Katrina Yap — 10/30/19
Project Manager (print name) — (date)

[signature]
(signature)

NICHOLAS SITAR — 10/30/2019
ASCE Student Chapter Faculty Advisor (print name) — (date)

[signature]
(signature)

Pre-Qualification Form (Page 2 of 3)

University of Califonia, Berkeley
(school name)

In 150 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?

All members are required to take an online health and safety course, followed by an in-person lab training session with our lab manager. In addition to this, members are trained to use any tools and equipment relevant to their roles during their first few weeks of participation on the team. Members are only allowed to work under the supervision of an officer, who is responsible for upholding safe practices during their shift. Whenever the team works with hazardous materials or conditions that not all members are familiar with, an officer will brief members on the required PPE and details of the hazard.

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?

The team's current QA/QC program is overseen by a lead QA/QC officer who implements QA/QC efforts in tandem with the project managers and other officers. The officer works with the division officers to provide quality assurance in the design process and materials procurement, including confirming adherence to regulations and materials standards. To guarantee quality control, the QA/QC officer is active in the canoe construction process and collaborates with the materials, construction, and graphics divisions to ensure consistency across concrete batching, cylinder testing, and construction practices.

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, all relevant Department and University safety policies are addressed in the required online health and safety course or during the in-person lab training.

The anticipated canoe name and overall theme is – *"Calaxy" and will feature space-themed graphics and embody the spirit of space exploration.*

Has this theme been discussed with the team's Faculty Advisor about potential Trademark or Copywrite issues?

Yes, our team aims to use generic graphical elements created by our members, unless proper permission is obtained.

The core project team is made up of 12 ***number of people.***

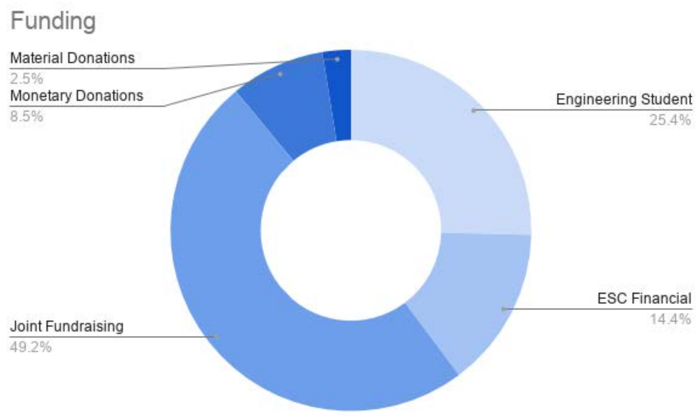
Pre-Qualification Form (Page 3 of 3)

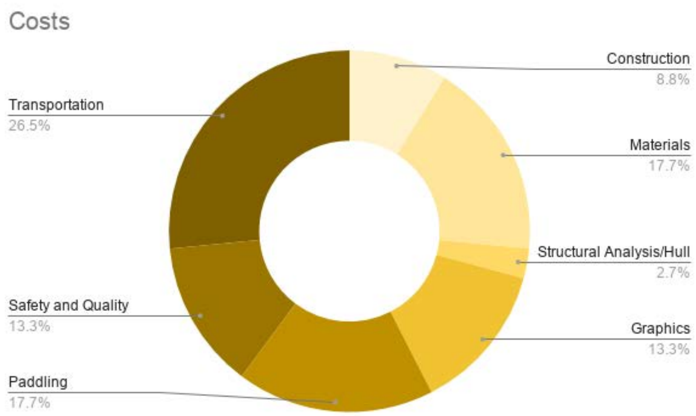
University of California, Berkeley

(school name)

Provide an estimated project budget for the year (including materials, transportation, etc.). Base this on real costs (not costs provided in the Detailed Cost Assessment). List and approximate (percentage (%) of overall) anticipated financial sources for the upcoming year (University, material donations, sponsors, monetary donations, etc.)

Description	Amount
Funding	
Engineering Student Council (ESC)	$3,000
ESC Financial Committee	$1,700
Joint Fundraising Committee	$5,815
Monetary Donations	$1,000
Material Donations	$300
TOTAL	$11,815
Costs	
Construction	$1,000
Materials	$2,000
Structural Analysis/Hull Design	$300
Graphics	$1,500
Paddling	$2,000
Safety and Quality Control	$1,500
Transportation	$3,000
TOTAL	$11,300





RFP Addendum Acknowledgment Form

UC Berkeley
(school name)

We acknowledge that we have received and acknowledge the following Addendums to the 2020 ASCE National Concrete Canoe Competition Request for Proposal (*initialed by team project manager and ASCE Faculty Advisor*):

Addendum No. 1: Presentation Q&A

This Addendum provides the Technical Presentation score card and a list of questions that the judges can use during the 10-minute Judge's question & answer period. In addition, a scorecard was provided.

Per Section 8.0 of the Request for Proposals (RFP), the presentation is limited to 3 minutes and will be cutoff at precisely 3 minutes by a signal. Also, per Section 8.0 of the RFP, the technical presentation "...should focus on the primary aspects of the design, construction, and technical capabilities. Briefly summarize the major aspects of the project, with the intent of demonstrating why your team, design, and prototype should be selected by the panel of judges for the standardized design (recall this is a hypothetical scenario to provide an end goal for the RFP and the competition)." KY N.S.

Addendum No. 2: Durability & Repairs

This Addendum provides information regarding how the durability of the canoe prototype is to be assessed, allowable repairs and materials, and forms including *Damage / Accident Report*, *Repair Procedure Report*, and *Reconstruction Request*. KY N.S.

Addendum No. 3: Detailed Cost Assessment

This Addendum provided a list of material costs for a variety of cementitious materials, pozzolans, admixtures, fibers, aggregates, and other constituents that were not presented in *Attachment 4: Detailed Cost Assessment* of the Request for Proposal. Teams were also advised that if they have products that were not given a specific price for, they should use their best judgement to use a price for a similar material in their Material Cost Estimate. KY N.S.

Katrina Yap — 2/12/20
Project Manager (print name) — *(date)*

Katrina Yap
(signature)

Nicholas Sitar — 02/12/20
ASCE Student Chapter Faculty Advisor (print name) — *(date)*

NICHOLAS SITAR
(signature)