2021 Technical Proposal

Arizona State University

Tempe, AZ

Cover Letter and Project Understanding

Date: February 19th, 2021

To: Committee on Concrete Canoe Competitions (C4)

Subject: Response to Request for Proposal – Arizona State University

Dear Committee on Concrete Canoe Competitions,

For the Arizona State University canoe, *Sun Devil Crossing*, this statement certifies that:

1. The proposed hull design, concrete mixture design, and reinforcement scheme are in full compliance with the specifications outlined in the Request for Proposal.
2. All relevant Material Technical Data Sheets (MTDS) and Safety Data Sheets (SDS) for materials proposed for the construction of the canoe have been reviewed by the team.
3. The team is in receipt of the Request for Information (RFI) Summary and that their submissions comply with the RFI responses provided.
4. The anticipated registered participants are qualified student members and Society Student Members of ASCE and meet all eligibility requirements (including the names and ASCE Society Member ID Numbers).

The names, preferred pronouns, and ASCE IDs for registered participants are listed as such:

Registered Participants					
Name	**Pronouns**	**ASCE ID**	**Name**	**Pronouns**	**ASCE ID**
Edward Apraku	**He/Him/His**	**11175672**	**Peter Nguyen**	**He/Him/His**	**11951429**
Arely Lopez Cortez	**She/Her/Hers**	**12216710**	**Alexandra Plukis**	**She/Her/Hers**	**12214362**
Lazaros Karakozis	**He/Him/His**	**12219506**	**Gabriella Stadler**	**She/Her/Hers**	**11951359**
Alejandro Muñoz	**He/Him/His**	**11798890**			

We recognize the impact that COVID-19 has had on the world and thank the efforts of C4 for continuing with the competition this year. We recognize it was not an easy decision given the uncertainty surrounding future conferences. Arizona State University is dedicated to completing this year's requirements while ensuring that all members stay healthy and safe during this unprecedented time.

Sincerely,

Arizona State University Concrete Canoe Team

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Executive Summary

In 2001, Nintendo released the original Animal Crossing game, establishing a virtual world where players can create a human character and socialize with anthropomorphic creatures in their village. Since then, the series has released seven other games and has become a worldwide phenomenon (Verge, 2020). Much of the world turned to the latest version of the game, *Animal Crossing: New Horizons*, during the stay-at-home orders caused by COVID-19. The escapism helped calm the nerves of many and allowed for social interaction while social distancing. To align with this, the ASU Concrete Canoe team wanted our theme to evoke joy, tranquility, and adventure during a moment plagued with fear and uncertainty. Thus, this year's canoe is aptly named *Sun Devil Crossing* to acknowledge the spirit of adventure and friendship brought by the Animal Crossing universe.

With four locations across the Phoenix metropolitan area, the main Arizona State University campus resides in Tempe, Arizona and is home to about 75,000 undergraduate and graduate students (Arizona State University, 2020). The university houses the Ira A. Fulton Schools of Engineering which currently enrolls more than 25,000 students with about 1,300 of those belonging to the School of Sustainable Engineering and the Built Environment (SSEBE) as civil, environmental, construction engineering, or construction management disciplines (Arizona State University, 2020). Recent national rankings place ASU in the top 50 public universities, top 45 best engineering schools, and #1 in innovation for the sixth year in a row (U.S. News, 2020).

The ASU Concrete Canoe Team (ASUCCT) competes in the Pacific Southwest Conference as one of the 18 university participants. This year, the conference will be hosted by the University of California, Los Angeles through the virtual space. The canoe team placed seventh with *Bullet Bill* (2018), fifth with *The Maroon Machine* (2019), and sixth with *Legacy* (2020). The ASU team was committed to producing a quality canoe despite the challenges caused by the COVID-19 pandemic.

The team this year consisted of an entirely new administrative team consisting of two project managers (PM), additional team alumni, new captains, and a dedicated number of underclassmen volunteers. The composition allowed for new innovative ideas to be implemented across all aspects of the canoe while also allowing for a smaller knowledge gap between the current and future teams.

Table 1. Canoe Physical Properties

Property	Value
Name	Sun Devil Crossing
Length	242 in
Maximum Width	25 in
Maximum Depth	15 in
Average Thickness	9/16 in.
Estimated Weight	215 lbs
Colors	Blue, Tan, and Green
Primary Reinforcement	Carbon Fiber Mesh
Secondary Reinforcement	Polypropylene Micro-Fibers Copolymer Macro-Fibers

Due to the cancellation of PSWC 2020 and the abrupt closing of campus laboratories, the team was unable to analyze racing performance for the previous canoe, *Legacy*. Thus, this year, the team utilized computer software to analyze various canoe dimensions until a final one was chosen, as seen in Table 1. This canoe incorporated elements from both 2019's *The Maroon Machine* and 2020's *Legacy* while emphasizing straight-line speed and efficacy.

The mix design team created a singular mix, adhering to C4 rules, focusing on creating a strong structural mix without the use of manufactured microspheres or cenospheres, and prioritizing team health. The team reduced the amount of materials in the cementitious mix and was able to satisfy strength requirements as shown in Table 2.

Table 2. Mix Design Properties

Concrete Properties	Final Mix
Density (Fresh Concrete)	65.7 pcf
Density (Hardened Concrete)	60 pcf
Compressive Strength	1450 psi
Tensile Strength	210 psi
Flexural Strength	880 psi
Slump	1 in
Air Content	3.7 %

The 2021 ASU Concrete Canoe team is proud to present *Sun Devil Crossing*: a competitive and aesthetically pleasing canoe submission that incorporates existing research and new designs while analyzed and constructed in the virtual space.

Introduction to Project Team

ASCE STUDENT CHAPTER PROFILE

The Arizona State University chapter of the American Society of Civil Engineers (ASU ASCE) was chartered in 1962 as one of the first student organizations in the newly established College of Engineering and has competed continuously in the Pacific Southwest Conference (PSWC). Today, the student organization has grown to be one of the largest in the Fulton Schools of Engineering with 441 members encompassing a wide variety of engineering disciplines. ASCE at ASU has won several awards, most notably being the Outstanding Undergraduate Fulton Student Organization in 2018, beating 60+ organizations (Inner Circle, 2018).

The ASU ASCE student chapter prides itself on the development of professional consciousness, the opportunity for SSEBE students to become acquainted and to practice working together effectively, the promotion of a spirit of congeniality among students, and the establishment of friendly contact with the engineering profession. The club maintains a high retention rate, with many students stating that the PSWC technical and non-technical competitions and the underclassmen mentorship program were the primary reasons why they stayed in their major.

The student chapter actively engages in community outreach programs, professional/student development, technical tours, Zoom social events, and interaction opportunities. An example of this is their annual participation in Night of the Open Door, an ASU event that focuses on inspiring the next generation of engineers by teaching elementary, middle, and high school students through hands-on activities. The club also works with other engineering organizations such as Engineers Without Borders, Chi Epsilon Honors Society, and the Society of Water and Environmental Leaders to execute social and volunteering events.

The organization offers biweekly general body meetings, allowing students to hear from local industry speakers, current PhD students, SSEBE faculty, and ASU ASCE alumni. During the 2019-2020 academic year, the speakers touched on topics ranging from financial responsibility after undergrad to research in structural finite element analysis.

Figure 1. ASU Attendees on Canoe Display Day at PSWC 2019

These diverse meeting topics allow for the holistic development of our members as they gain exposure to real problems facing the future of the profession.

The organization is run by fifteen student officers, two faculty advisors, and two Phoenix YMF industry advisors. Year-long officer positions include the Treasurer, Secretary, Facilities Manager, Conference Coordinator, Competition Manager, and Concrete Canoe Project Manager. Semester-long positions include the President, Vice President, Undergraduate Student Government Representative, Outreach Chair, Recruitment Chair, Fundraising Chair, Social Chair, Public Relations Director, and Industry Liaison. This division in officer positions lengths is meant to encourage freshmen and sophomore members to gain experience through introductory positions. The chapter maintains a strong relationship with the local Phoenix Branch YMF Chapter by regularly attending its meetings and engaging in a mentorship program that pairs upperclassmen with recent ASU graduates in industry. ASU ASCE and Concrete Canoe officers have attended several ASCE conferences such as the ASCE National Convention, Workshop for Student Chapter Leaders (WSCL), Geo-Congress, and the Arizona ASCE Virtual Conference.

The chapter has sent a myriad of students to the PSWC regional competition to participate in the technical, sporting, and miscellaneous competitions since its founding. The chapter co-hosted the conference with NAU in 2018 and sent 65 students, 73 students competed in 2019 at Cal Poly SLO, and finally 85 students were registered for PSWC 2020 at Cal State Fullerton prior to its cancellation.

Introduction to the Project Team

Key Team Members

Project Managers & Mix Design Captains

Senior

Edward Apraku

Responsible for recruitment, scheduling, fundraising, task delegation, rule compliance, quality assurance & control, safety, and material procurement.

Senior

Alejandro Muñoz

Responsible for research and development of multiple concrete mixes and performing laboratory testing.

Arely Lopez Cortez

Senior

Construction Captain

Responsible for mold construction, concrete casting, finishing, and curing chamber construction.

Gabriella Stadler

Junior

Aesthetics Captain

Responsible for theme, canoe design, report aesthetics, alumni video, t-shirt design, and helping with website.

Peter Nguyen

Junior

Hull Design Captain

Responsible for design and analysis of the hull and determining the strength requirements.

Laz Karakozis

Senior

Structural Captain

Responsible for performing structural calculations.

Alexandra Plukis

Senior

Coding Captain

Responsible for creating the website.

Introduction to the Project Team

Organizational Chart

Project Management

Edward Apraku (Sr) – Team Captain
Alejandro Muñoz (Sr) – Team Captain

Hull Design

Peter Nguyen (Jr) – Hull Design Captain
Edward Apraku (Sr) – Team Captain
Caleb Siff (So)
Maya Elliott (Jr)

Construction

Arely Cortez (Sr) – Construction Capt.

Webmasters

Alexandra Plukis (Sr) – Coding Captain
Gabriella Stadler (Jr) – Aesthetics Capt.

Academics

Initial Research
Edward Apraku (Sr) – Team Captain
Technical Report
All Captains
Susanna Westersund (So)
Jillian Barcena (Jr)
Enhanced Focus Areas Report
Edward Apraku (Sr) – Team Captain
Alexandra Plukis (Sr) – Coding Captain
Gabriella Stadler (Jr) – Aesthetics Capt.
Peyton Wisch (Jr)
Presentation
Edward Apraku (Sr) – Team Captain
Alejandro Muñoz (Sr) – Team Captain

Finances

Edward Apraku (Sr) – Team Captain
Jeremy Guerrero (Sr)

Facilities Manager

Nicole Trujillo (Sr)

Mix Design

Alejandro Muñoz (Sr) – Team Captain
Edward Apraku (Sr) – Team Captain
Laz Karakozis (Sr) – Structural Captain
Peter Nguyen (Jr) – Hull Design Captain
Addison Sherman (Sr)
Alyssa Sygrove (Sr)
Grace Brenize (Fr)
Janelle Miguel (Fr)
Jeremy Guerrero (Sr)
Maaz Ullah (Sr)
Marcela Strane (Sr)
Marisela Arias (Sr)
Maya Elliott (Jr)
Thomas Crosby (Jr)
Samuel Suwarno (Jr)
Susanna Westersund (So)
Valentina Rivera (Jr)

Transfer of Knowledge

Caleb Siff (So)
Grace Brenize (Fr)
Idali Reyes Nevarez (Fr)
Janelle Miguel (Fr)
Joseph Todsen (Jr)
Jose Mari Hilao (So)
Jillian Barcena (Jr)
Liam Orourke (Jr)
Maya Elliott (Jr)
Peyton Wisch (Jr)
Thomas Crosby (Jr)
Si Thu Tun Oo (Fr)
Susanna Westersund (So)
Valentina Rivera (Jr)
Zane Monell (So)

Canoe Analysis

Structural Analysis
Laz Karakozis (Sr) – Structural Captain
Edward Apraku (Sr) – Team Captain
Gabriella Stadler (Jr) – Aesthetics Capt.
Caleb Siff (So)
Joseph Todsen (Jr)
Concrete Mixture Analysis
Alejandro Muñoz (Sr) – Team Captain

Aesthetics

Gabriella Stadler (Jr) – Aesthetics Capt.
Alexandra Plukis (Sr) – Coding Captain
Camila Ibarra (Sr)
Janelle Miguel (Fr)
Joseph Todsen (Jr)
Marcela Strane (Sr)

Alumni

Brielle Januszewski – (BSE '20)
Mark Natale – (BSE '19)
Matthew Aguayo – (PhD '18)
Aashay Arora – (PhD '18)
Steven Sherant – (BSE '15)

Faculty/Staff Advisors

Dr. Keith Hjelmstad
Dr. Kristen Ward
Dr. Narayan Neithalath
Kristen Pena
Shelli Wright
Stan Klonowski

Technical Approach to the Overall Project

HULL DESIGN

The primary goal for hull design this year was to incorporate a modeling software to better justify the chosen hull design and mitigate the lack of feedback from *Legacy*. Simulated race day iterations from *Legacy*, paddler feedback from *The Maroon Machine*, and alumni suggestions were combined to create the competitive design for *Sun Devil Crossing*. Continuing on the last five years, the team utilized a MATLAB code developed by an alumnus to design and analyze the canoe hull.

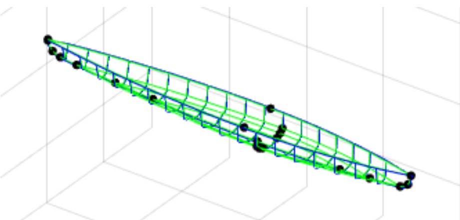


Figure 2. MATLAB Quadratic Spline Output

Figure 2 shows the finalized spline interpolation after being given inputs through an Excel file.

Four coordinate models were constructed using the code and individual characteristics are shown in Table 3. These Microsoft Excel designs were modeled in the computer software DELFTship™ for residual and frictional resistance calculations using the John Winters' (KAPER) Resistance Method (DELFTship™ 2020). Each model was tested for effective power, frictional resistance, and residual resistance at various speeds. The team utilized race day performances and paddling practices to best identify likely power scenarios.

Table 3. Model Characteristics

Hull Model Specifications				
Model	**Bow Height**	**Stern Height**	**Max Depth**	**Max Width**
Scenario 1	8 in	8 in	14 in	24 in
Scenario 2	9 in	9 in	15 in	26 in
Scenario 3	8.5 in	8.3 in	15 in	25 in
Legacy	7.7 in	7.5 in	15 in	26 in
Sun Devil Crossing	9 in	9 in	15 in	25 in

The prismatic coefficient was optimized in the software after taking multiple hull designs and plotting their resistance graphs against *Legacy* and *The Maroon Machine*. The software used the spline coordinates from MATLAB to construct a 3D model of the current and former canoes. Multiple models were made in the program and the resistance and power graphs were generated in Figure 3.

Table 4. Prismatic Coefficient Values

Prismatic Coefficient	
Bullet Bill (2018)	0.48
Maroon Machine (2019)	0.50
Legacy (2020)	0.52
Sun Devil Crossing (2021)	0.53

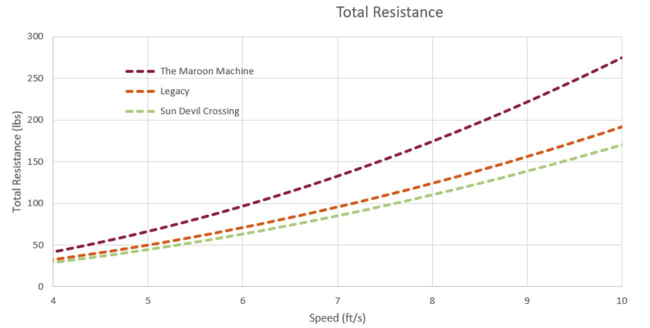


Figure 3. Total Resistance Testing Against ASUCCT Canoes

The asymmetrical hull profile continued with *Legacy's* curved bottom but also incorporated the straight, but slightly flared, sides above the chine seen in *The Maroon Machine*. This configuration would allow for increased straight-line speed while providing paddlers with the easy maneuverability through stability. The width of the canoe was decreased by 1" to 25" due to the less dramatic flaring of the sides and allows for comfortable paddling motion and decreased resistance at higher speeds. This alteration also decreased the overall wetted surface area. The team counteracted this by raising the bow and stern coordinates and increasing the prismatic coefficient by 1.92% as shown in Table 4. The location of the widest cross-section on the canoe was placed 18" behind the symmetrical center of canoe to accommodate the small angle of attack at the bow. While the offset from center of gravity may contribute to difficulty during turns, the team believed this could be counteracted through improved paddling training using *Legacy*.

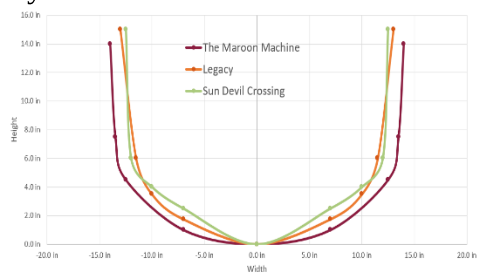


Figure 4. Hull Comparison at Widest Section

The slight angle decrease from 15° to 13° allowed for narrower entry and reduces the amount of concrete used throughout. In the past, water at the widest cross section had been stagnant rather than diverted towards the sides, therefore the max beam was decreased, and the depth was kept at 15”. The bow and the stern rocker were both increased from 7.5” and 7.7” respectively to 9” to help with maneuverability. Similar to *Legacy*, the gunnels and ribs were removed from the final design. The absence of these components was due to previous canoes undergoing crack propagation from the top of the hull during transportation from conference.

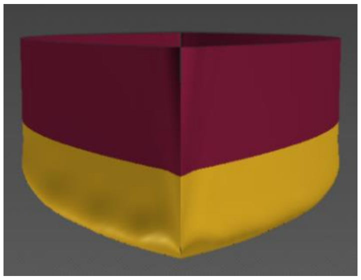


Figure 5. 2021 canoe in DELFTship™

Sun Devil Crossing’s final hull design is asymmetric with a shallow arc bottom across the ends with arched bottom, with straight but slightly flared walls. The overall length is 20’-2”, the beam width at the widest section is 25”, and depth is 15”. The thickness of the canoe is 9/16” throughout. The transverse metacentric height (GM_T) will remain at 1.10 to help with stability and overturning resistance.

STRUCTURAL ANALYSIS

Upon completing the hull design, the team performed a two-dimensional longitudinal and lateral analysis to ensure *Sun Devil Crossing* would endure all loading conditions. MATLAB was used in combination with Excel to compute cross-sectional properties and perform each analysis. Five load cases were considered: (1) display, (2) carrying, (3) two female paddlers, (4) two male paddlers, and (5) coed.

To complete the longitudinal analysis, the canoe was modeled as a simply supported beam with self-weight and paddler weight acting in the negative gravity direction and buoyant force acting in the positive gravity direction. Cuts were taken at 1” intervals to compute the internal forces and moments acting on the cross section shown in Figure 6. Structural analysis was completed using the team MATLAB code.

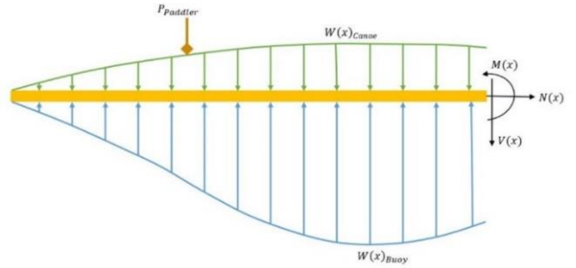


Figure 6. Free Body Diagram for Longitudinal Analysis

Unit weight of concrete was estimated at 60 pcf, a conservative estimate resulting in a total weight of 215 lbs, a 6.5% reduction from *Legacy*. The paddlers were modeled as 190 lbs point loads for males, and 130 lbs for females. To analyze paddling load cases, the net downward forces were set equal to the resultant of the upward buoyant force, allowing for the canoe to remain in static equilibrium and the elimination of simple support reactions. The resultants of the net downward and upward forces were aligned at the centroid of the canoe to eliminate any residual moments. Bending stresses were determined using the theory of simple bending: $\sigma = Mc/I_x$, where: M is the bending moment, c is the distance from the neutral axis to the outer most fiber, and I is the section modulus. The bending stresses were computed using MATLAB and displayed in Figure 7. On-land load cases were analyzed as a simply supported beam. Bending moment diagrams were created for each load case. A dynamic load amplification factor of 2 was applied to account for momentum generated by paddlers. Final analysis values are shown in Table 5.

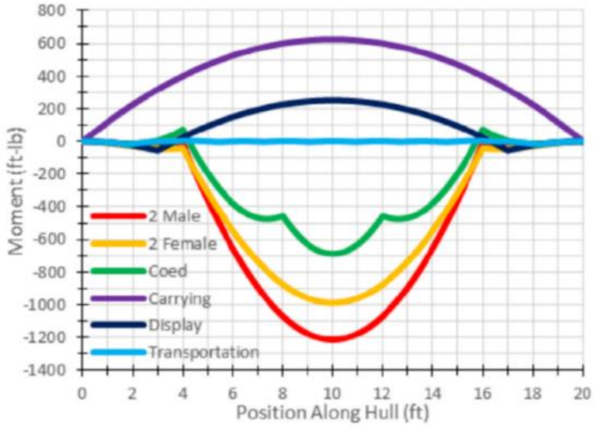


Figure 7. Bending Moment Envelope

Table 5. Maximum Theoretical Structural Stresses

Load Case	Compressive (psi)	Tensile (psi)
2 Male	160	155
2 Female	127	123
Coed	231	224
Carrying	131	110
Display	16	31

CONCRETE DEVELOPMENT AND TESTING

ASUCCT was uncertain regarding the status of the regional and national competition but were determined to complete *Legacy*. As a result, the team began the mix design process in the late summer by working closely with university laboratory officials to estimate the possibility of conducting in-person mix design testing. If restrictions continued into the semester, several local industry partners were identified to help with *Legacy* completion, concrete cylinder creation, and strength testing. Fortunately, the project managers were approved to conduct preliminary testing in early October, and volunteers were approved to help later that month. Test were conducted under strict health guidelines enforced by university officials and team captains including weekly testing and daily health check submission.

The goals for the mix were to develop a highly pigmented structural mix that was lightweight, strong, provides easy workability for placement and finishing. Last year's mix was initially used as a baseline but all microspheres and cenospheres were removed in accordance with the RFP. The initial goals, final results, and comparison results are shown in Table 6.

Table 6. Final 28-day Testing Results

Property	Mix Design Goals	2020-2022 Structural	2019-2020 Structural
Wet Density	60-68 pcf	65.7 pcf	65.1 pcf
Dry Density	<62 pcf	60 pcf	60 pcf
Compressive Strength	1200 psi	1450 psi	2620 psi
Tensile Strength	200 psi	210 psi	280 psi
Flexural Strength	500 psi	880 psi	1060 psi

Legacy's mix consisted of 35% ordinary Portland cement (OPC) (ASTM C150), 20% Class C Fly Ash (ASTM C618), 10% Metakaolin (ASTM C618), 15% VCAS-8 (ASTM C618), 10% Slag cement (ASTM C989) and 10% Silica fume (ASTM C1240). For aggregates, last year's team used varying sizes of Poraver and lightweight clay shale (ASTM C330). Other materials used in the mix include 3M glass bubbles, pigments (ASTM C979), superplasticizer (Plastol 6400) (ASTM C494), air entrainer (AEA 92) (ASTM C260), Grace micro-fibers, and Tuf-Strand Maxten macro-fibers (ASTM C1116). The mix had a unit weight of 60pcf and compressive strength of 2620psi.

The team first focused on reducing the number of materials in the cement paste and justifying the use of each ingredient with external research. To do so, two former ASU Ph.D. students, who previously helped 2017's *Firebolt* team, were contacted for advice on the portion of cementitious materials. After this guidance, the team began researching Ultra-High Performance Concrete (UHPC) and the synergistic properties within its materials.

Mortar cube tests began by alternating volumetric percentages common with UHPC materials. VCAS-8 and Metakaolin were removed and Class C Fly Ash was replaced with its Class F counterpart. The combination of OPC, F Ash, and limestone can improve the mechanical property and durability of concrete and can accelerate the property development at early ages due to the lower heat of hydration (Vance et al., 2013a).

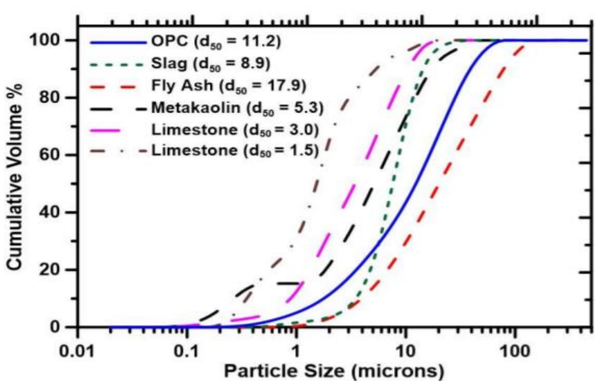


Figure 8. Gradation Size of Materials in UHPC

Figure 8 shows the gradation curve of tested cementitious materials ranging in particle size and cumulative volume. Silica fume was incorporated in the paste due to its beneficial nature with carbonates in the system. The combination of OPC, fly ash, limestone, and silica fume allowed for a dense microstructure and increase in packing density. The team was able to create four separate cementitious paste mixes and conduct mortar cube compression testing, per ASTM C109, as shown in Figure 9. This was an iterative process with slight changes in each design. The maximum compressive strength among different iterations was 5630 psi.

Figure 9. Compression Testing of Mortar Cubes

The final cementitious distribution of the structural mix was determined to be composed of 60% OPC, 20% Class F Fly Ash, 12.5% Limestone, and 7.5% Silica Fume. The composition of the cementitious mix is compared to the composition of last year in Figure 10.

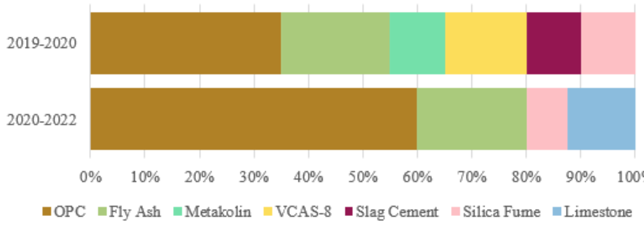


Figure 10. Cementitious Material Gradation

Next, the team then shifted its focus to the aggregate gradation of the mix. ASUCCT welcomed the removal of manufactured microspheres and cenospheres from the aggregate mixture. This change will greatly protect the current and future lung health of mix design volunteers, especially as a respiratory-based pandemic ravages the globe. ASTM C39, C142, C192, and C470 standards for mixing, sampling concrete, curing, and testing concrete cylinders were followed, and 3''x6'' cylinders were used to reduce necessary batch volumes needed to create testing samples and improving project sustainability by reducing the batch volume needed to create testing samples. The team better optimized the mix design spreadsheet to reduce waste material of donated items. This reduction will help improve ASUCCT's waste footprint and provide excess materials for next year. The team began testing replacements with residual pumice samples but due to preliminary density data and delayed material procurement, the material was quickly abandoned. Ultimately, the team found a new material and excellent substitute, foamed glass spheres. This aggregate was composed of recycled post-consumer glass and advertised to improve compressive strength while reducing weight.

ASUCCT had not extensively altered the mix design in several years so the new material brought a comprehensive team exploration of material testing. The team re-evaluated the absorption values of the foamed glass spheres using the ASTM C127 procedure for testing absorption of fine aggregates. The absorption values were originally stated by the manufacturer to be less than 2% but this was deemed inaccurate by the team. The team determined that the absorbance of foamed glass spheres was roughly 19.0% for all gradations. The same tests were used on clay shale whose previous absorption values were listed as 17.6% for fine clay shales, 16.5% for crushed fine clay shales, and 14.3% for 10 mesh clay shale. The team determined an adsorption of 17.4% for all clay shale materials. The adsorption values for the foamed glass spheres were much lower than Poraver (20%-35% for various gradations) and thus the overall water demand for testing was decreased while maintaining adequate workability. The properties of aggregates are shown in Table 7. The team began conducting mix design through an iterative process, using the 14-day compressive strength and workability as the main factors controlling the future iterations.

Table 7. Properties of Aggregates

Aggregate		Specific Gravity	Adsorption (mass %)
Agsco	0.1-0.3 mm	0.4	19
	0.25-0.5 mm	0.340	19
	0.5-1.0 mm	0.260	19
Clay Shale	Fines	0.854	17.4
	Crushed Fines	0.845	17.4
	10 Mesh	0.825	17.4

Technical Approach to the Overall Project

After determining the aggregate portioning, the team iteratively changed the ratio of aggregates to cementitious materials to optimize strength and reduce the unit weight (measured using ASTM C138 and C567). Due to time constraints and reduction of volunteers, only 11 unique mix proportions were created, tested, and recorded. The team then moved onto testing fiber proportioning to see if any adjustments needed to be made. GRACE micro-fibers and Tuf-Strand Maxten macro-fibers (ASTM C1116) were already in use in *Legacy* and the team viewed the longevity as an asset and began testing with these materials. Again, the fibers were tested iteratively using identical mixes with various fiber amounts, flexural concrete beams, and tensile testing. Flexural testing relied on ASTM C78 standard to guide the testing procedure for beam specimens under three-point loading. The tensile testing used ASTM C496 standards as a guide. However, the micro-fiber and macro-fiber dosages remained at 3.10 lb/yd^3 and 4.00 lb/yd^3 respectively because of their known mutual reliability and synergistic relationship.

Figure 11. Beam Mold Prior to Three Point Bending Test

Finally, the team tested admixtures to find suitable dosages to achieve appropriate workability and to reduce the unit weight. *Legacy* used 18.26 fl oz/cwt AEA 92 (air entrainer) and 9.96 fl oz/cwt Plastol 6400 (superplasticizer). This ratio needed to be changed due to the decrease in aggregate water. When superplasticizer is added, it increases the workability of the concrete without changing the w/cm ratio. However, if the dosage is too high, it makes the concrete more fluid, like a non-Newtonian fluid, and does not lend itself to sticking to the canoe mold. The team used the remaining admixture materials as they were already pre-set in syringes. Superplasticizer was added to the mix at a dosage of 5.89 fl oz/cwt. Air entrainer is typically added to concrete to entrap small air bubbles into the mix to reduce the unit weight and provides resistance to freeze/thaw conditions. After several iterations, the optimal dosage of air entrainer was determined to be 10.75 fl oz/cwt.

For aesthetics, pigment testing was conducted to ensure that the vibrant colors of *Sun Devil Crossing* were highlighted and cylinders from *Legacy* were used as a baseline as shown in Figure 11. Thanks to generous donations, the team was able to switch the pigment material from direct pigment powder to Color-Crete. This change resulted in a wider range of pigments for the colorful canoe interior and exterior.

Figure 12. Pigment Testing Using *Legacy* samples.

Trial tests are planned for color creation to compliment the intricate hues on the inlay interior and exlays exterior. Additionally, the team tested the chosen mix design with remaining rubber inlays to anticipate their mutual workability. While the chosen mix had a faster drying time than previous mixes, this was dissipated with the use of spray bottles.

Rather than using the constructed cooler cylinder curing chamber of last year, the team returned to utilizing campus concrete laboratory spaces for curing. This reduced the travel time to laboratory testing machines and resulted in a curing configuration that closely followed the misting system of the prototype canoe and would produce more accurate strength reading. Finally, the team conducted gravimetric air content testing under ASTM C138 standards to obtain accurate void results, independent of mixture proportion calculations.

Much of the mix design components were left stagnant from *Legacy* due to reliability in mix and

Figure 13. Mix Design Volunteers and Aesthetics Team

time constraints brought by lab closures and shipping delays. The vast decrease in compressive strength alarmed the team, but it closely followed the strength values of 2011's *Devils Du Soleil* and 2019's *The Maroon Machine*, both of which had desired racing performances and longevity. The team believes the chosen mix design will successfully bring *Sun Devil Crossing* to fruition in strength and resilience.

PROPOSED CONSTRUCTION FOR 2021

The team will utilize the additional construction time to fine-tune the construction process and prioritize increased safety. The goal for construction is to improve upon the techniques made by its predecessor, *Legacy*, by developing an innovative design with a safer technical approach due to the new norms we are facing today.

Continuing on *Legacy's* successful model, the mold will be made of 2 pcf expanded polystyrene (EPS) foam due to the additional buoyancy when left in the bulkheads and its easy constructability.

AutoCAD was used to draft the finalized hull design from the team MATLAB code where cross-section cuts were taken at two-inch intervals, generating a stair-step pattern when assembled. The inward-facing, rounded gunnels were removed from the design so that the mold could be removed in one piece from the concrete. The cross-sections need to be imported into VCarve Pro, which converts AutoCAD cut files into readable CNC machine files. ASU Innovation Hub located at the Polytechnic campus provides free access and expert training to the CNC machine, resulting in cost savings compared to outsourcing the milling.

Sun Devil Crossing will incorporate two layers of carbon fiber mesh that need to be pre-cut to the mold shape that will expedite their placement while casting. According to the *Legacy* team, using this method saved them an hour on casting day. This placement was used again allowing for better impregnation of the mesh.

Throughout the design and construction process, safety will be a high priority, especially with COVID-19. The pandemic will likely be a prevailing issue for the 2021-2022 team, and extra steps will be set to ensure health and safety. During the mix design, all team members would be required to wear gloves, goggles, cloth masks during downtime, and N-95 masks during canoe construction and mix design. Temperatures will be taken before entering the lab, and participants will be required to be in good health standing with ASU by completing their Daily Health Checks. Similarly, by October 2021, Arizona expects to be in Phase 3 of the vaccine distribution, allowing for general members of the population to receive vaccine doses (AZDHS). All members will be encouraged to have both doses completed before aiding in casting day. Protocols will be set in place such as temperature checks, sanitizing stations, and a maximum of a 15 team members per session to ensure the health of team members and adherence to social distancing. Additionally, the team will have an internal goal of creating a 10' smaller canoe to familiarize team member with the process and decrease the knowledge gap several members have.

The construction team worked with the aesthetics team to ensure that each section of the canoe could be completed even with a decreased number of volunteers in the construction space. The volunteers will be evenly stationed on each side and start with their section and continuously move clockwise in 10-minute intervals. We believe this will allow for decreased variability between sections while maintaining distance between volunteers. Advanced preparation and training will be given to volunteers to ensure that large sections can be completed accurately and efficiently.

Technical Approach to the Overall Project

During all future construction events, team members will be required to have the proper protective equipment. The construction captain will have proper safety training and an OSHA safety card to oversee the team members and maintain a proper working environment. All team members are required to watch a safety video to ensure all safety measures meet OSHA standards. The canoe captain this year was a construction management student so new access to concrete lab testing and quality assurance was introduced.

Figure 14. *Legacy*'s Three-Layer Construction Detail

The first layer of the mix will be the foundation for the canoe. We will first place the concrete onto the mold and work down the side to prevent the concrete from slumping. Similar to *Legacy*, tire tread-depth gauges will be used to ensure an even 3/16" thickness over the entire layer. Since the thickness of the canoe remained unchanged between the two canoes, the tread depth gauges will be repurposed and unchanged. To ensure a smooth finish once the concrete is placed, a steel trowel will be used. The carbon fiber mesh will be placed over the body of the canoe and smoothed into the layer of concrete to allow proper adhesion of the mesh to the layer of concrete. The first carbon fiber mesh will be placed after the completion of the first blue concrete layer. The second layer of 3/16" gray structural concrete will be placed, followed by the second layer of carbon fiber mesh. Finally, the third exterior layer of 3/16" thick concrete will be placed. Spray bottles will be filled with water to lightly wet the concrete to prevent drying where necessary. The proposed mix for *Sun Devil Crossing* has a faster drying time than *Legacy's* but the team believed larger batches and increased usage of spray bottles could minimize any issues from the mix. After the body is cast, concrete requires to be set for 12-14 hours and needs to be swathed in damp cheesecloth.

The aesthetics team created an intricate design for *Sun Devil Crossing*, incorporating elements from the game's fishing tasks on the interior and popular characters and sea items on the exterior. To complete this colorful feat, the construction team will work with the aesthetics layers to laser cut and prepare the rubber inlays seen on the canoe interior. Volunteers will then fill in the darker tinted concrete to the required thickness. For the external design, 1" exlays will be created for character outlines and beach items. This will be overseen by the aesthetics team members after casting day. This process was similar to the cactus and flowers shown on *Legacy* in Figure 15.After this process, the canoe needs to be placed in the curing chamber and covered in towels to ensure the canoe remains moist between misting cycles. Otherwise it can have lower strength, reduced durability, shrink, and crack.

Figure 15. Sonoran Cactus Exlay from *Legacy*

For curing, the team constructed an efficient, automated curing chamber. A cage of PVC pipes was built to stand on the table, and closely follow the shape of the canoe and the configuration needs to be wrapped in a plastic tarp to maintain humidity in the chamber and to direct the excess water to gutters attached to the table. By having misers along the side of the cage, the system reduces the distance between the misters, thus, allowing for more water to directly hit the canoe, giving it a better cure. The misting system should run every hour for five minutes, allowing us to create a controlled environment providing proper hydration and humidity for an efficient wet curing process to combat the dry Phoenix air. Changing the timing of the misting system will be more sustainable as water usage will be reduced by half but doing so results in a higher-quality cure. Before casting, the construction team will analyze the curing humidity to compression strength relationship using test cylinders to see which method would be best for the full-scale canoe. The change in construction timeline was also considered when detailing the misting time. Historically, casting day has occurred in the cooler late January, so the change to a late October date would result in average daily temps of 92°, a 28° temperature increase. Thus, the misting time will be increased during the day and manually lowered during the night when temps reach 60°. After curing ends, sanding can begin on the canoe exterior. After all the sanding is completed, any gaps should be filled with patch mix and sanded where needed.

Once the canoe has almost completed curing, the team will start sanding with wet sand to reduce exposure to dust particles containing calcium hydroxide and crystalline silica, providing a safer work environment. Sanding will consist of several stages, beginning with hand sanding of the exterior with 60-1000 grit sandpaper and progressing to orbital sanders on thicker areas along the walls.

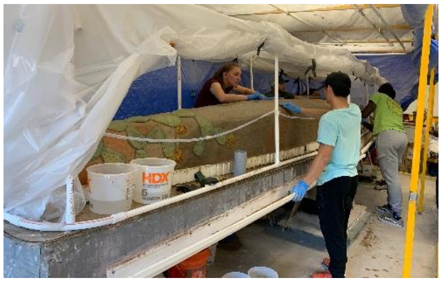


Figure 16. *Legacy* Paddlers Sanding Using 240 Grit Sandpaper

Members will be required to wear gloves, N-95 masks, and safety goggles. Demolding will be easier with the EPS mold because it can be removed in one piece with minimal damage to the canoe interior. *Legacy* had difficulty during the demolding process due to excess resin dripping to the table and fusing the mold to the table. Moreover, the releasing agent did not perform to the necessary standards, so a new releasing agent will be used and extra layers will be placed to ensure a separation between mold and canoe. After the mold is removed and both the interior and exterior of the canoe are sanded, two coats of EverClear 350 acrylic sealant need to be applied to the entire canoe interior and exterior. Once the construction process is completed, the canoe will be moved to Tempe Town Lake for paddling practice so paddlers may get familiar with the slightly unstable maneuverability prior to the regional conference.

The overall construction process will utilize past materials, employ more lean construction, and include more safety techniques to create *Sun Devil Crossing* efficiently and sustainably. Ultimately, this new process will produce an aesthetically colorful canoe exhibiting friendship, adventure, and new methods of exploration.

Management Approaches

SCOPE, SCHEDULE, AND FEE

Immediately following the cancelation of PSWC 2020, the outgoing team began preparing for the next academic year to mitigate the knowledge gaps that the incoming team would have. The current PMs were both involved in canoe design and construction but in minor roles, one as a paddler and the other as consistent mix design aid. Transitioning between PMs had been a challenge for the team, but the outgoing PM created a comprehensive document summarizing the canoe making process with recommendations for the future. This will be a living document to incorporate the new knowledge learned this year and in future years. Due to university restrictions caused by COVID-19, the previous canoe, *Legacy*, was left unfinished in our construction space for the reminder of Spring 2020 semester and beginning of the following semester. Current plans are to complete *Legacy* and use it for paddling practice towards the end of the spring semester, allowing the team to retire the 2011 canoe, *Devil Du Soleil*.

Team captains were given a crash course detailing their roles during the summer prior to the academic year. The team also anticipated the event of a nationwide concrete canoe competition cancellation and created internal goals of making a 10’ smaller canoe to bridge knowledge gaps and stimulate underclassmen enthusiasm. Once the rules were released, the team focused on implementing new computer analysis software, creating a team website to strengthen sponsor and university relations, preparing infrastructure for next year, and ensuring team safety during the pandemic.

After PSWC 2020, the team reached out to conference judges to receive constructive feedback about how to improve the project for the next year. Team captains worked to implement many of the recommendations and drafted a two-year schedule of canoe design and construction. Meetings with all team members were conducted biweekly over Zoom while instant messaging and emailing were used to contact team captains. For the first time, the team Google Drive was shared with all consistent volunteers so that they may better understand the intricacy of the project and aid with different tasks.

Sun Devil Crossing’s schedule focused on incorporating additional time to improve current methods and explore new techniques. Continuing on the previous years, time was added to teach members their roles to ensure completion by their designated deadline. Added time was greatly reduced due to the comprehensive document and independence given to captains to lead their own subcommittee of members. The project milestones within the critical path are shown in Table 8.

Table 8. Project Milestones

Milestone	Delay	Cause
Finalize Hull Design	2 weeks	Editing MATLAB code and learning DELFTship™
Finalize Mix Design	5 weeks	Delayed material procurement and COVID building restrictions
Team Website	None	-
Video Competition	None	-

The expenses for this year were drastically reduced, thanks in part to the sustainable practices that allowed for the reuse of Legacy’s materials, the strengthened industry relationships, and the movement to a second construction year. The budget was decreased due to a reduction in university club funding caused by the pandemic. Therefore, the team looked to new companies for partnerships and strengthened relationships with existing ones. ASUCCT was able to cover the project costs using joint fundraising with ASU ASCE and leftover funds from last year’s team. Overall, the team emphasized proper infrastructure for future teams, most notably

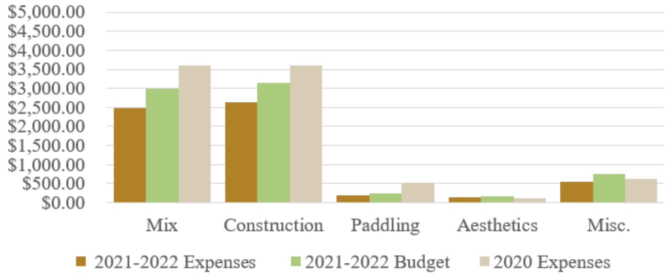


Figure 17: Budget and Expenditure Estimates

securing enough foam sheets for the next two years.

The project was successfully completed under budget and saw very little variance against the proposed schedule. Overall, the 35+ members on the team dedicated a little over 1900 person-hours to create *Sun Devil Crossing*, as shown in Figure 18, an overall 22% increase from *Legacy*.

Management Approaches

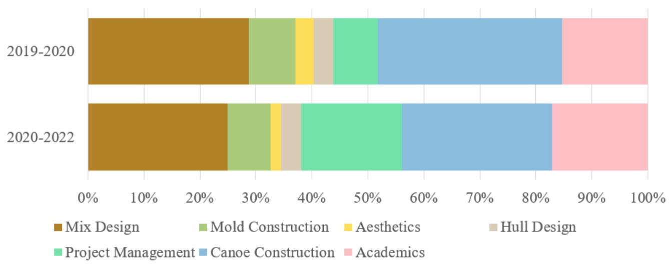


Figure 18. Comparison of Person Hour Allocation

QUALITY CONTROL AND QUALITY ASSURANCE

The team will produce a quality canoe by maintaining a consistent schedule and careful planning to ensure all rules and regulations set by the C4 are met. To better adapt to the increased virtual presence of the world, the team created an email account and website to better maintain team documents and correspondence with industry partners and university staff. The team ensured quality by creating a "Transfer of Knowledge" program for the underclassmen and juniors on the team. During the design process, virtual meetings were held to teach members the step-by-step process for topics such as how to rigorously examine the RFP document to an explanation of the MATLAB hull design code. Recordings for these steps were created to supplement the comprehensive document and better facilitate knowledge transfer.

For quality control, the team purchased many new materials to help with cylinder transportation, concrete testing, and paddling practices. Each mix was carefully documented to record its composition and workability, with each iteration going through compressive, tensile, and flexural strength testing with the averages being taken. Mix volunteers were assigned to either the cementitious or aggregate sectors for weighing, each led by the one of the project managers. Prior to construction day, pre-batches will be made to ensure consistency between mixes. The team consulted university faculty, alumni, and writing service for review of structural analysis, mix design, resistance calculations, and overall technical proposal.

SUSTAINABILITY

The canoe team recognizes and admires ASCE's commitment towards sustainability in the civil engineering field and took inspiration from ASU's Sustainable Campus Goals to implement sustainable practices across all aspects of the canoe (ASU Institute of Sustainability). For social sustainability, the team worked to recruit a diverse team of engineering and construction management students at the ASCE meetings and worked to maintain enthusiasm regarding the project throughout the year. The team, this year had a range of majors from computer science to sustainability. In terms of economical sustainability, the team saved nearly $600 by reusing styrofoam sheets from the previous years and utilizing campus resources to save upwards of $3000 on mold milling. For environmental sustainability, the mix design team removed metakaolin and VCAS 8 from the cementitious mix and incorporated more recycled materials. Future teams will incorporate crushed concrete cylinders as recycled aggregate and donate waste to the ASU PSWC Environmental Team.

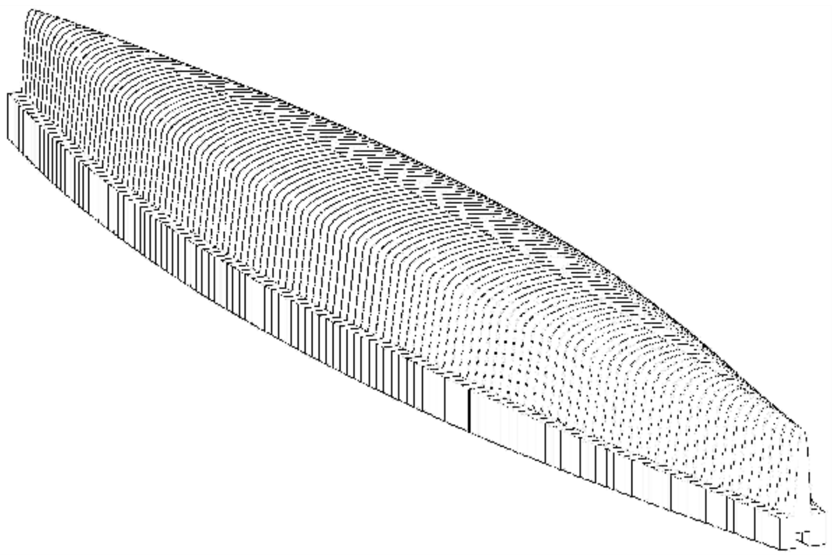
HEALTH AND SAFETY/IMPACT OF COVID-19

ASUCCT continued its legacy of holding the safety of its members paramount. The team coordinated with the ASCE Student Facilities Manager for the Urban Systems Engineering building to create a mix design entrance schedule and closely watched the weekly COVID metrics provided by both Arizona State University and across the state of Arizona by the Arizona Department of Health Services (AZDHS). All members were required to complete their ASU Daily Health Check and to monitor symptoms throughout the year, regardless of whether they were strictly virtual members or not. Partially thanks to our efforts, none of the in-person or virtual team members tested positive for COVID-19. In-person team members were instructed to use personal protective equipment (PPE) when in the construction space, and all areas of the space were cleared of debris. Safety data sheets were read by the mix design teams, and dangers were explained to volunteers prior to their involvement and handling.

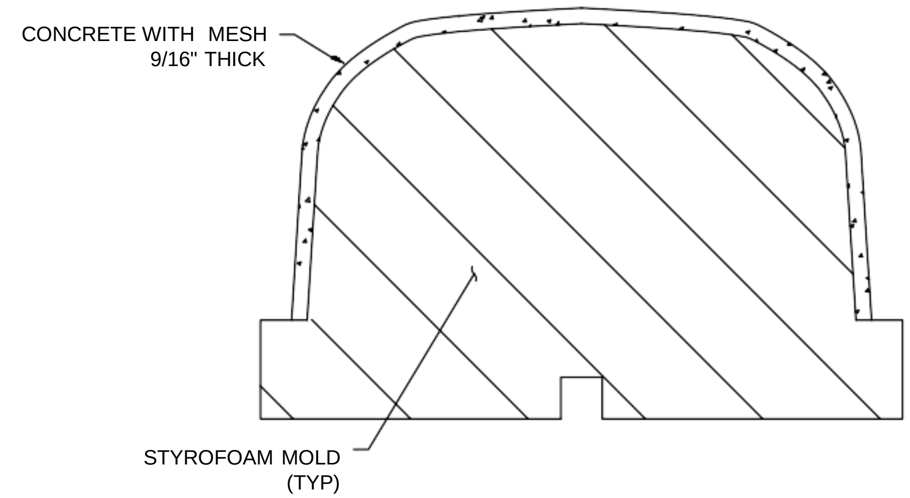
Figure 19: 2021 Team General Body Meeting

PRODUCED BY AN AUTODESK STUDENT VERSION

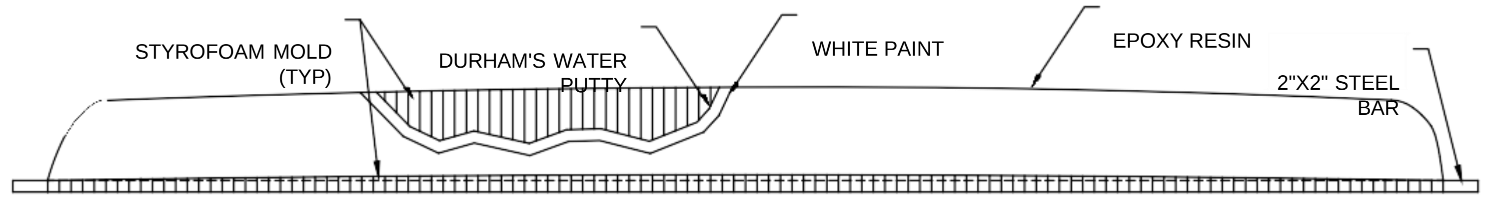
MOLD ISOMETRIC VIEW



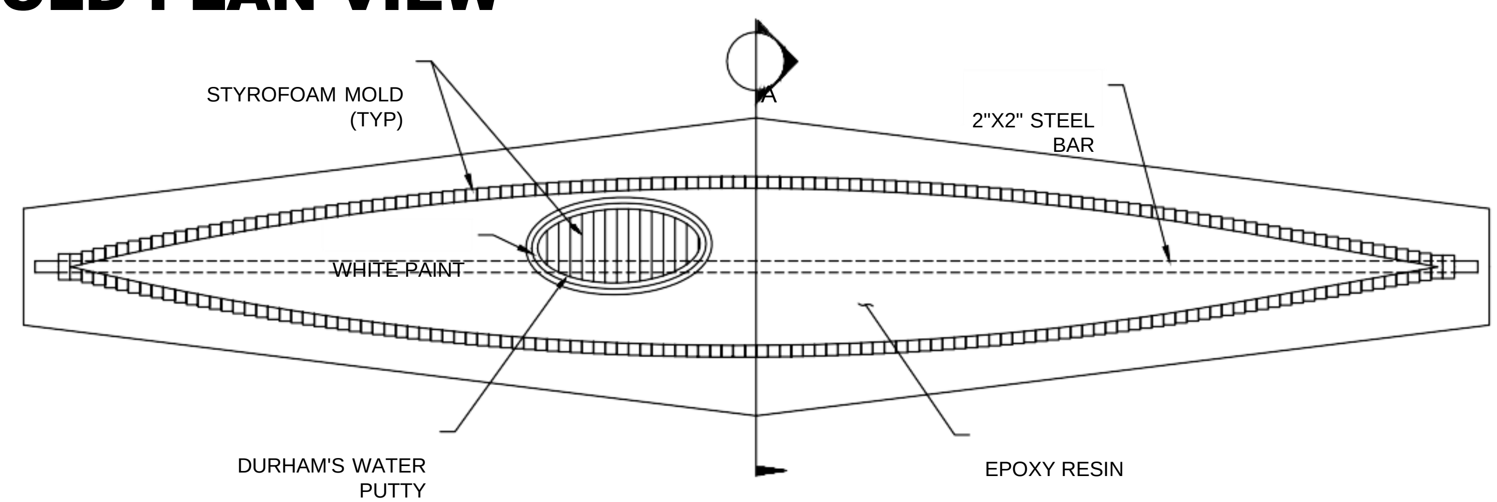
SECTION A-A WIDEST SECTION



MOLD ELEVATION VIEW



MOLD PLAN VIEW



ARIZONA STATE UNIVERSITY

CONCRETE CANOE

BILL OF MATERIALS	
Material	**Quantity**
Cementitious Materials	
Styrofoam	139 cu ft
Glidden Gripper	0.5 gal
Rope	50 ft
Durham's Water Putty	80 lbs
White Paint	1 gal
Epoxy Resin	2 gal
Kleen Kote	0.25 gal
Shelf Liner	3 sq ft

Welcome to Sun Devil Crossing CONCRETE CANOE

PROJECT: 2021 PACIFIC SOUTHWEST CONFERENCE LOS ANGELES, CALIFORNIA

TITLE: MOLD - CONSTRUCTION DOCUMENT

DRAWN BY:	MEN/EA	DATE: 2/14/21
CHECK BY:	EA/AM	
SCALE:	VARIES	PAGE: 2 OF 2

PRODUCED BY AN AUTODESK STUDENT VERSION

PRODUCED BY AN AUTODESK STUDENT VERSION

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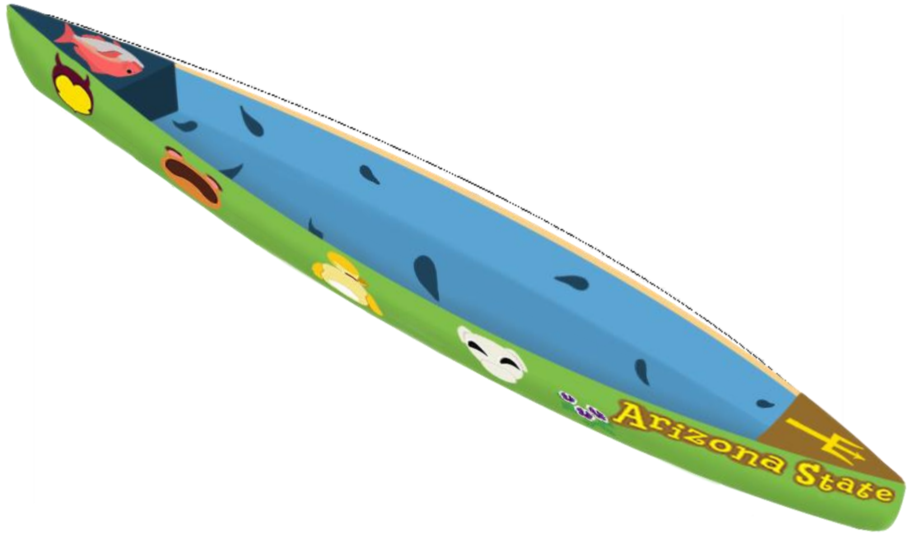
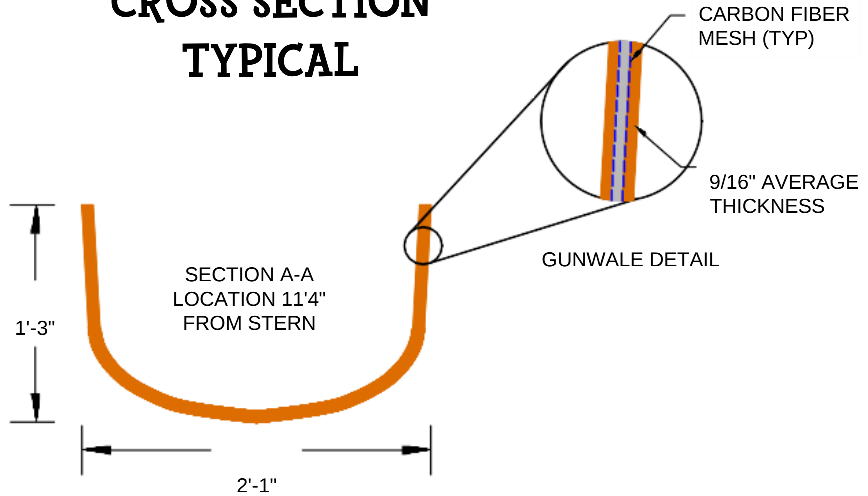
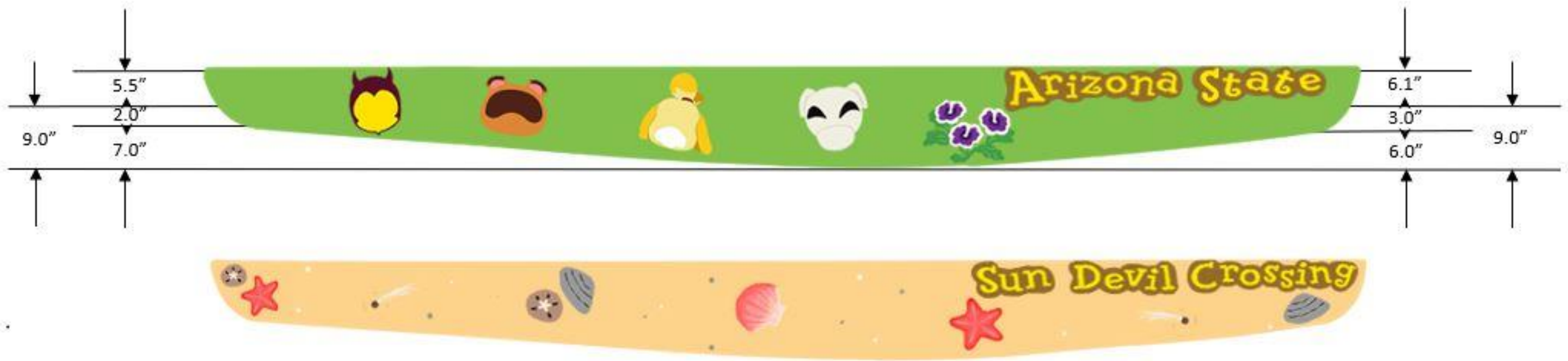
Isometric View



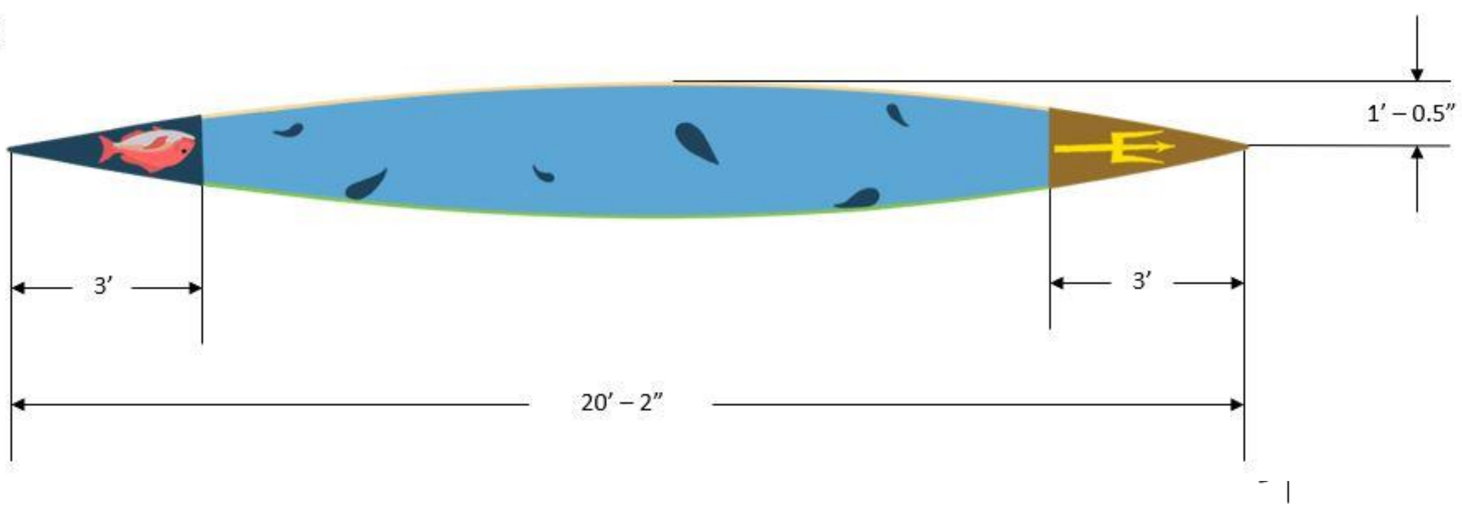
CROSS SECTION TYPICAL



Elevation Views



Plan View



20'-2"

ARIZONA STATE UNIVERSITY

CONCRETE CANOE

BILL OF MATERIALS	
Material	**Quantity**
Cementitious Materials	
Ordinary Portland Cement	48.78 lbs
Class F Fly Ash	16.621 lbs
Type S Hydrated Lime	10.163 lbs
Silica Fume	6.098 lbs
Aggregates	
Clay Shale (Fine)	10.819 lbs
Clay Shale (Crushed Fine)	7.213 lbs
Clay Shale (10 Mesh)	3.606 lbs
Agsco® 0.1-0.3mm	14.425 lbs
Agsco® 0.25-0.5mm	10.819 lbs
Agsco® 0.5-1.0mm	25.244 lbs
Admixtures	
Plastol 6400	0.068 gal
AEA-92	0.04 gal
Non-Carbonated Water	4.728 gal
Solids	
Direct Colors Pigment	5.74
Concrete Fibers	
Grace MicroFiber™	0.407 lbs
Tuf-Strand Maxten	0.525 lbs
Reinforcement	
Carbon Fiber Mesh	130 sq ft
Finishing	
Everclear 350	1.5 gal
Styrofoam	1.05 cu ft

Welcome to Sun Devil Crossing — CONCRETE CANOE

PROJECT: 2021 PACIFIC SOUTHWEST CONFERENCE LOS ANGELES, CALIFORNIA

TITLE: CANOE - CONSTRUCTION DOCUMENT

DRAWN BY:

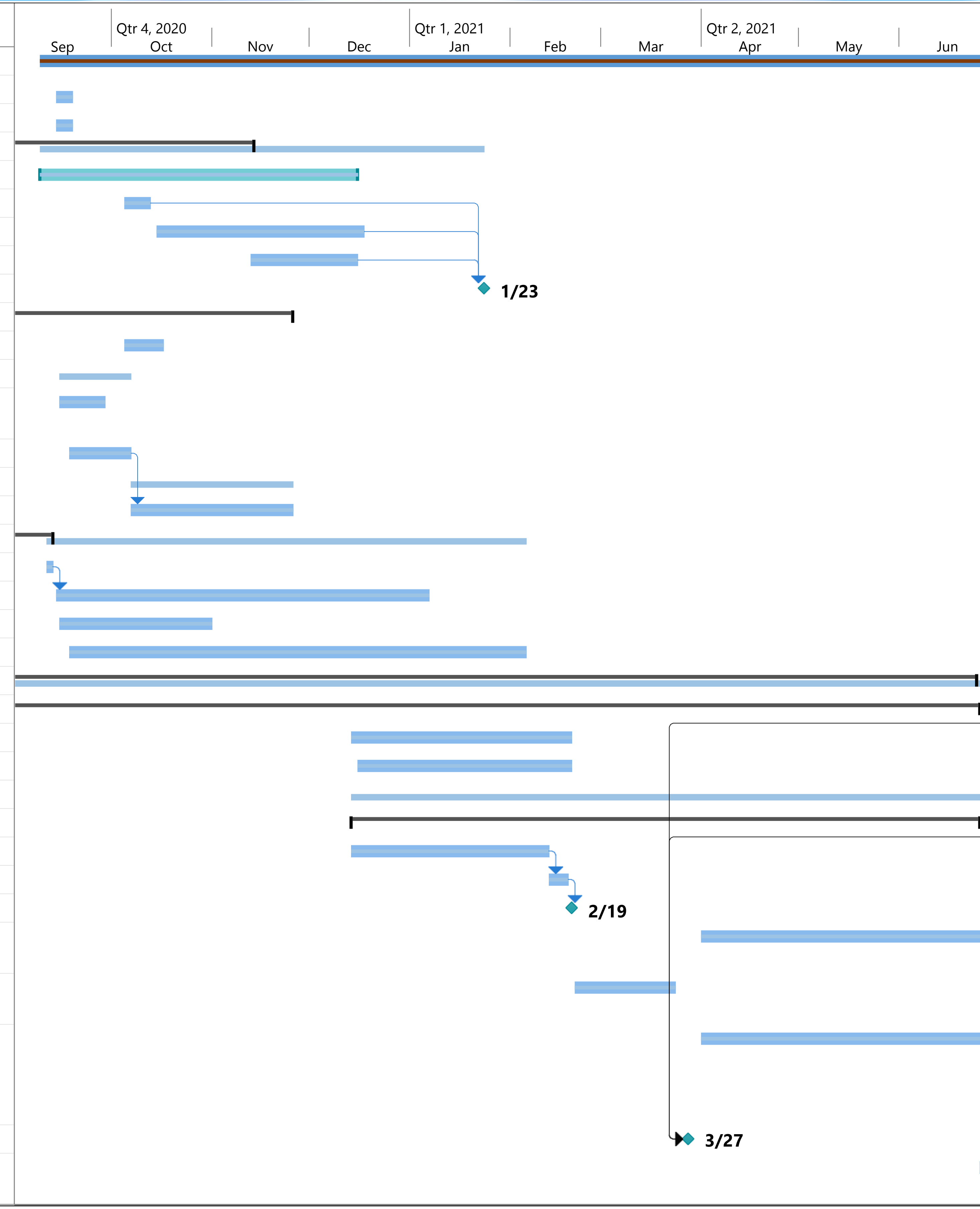
CHECK BY:

PRODUCED BY AN AUTODESK STUDENT VERSION

PRODUCED BY AN AUTODESK STUDENT VERSION

2020-2021 Schedule

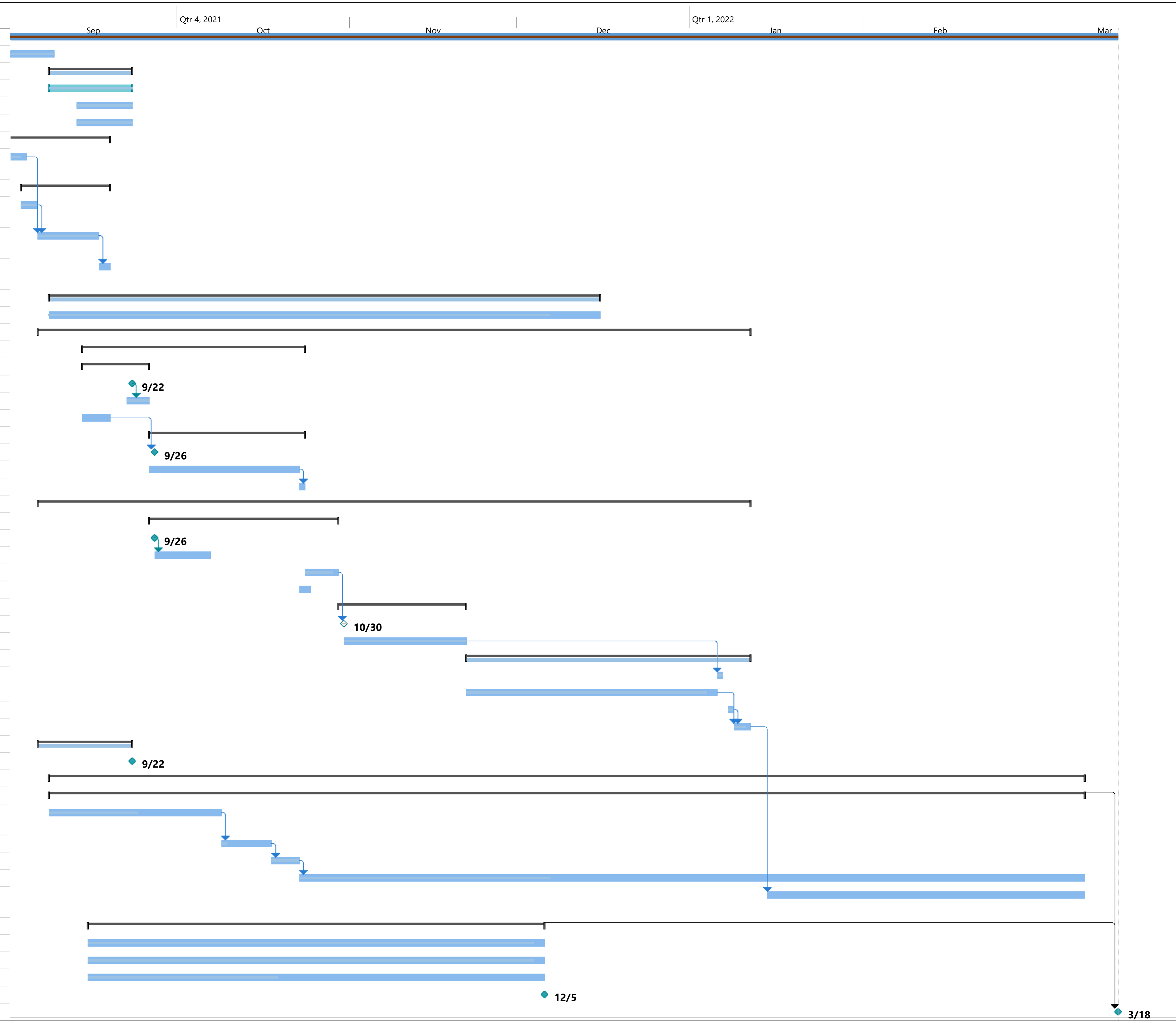
ID	Task Name	Duration	Baseline Start	Baseline Finish	Actual Start	Actual Finish
1	**Concrete Canoe 2020-2021**	209 days	Wed 9/9/20	Mon 6/28/21	Wed 9/9/20	Mon 6/28/21
2	**Performance Review**	5 days	Wed 9/9/20	Fri 9/18/20	Mon 9/14/20	Fri 9/18/20
3	**Project Planning & Research**	5 days	Wed 9/9/20	Fri 9/18/20	Mon 9/14/20	Fri 9/18/20
4	**Mix Design**	**145 days**	**Wed 9/9/20**	**Thu 1/23/21**	**Wed 9/9/20**	**Sat 1/23/21**
5	Materials Procurement	73 days	Wed 9/9/20	Fri 11/27/20	Wed 9/9/20	Tue 12/15/20
6	Cementitious Materials Testing	6 days	Sat 9/12/20	Sat 9/19/20	Mon 10/5/20	Mon 10/12/20
7	Baseline Mixes	46 days	Sun 9/20/20	Sun 11/8/20	Thu 10/15/20	Thu 12/17/20
8	Aggregate Testing	32 days	Fri 10/9/20	Tue 11/10/20	Fri 11/13/20	Tue 12/15/20
9	Final Mix Selection	38 days	Tue 11/10/20	Sat 12/19/20	Tue 12/15/20	Sat 1/23/21
10	**Hull Design and Structural Analysis**	**52 days**	**Tue 9/15/20**	**Thu 11/5/20**	**Tue 9/15/20**	**Wed 11/25/20**
11	Learn DELFTShip Program	14 days	Mon 10/5/20	Mon 10/19/20	Mon 10/5/20	Fri 10/16/20
12	**Hull Design**	**16 days**	**Tue 9/15/20**	**Wed 10/28/20**	**Tue 9/15/20**	**Tue 10/6/20**
13	Drafting & Modeling (Final Canoe)	10 days	Tue 9/15/20	Fri 9/25/20	Tue 9/15/20	Mon 9/28/20
14	Finalize Design (Final Canoe)	13 days	Sat 9/26/20	Tue 10/6/20	Fri 9/18/20	Tue 10/6/20
15	**Structural Analysis**	**36 days**	**Wed 10/7/20**	**Wed 11/25/20**	**Wed 10/7/20**	**Wed 11/25/20**
16	Finalize Analysis	36 days	Wed 10/7/20	Tue 11/24/20	Wed 10/7/20	Wed 11/25/20
17	**Aesthetics**	**158 days**	**Fri 9/11/20**	**Fri 2/5/21**	**Fri 9/11/20**	**Fri 2/5/21**
18	Theme Selection	2 days	Fri 9/11/20	Sat 9/12/20	Fri 9/11/20	Sat 9/12/20
19	Design Sketching & Planning	128 days	Mon 9/14/20	Tue 1/5/21	Mon 9/14/20	Wed 1/6/21
20	Legacy Video Competition	46 days	Tue 9/15/20	Sun 11/22/20	Tue 9/15/20	Sat 10/31/20
21	ASU Concrete Canoe Website	154 days	Fri 9/18/20	Fri 2/19/21	Fri 9/18/20	Fri 2/5/21
22	**Conference Preparation**	**194 days**	**Mon 12/14/20**	**Fri 6/25/21**	**Mon 12/14/20**	**Fri 6/25/21**
23	**Design Papers**	**68 days**	**Mon 12/14/20**	**Fri 2/19/21**	**Mon 12/14/20**	**Fri 6/25/21**
24	Technical Proposal	68 days	Mon 12/14/20	Fri 2/19/21	Mon 12/14/20	Fri 2/19/21
25	Enhanced Focus Areas	66 days	Wed 12/16/20	Fri 2/19/21	Wed 12/16/20	Fri 2/19/21
26	**Design Paper and Rehearsal**	**194 days**	**Mon 12/14/20**	**Fri 6/25/21**	**Mon 12/14/20**	**Fri 6/25/21**
27	**Design Paper**	**194 days**	**Mon 12/14/20**	**Fri 6/25/21**	**Mon 12/14/20**	**Fri 6/25/21**
28	Rough Draft	63 days	Mon 12/14/20	Fri 2/12/21	Mon 12/14/20	Fri 2/12/21
29	Final Draft & Editing	5 days	Fri 2/12/21	Thu 2/18/21	Sat 2/13/21	Thu 2/18/21
30	Send Paper	1 day	Fri 2/19/21	Fri 2/19/21	Fri 2/19/21	Fri 2/19/21
31	Revisions for National Paper	62 days	Thu 4/1/21	Fri 6/25/21	Thu 4/1/21	Fri 6/25/21
32	Rehearse Technical Presentation at UCLA	32 days	Sun 2/21/21	Thu 3/25/21	Sun 2/21/21	Tue 3/23/21
33	Rehearse Technical Presentation at University of Wisconsin-Platteville	89 days	Thu 4/1/21	Mon 6/28/21	Thu 4/1/21	Fri 6/25/21
34	**Attend PSWC at UCLA**	3 days	Thu 3/25/21	Sat 3/27/21	Thu 3/25/21	Sat 3/27/21
35	**Attend National Competition at University of Wisconsin-Platteville**	2 days	Sat 6/26/21	Mon 6/28/21	Sat 6/26/21	Mon 6/28/21



Milestone ◇ Summary Task Baseline

2021-2022 Proposed Schedule

ID	Task Name	Duration	Baseline Start	Baseline Finish	Predecessors
1	**Concrete Canoe 2021-2022**	143 days	Wed 9/1/21	Fri 3/18/22	
2	**Project Planning & Research**	6 days	Wed 9/1/21	Wed 9/8/21	
3	**Mix Design**	**11 days**	**Wed 9/8/21**	**Wed 9/22/21**	
4	Humidity Testing	11 days	Wed 9/8/21	Wed 9/22/21	
5	Additional Pigment Testing	8 days	Mon 9/13/21	Wed 9/22/21	
6	Additional Admixture Testing	8 days	Mon 9/13/21	Wed 9/22/21	
7	**Hull Design and Structural Analysis**	**13 days**	**Wed 9/1/21**	**Sat 9/18/21**	
8	Revise MATLAB Program for Miniature Canoe	3 days	Wed 9/1/21	Fri 9/3/21	
9	**Hull Design (Miniature Canoe)**	**11 days**	**Fri 9/3/21**	**Tue 9/14/21**	
10	Drafting & Modeling (Miniature Canoe)	2 days	Fri 9/3/21	Sun 9/5/21	
11	Finalize Design (Miniature Canoe)	9 days	Mon 9/6/21	Thu 9/16/21	10,8
12	CNC Drafting (Miniature Canoe)	2 days	Fri 9/17/21	Sat 9/18/21	11
13	**Aesthetics**	**71 days**	**Wed 9/8/21**	**Sun 12/5/21**	
14	Banner and Poster Creation	71 days	Wed 9/8/21	Sun 12/5/21	
15	**Construction**	**92 days**	**Sat 9/18/21**	**Tue 1/11/22**	
16	**Miniature Canoe Construction**	**29 days**	**Sat 9/18/21**	**Fri 10/4/19**	
17	**Preparation**	**9 days**	**Tue 9/14/21**	**Sat 9/25/21**	
18	CNC Form	4 days	Sat 9/18/21	Wed 9/22/21	
19	Mold Construction	4 days	Wed 9/22/21	Sat 9/25/21	18
20	Prebatching for Cast Day	5 days	Tue 9/14/21	Sat 9/18/21	
21	**Casting Concrete**	**20 days**	**Sun 9/26/21**	**Sat 10/23/21**	
22	Cast Day	1 day	Sun 9/26/21	Sun 9/26/21	20
23	Curing	21 days	Sun 9/26/21	Fri 10/22/21	
24	Form Removal	1 day	Sat 10/23/21	Sat 10/23/21	23
25	**Final Canoe Construction**	**92 days**	**Mon 9/6/21**	**Tue 1/11/22**	
26	**Preparation**	**25 days**	**Sun 9/26/21**	**Fri 10/29/21**	
27	Reassemble Form	1 day	Sun 9/26/21	Sun 9/26/21	
28	Patch and Repair Mold	8 days	Mon 9/27/21	Wed 10/6/21	27
29	Prebatching for Cast Day	6 days	Sun 10/24/21	Fri 10/29/21	
30	Member Training	2 days	Sat 10/23/21	Sun 10/24/21	
31	**Casting Concrete**	**15 days**	**Sat 10/30/21**	**Sun 11/21/21**	
32	Cast Day	1 day	Sat 10/30/21	Sat 10/30/21	29
33	Curing	17 days	Sun 10/31/21	Sun 11/21/21	
34	**Finishing**	**37 days**	**Mon 11/22/21**	**Tue 1/11/22**	
35	Form Removal	1 day	Thu 1/6/22	Thu 1/6/22	33
36	Sanding	33 days	Mon 11/22/21	Wed 1/5/22	
37	Bulkhead Placement and Const	1 day	Sat 1/8/22	Sat 1/8/22	
38	Sealing	3 days	Sun 1/9/22	Tue 1/11/22	36,37
39	**Aesthetics**	**13 days**	**Mon 9/6/21**	**Wed 9/22/21**	
40	Implement Inlays and Exlays	13 days	Mon 9/6/21	Wed 9/22/21	
41	**Conference Preparation**	**133 days**	**Wed 9/8/21**	**Sat 3/12/22**	
42	**Paddling**	**133 days**	**Wed 9/8/21**	**Wed 3/16/22**	
43	Information Sessions & Open Training	23 days	Wed 9/8/21	Fri 10/8/21	
44	Tryouts	7 days	Sat 10/9/21	Sun 10/17/21	43
45	Team Selection	5 days	Mon 10/18/21	Fri 10/22/21	44
46	Practice	102 days	Sat 10/23/21	Sat 3/12/22	45
47	Switch from Devil Du Soleil to Sun Devil Crossing	42 days	Sat 1/15/22	Sat 3/12/22	38
48	**Final Product Display**	**58 days**	**Wed 9/15/21**	**Sun 12/5/21**	
49	Construct Stand	59 days	Wed 9/15/21	Sun 12/5/21	
50	Construct Table Display	59 days	Wed 9/15/21	Sun 12/5/21	
51	Cutaway	59 days	Wed 9/15/21	Sun 12/5/21	
52	Complete Display	59 days	Wed 9/15/21	Sun 12/5/21	
53	**Attend Regional Competition**	3 days	Wed 3/16/22	Fri 3/18/22	42,48



Milestone ◆ Summary Task Baseline

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Appendix B: Mixture Porporotions and Primary Mixture Calculations

MIXTURE: STRUCTURAL MIX, MADE IN A VARIETY OF COLORS SYNONYMOUS WITH ANIMAL CROSSING (BLUE, GREEN, TAN, ETC)

Cementitious Materials				
Component	*Specific Gravity*	*Volume (ft^3)*	*Amount of CM (lb/yd^3)*	
Type II Ordinary Portland Cement	*3.15*	*1.893*	*372.00*	*Total cm (includes c)* ***620.00** lb/yd^3* *c/cm ratio, by mass* ***0.6***
Class F Fly Ash	*2.14*	*0.929*	*124.00*	
Silica Fume	*2.20*	*0.339*	*46.50*	
Type S Hydrated Lime	*2.60*	*0.478*	*77.50*	

Fibers				
Component	*Specific Gravity*	*Volume (ft^3)*	*Amount of Fibers (lb/yd^3)*	
GRACE Micro-Fibers	*0.91*	*0.055*	*3.10*	*Total Amount of Fibers 7.10 lb/yd^3*
Tuf-Strand Maxten Macro-Fibers	*0.91*	*0.070*	*4.00*	

Aggregates (Excluding Mineral Fillers Passing No. 200 Sieve)						
Aggregates	*Abs (%)*	*SG_{OD}*	*SG_{SSD}*	*Base Quantity, W (lb/yd^3)*		*Volume, $V_{agg,\,SSD}$ (ft^3)*
				W_{OD}	*W_{SSD}*	
Clay Shale (Fines)	*17.4*	*0.727*	*0.854*	*70.23*	*82.50*	*1.548*
Clay Shale (Crushed Fines)	*17.4*	*0.720*	*0.845*	*46.86*	*55.00*	*1.043*
Clay Shale (10 Mesh)	*17.4*	*0.703*	*0.825*	*23.42*	*27.50*	*0.534*
Agsco® 0.1-0.3mm	*19.0*	*0.336*	*0.400*	*92.44*	*110.00*	*4.407*
Agsco® 0.25-0.5mm	*19.0*	*0.286*	*0.340*	*69.33*	*82.50*	*3.889*
Agsco® 0.5-1.0mm	*19.0*	*0.218*	*0.260*	*161.77*	*192.50*	*11.865*

Liquid Admixtures					
Admixture	*lb/ US gal*	*Dosage (fl. oz / cwt)*	*% Solids*	*Amount of Water in Admixture (lb/yd^3)*	
Euclid AEA 92	*8.5*	*10.75*	*6*	*4.16*	*Total Water from Liquid Admixtures, $\sum w_{admx}$ 5.64 lb/yd^3*
Euclid Plastol 6400	*8.8*	*5.89*	*41*	*1.48*	

Solids (dyes, powdered admixtures)				
Component	*Specific Gravity*	*Volume (ft^3)*	*Amount (lb/yd^3)*	
Euclid Increte Color-Crete	2.5	*0.281*	*43.80*	*Total Solids. S_{total} 43.80 lb/yd^3*

Water			
	Amount (lb/yd^3)		*Volume (ft^3)*
***Water**, w, [$=\sum (w_{free} + w_{admx} + w_{batch})$]*	*w/c ratio, by mass* ***0.55*** *w/cm ratio, by mass* ***0.33***	*204.60*	*3.28*
***Total Free Water from All Aggregates**, $\sum w_{free}$*		*-84.31*	
***Total Water from All Admixtures**, $\sum w_{admx}$*		*5.64*	
***Batch Water**, w_{batch}*		*283.27*	

Densities, Air Content, Ratios, and Slump						
Values for 1 cy of concrete	***cm***	***Fibers***	***Aggregate** (SSD)*	***Solids**, S_{total}*	***Water, w***	***Total***
***Mass**, M*	*620 lb*	*7.10 lb*	*550 lb*	*43.80 lb*	*204.60 lb*	*$\sum M$: 1425.50 lb*
***Absolute Volume**, V*	*3.638 ft^3*	*0.125 ft^3*	*23.286 ft^3*	*0.281 ft^3*	*3.28 ft^3*	*$\sum V$: 30.61*
***Theoretical Density**, T, ($=\sum M / \sum V$)*	*46.57 lb/ft^3*		***Air Content, Air**, [= (T – D)/T x 100%]*			*3.37%*
***Anticipated Density**, D*	*45 lb/ft^3*		***Air Content, Air**, [= (27 – $\sum V$))/27 x 100%]*			*-13.36%*
***Total Aggregate Ratio** ($=V_{agg,SSD} / 27$)*	*86.25%*		***Slump, Slump flow, Spread** (as applicable)*			*1.00 in*
***C330 + RCA Ratio** ($=V_{C330+RCA} / V_{agg}$)*	*100%*					

Appendix B: Mixture Porporotions and Primary Mixture Calculations

Cementitious Materials

$$\mathbf{Mass = given}$$

$$\text{Mass}_{portland\ \text{cement}} = 372lbs$$

$$Mass_{F\ \text{ash}} = 124lbs$$

$$Mass_{silica\ \text{fume}} = 46.5lbs$$

$$Mass_{\text{lim}e} = 77.5lbs$$

$$\sum \mathbf{Mass_{cementitious} = cm = 620lbs}$$

$$\mathbf{Volume = \frac{Mass}{specific\ gravity * 62.4lb / ft^3}}$$

$$Volume_{portland\ \text{cement}} = \frac{372}{3.15*62.4} = 1.893\,ft^3$$

$$Volume_{F\ \text{ash}} = \frac{124}{2.14*62.4} = .929\,ft^3$$

$$Volume_{silica\ \text{fume}} = \frac{46.5}{2.20*62.4} = .339\,ft^3$$

$$Volume_{\text{lim}e} = \frac{77.5}{2.60*62.4} = .478\,ft^3$$

$$\sum \mathbf{Volume_{cementitious} = 3.638ft^3}$$

Fibers

$$\mathbf{Mass = given}$$

$$\text{Mass}_{micro\ \text{fibers}} = 3.10lbs$$

$$Mass_{\text{macro fibers}} = 4.00lbs$$

$$\sum \mathbf{Mass_{fibers} = 7.10lbs}$$

$$\mathbf{Volume = \frac{Mass}{specific\ gravity * 62.4lb / ft^3}}$$

$$Volume_{\text{micro fibers}} = \frac{3.10}{0.91*62.4} = .055\,ft^3$$

$$Volume_{\text{macro fibers}} = \frac{4.00}{0.91*62.4} = .070\,ft^3$$

$$\sum \mathbf{Volume_{fibers} = 0.125ft^3}$$

Aggregates

$$\mathbf{Mass\left(W_{SSD}\right) = given}$$

$$\text{Mass}_{\text{clay shale (fine)}} = 82.5lbs$$

$$Mass_{\text{clay shale (crushed fine)}} = 55.0lbs$$

$$Mass_{\text{clay shale (10 mesh)}} = 27.5lbs$$

$$Mass_{\text{foamed glass (0.1-0.3)}} = 110.0lbs$$

$$Mass_{\text{foamed glass (0.25-0.5)}} = 82.5lbs$$

$$Mass_{\text{foamed glass (0.5-1.0)}} = 192.5lbs$$

$$\sum \mathbf{Mass_{aggregates} = 550lbs}$$

$$\mathbf{Volume = \frac{Mass}{specific\ gravity * 62.4lb / ft^3}}$$

$$Volume_{\text{clay shale (fine)}} = \frac{82.5}{0.854*62.4} = 1.548\,ft^3$$

$$Volume_{\text{clay shale (crushed fine)}} = \frac{55.0}{0.845*62.4} = 1.043\,ft^3$$

$$Volume_{\text{clay shale (10 mesh)}} = \frac{27.5}{0.825*62.4} = .534\,ft^3$$

$$Volume_{\text{foamed glass (0.1-0.3)}} = \frac{110.0}{0.400*62.4} = 4.407\,ft^3$$

$$Volume_{\text{foamed glass (0.25-0.5)}} = \frac{82.5}{0.34*62.4} = 3.889\,ft^3$$

$$Volume_{\text{foamed glass (0.5-1.0)}} = \frac{192.5}{0.26*62.4} = 11.865\,ft^3$$

$$\sum Volume_{aggregates} = \mathbf{23.286ft^3}$$

$$\textbf{Specific Gravity}\left(\mathbf{SG_{SSD}}\right)=\textbf{given}$$

$$SG_{SSD-clay\ \text{shale (fine)}}=0.854$$
$$SG_{SSD-clay\ \text{shale (crushed fine)}}=0.845$$
$$SG_{SSD-clay\ \text{shale (10 mesh)}}=0.825$$
$$SG_{SSD-\ foamed\ glass\ \text{(0.1-0.3)}}=0.400$$
$$SG_{SSD-\ foamed\ glass\ \text{(0.25-0.5)}}=0.34$$
$$SG_{SSD-\ foamed\ glass\ \text{(0.5-1.0)}}=0.26$$

$$\textbf{Absorption}\left(\mathbf{Abs}\right)=\textbf{given}$$

$$Abs_{clay\ \text{shale (fine)}}=17.4\%$$
$$Abs_{clay\ \text{shale (crushed fine)}}=17.4\%$$
$$Abs_{clay\ \text{shale (10 mesh)}}=17.4\%$$
$$Abs_{\ foamed\ glass\ \text{(0.1-0.3)}}=19.0\%$$
$$Abs_{\ foamed\ glass\ \text{(0.25-0.5)}}=19.0\%$$
$$Abs_{\ foamed\ glass\ \text{(0.5-1.0)}}=19.0\%$$

$$\textbf{Specific Gravity}\left(\mathbf{SG_{OD}}\right)=\frac{\mathbf{SG_{SSD(Aggregate)}}}{\mathbf{1+Abs_{Aggregate}}}$$

$$SG_{OD-clay\ \text{shale (fine)}}=\frac{0.854}{1+.174}=0.727$$
$$SG_{OD-clay\ \text{shale (crushed fine)}}=\frac{0.845}{1+.174}=0.720$$
$$SG_{OD-clay\ \text{shale (10 mesh)}}=\frac{0.825}{1.+.174}=0.702$$
$$SG_{OD-\ foamed\ glass\ \text{(0.1-0.3)}}=\frac{0.400}{1+.19}=0.336$$
$$SG_{OD-\ foamed\ glass\ \text{(0.25-0.5)}}=\frac{0.34}{1+.19}=0.286$$
$$SG_{OD-\ foamed\ glass\ \text{(0.5-1.0)}}=\frac{0.26}{1+.19}=.218$$

$$\textbf{Mass}\left(\mathbf{W_{OD}}\right)=\mathbf{Volume_{aggregate}}*\mathbf{SG_{OD(Aggregate)}}*\mathbf{62.4}\frac{\mathbf{lb}}{\mathbf{ft^3}}$$

$$W_{OD-clay\ \text{shale (fine)}}=1.548*0.727*62.4=70.27lbs$$
$$W_{OD-clay\ \text{shale (crushed fine)}}=1.043*.720*62.4=46.85lbs$$
$$W_{OD-clay\ \text{shale (10 mesh)}}=.534*.702*62.4=23.42lbs$$
$$W_{OD-\ foamed\ glass\ \text{(0.1-0.3)}}=4.407*.336*62.4=92.44lbs$$
$$W_{OD-\ foamed\ glass\ \text{(0.25-0.5)}}=3.889*.286*62.4=69.33lbs$$
$$W_{OD-\ foamed\ glass\ \text{(0.5-1.0)}}=11.865*.218*62.4=161.77lbs$$
$$\sum\mathbf{W_{OD(Aggregate)}}=464.08lbs$$

$$\mathbf{Mass}\left(\mathbf{W_{SSD}}\right) = \mathbf{W_{OD}} * \left(\mathbf{1} + \mathbf{Abs}\right)$$

$$W_{SSD-clay\ \text{shale (fine)}} = 70.27*(1+.174) = 82.50 lbs$$

$$W_{SSD-clay\ \text{shale (crushed fine)}} = 46.85*(1+.174) = 55 lbs$$

$$W_{SSD-clay\ \text{shale (10 mesh)}} = 23.42*(1+.174) = 27.5 lbs$$

$$W_{SSD-foamed\ glass\ \text{(0.1-0.3)}} = 92.44*(1+.19) = 110 lbs$$

$$W_{SSD-foamed\ glass\ \text{(0.25-0.5)}} = 69.33*(1+.19) = 82.5 lbs$$

$$W_{SSD-foamed\ glass\ \text{(0.5-1.0)}} = 161.77*(1+.19) = 192.5 lbs$$

$$\sum \mathbf{W_{SSD(aggregates)}} = \mathbf{550lbs}$$

$$\mathbf{Stock\ Moisture\ Contents}\left(\mathbf{MC_{stk}}\right)$$

$$MC_{clay\ \text{shale (fine)}} = 0\%$$

$$MC_{clay\ \text{shale (crushed fine)}} = 0\%$$

$$MC_{clay\ \text{shale (10 mesh)}} = 0\%$$

$$MC_{foamed\ glass\ \text{(0.1-0.3)}} = 0.5\%$$

$$MC_{foamed\ glass\ \text{(0.25-0.5)}} = 0.5\%$$

$$MC_{foamed\ glass\ \text{(0.5-1.0)}} = 0.5\%$$

$$\mathbf{Mass\ at\ Stock\ Moisture}\left(\mathbf{W_{stk(aggregate)}}\right) = \mathbf{W_{OD(agg)}} * \left(\mathbf{1} + \frac{\mathbf{MC_{stk}}}{\mathbf{100\%}}\right)$$

$$W_{stk-clay\ \text{shale (fine)}} = 70.27*(1+\frac{0}{100}) = 70.27 lbs$$

$$W_{stk-clay\ \text{shale (crushed fine)}} = 46.85*(1+\frac{0}{100}) = 46.85 lbs$$

$$W_{stk-clay\ \text{shale (10 mesh)}} = 23.42*(1+\frac{0}{100}) = 23.42 lbs$$

$$W_{stk-foamed\ glass\ \text{(0.1-0.3)}} = 92.44*(1+\frac{0.5}{100}) = 92.90 lbs$$

$$W_{stk-foamed\ glass\ \text{(0.25-0.5)}} = 69.33*(1+\frac{0.5}{100}) = 69.67 lbs$$

$$W_{stk-foamed\ glass\ \text{(0.5-1.0)}} = 161.77*(1+\frac{0.5}{100}) = 162.57.5 lbs$$

$$\textbf{Moisture Contents}\left(\mathbf{MC_{free}}\right)=\mathbf{MC_{total}}-\mathbf{Abs}$$

$$MC_{free-clay\ \text{shale (fine)}}=0.0\%-17.4\%=-17.4\%$$

$$MC_{free-clay\ \text{shale (crushed fine)}}=0.0\%-17.4\%=-17.4\%$$

$$MC_{free-clay\ \text{shale (10 mesh)}}=0.0\%-17.4\%=-17.4\%$$

$$MC_{free-foamed\ glass\ \text{(0.1-0.3)}}=0.5\%-19.0\%=-18.5\%$$

$$MC_{free-foamed\ glass\ \text{(0.25-0.5)}}=0.5\%-19.0\%=-18.5\%$$

$$MC_{free-foamed\ glass\ \text{(0.5-1.0)}}=0.5\%-19.0\%=-18.5\%$$

$$\textbf{Free water}\left(\mathbf{w_{free}}\right)=\mathbf{W_{OD}}*\left(\frac{\mathbf{MC_{free}}}{100\%}\right)$$

$$w_{free-clay\ \text{shale (fine)}}=70.27*\frac{-17.4}{100}=-12.23lbs$$

$$w_{free-clay\ \text{shale (crushed fine)}}=46.85*\frac{-17.4}{100}=-8.15lbs$$

$$w_{free-clay\ \text{shale (10 mesh)}}=23.42*\frac{-17.4}{100}=-4.08lbs$$

$$w_{free-foamed\ glass\ \text{(0.1-0.3)}}=92.44*\frac{-18.5}{100}=-17.10lbs$$

$$w_{free-foamed\ glass\ \text{(0.25-0.5)}}=69.33*\frac{-18.5}{100}=-12.83lbs$$

$$w_{free-foamed\ glass\ \text{(0.5-1.0)}}=161.77*\frac{-18.5}{100}=-29.93lbs$$

$$\sum\mathbf{w_{free}}=\mathbf{-84.31lbs}$$

<u>Admixtures</u>

$$\textbf{Dosage}=\textbf{given}$$

$$Dosage_{AEA92}=10.75\frac{fl\ \text{oz}}{cwt}$$

$$Dosage_{Plastol\,6400}=5.89\frac{fl\ \text{oz}}{cwt}$$

$$\mathbf{water\ content} = \mathbf{1} - \mathbf{\%solids}$$

$$\mathbf{water_{admixtures}} = \left(\mathbf{dosage}\left(\frac{\mathbf{fl\ oz}}{\mathbf{cwt}}\right)\right) * \left(\mathbf{cm}\left(\mathbf{cwt}\right)\right) * \left(\frac{\mathbf{1gal}}{\mathbf{128fl\ oz}}\right) * \left(\frac{\mathbf{lb}}{\mathbf{gal}}\ \mathbf{of\ admixture}\right)$$

$$water_{AEA92} = 10.75 * 6.2 * (1-0.06) * \frac{1gal}{128\,fl\ \text{oz}} * 8.5\frac{lb}{gal} = 4.16lbs$$

$$water_{Plastol\,6400} = 5.89 * 6.2 * (1-0.41) * \frac{1gal}{128\,fl\ \text{oz}} * 8.8\frac{lb}{gal} = 1.48lbs$$

$$\sum \mathbf{water_{admixtures}} = \mathbf{5.64lbs}$$

Solids

$$\mathbf{Mass} = \mathbf{given}$$

$$\text{Mass}_{pigment} = 43.80lbs$$

$$\sum \mathbf{Mass_{solids}} = \mathbf{43.80lbs}$$

$$\mathbf{Volume} = \frac{\mathbf{Mass}}{\mathbf{specific\ gravity} * \mathbf{62.4lb / ft^3}}$$

$$Volume_{pigment} = \frac{43.8}{2.5 * 62.4} = .281\,ft^3$$

$$\sum \mathbf{Volume_{solids}} = \mathbf{0.281ft^3}$$

Water

$$\mathbf{water} = \frac{\mathbf{w}}{\mathbf{cm}} * \mathbf{cm}$$

$$Mass_{water} = \mathbf{w} = 0.33 * 620 = 204.60lbs$$

$$\mathbf{Volume} = \frac{\mathbf{Mass}}{\mathbf{specific\ gravity} * \mathbf{62.4lb / ft^3}}$$

$$\text{Volume}_{\text{water}} = \frac{204.6}{1*62.4} = 3.28\text{ft}^3$$

$$\mathbf{Batch\ Water}\left(\mathbf{w_{batch}}\right) = \mathbf{w} - \left(\sum \mathbf{w_{free}} + \sum \mathbf{w_{admix}}\right)$$

$$w_{batch} = 204.6 - \left(-84.31 + 5.64\right) = 283.27lbs$$

Concrete Analysis

$$\sum Mass = Mass_{concrete} = 1425.50lbs$$

$$\sum Volume = Volume_{concrete} = 30.608\,ft^3$$

Theoretical Density(T)= $46.57 lbs/ft^3$

Anticipated Density(D)= $45 lbs/ft^3$

Air Content:

$$Air\ \text{Content} = \frac{T-D}{T} * 100\% = \frac{46.57-45}{46.57} * \% = 3.37\%$$

$$Air\ \text{Content} = \frac{27 - volume_{concrete}}{27} * 100\% = -13.36\%$$

Important Ratios:

$$\text{cement/cementitious ratio} = \frac{c}{cm} = \frac{372}{620} = 0.6$$

$$\text{water/cementitious ratio} = \frac{w}{cm} = \frac{204.6}{620} = 0.33$$

$$\text{water/cement ratio} = \frac{w}{c} = \frac{204.6}{372} = 0.55$$

$$C330 + RCA(\%) = V_{C330+RCA} / V_{agg} * 100\% = \frac{23.286}{23.286} = 100\% > 50\%(OK!)$$

<u>Aggregate Ratio Check</u>

$$\text{Aggregate Ratio (\%)} = \frac{volume_{aggregate}}{27} * 100\% = \frac{23.29}{27} * 100\% = 86.25\% > 30\%(OK!)$$

<u>Slump</u>

Measured at 1’’ plus or minus 0’’.

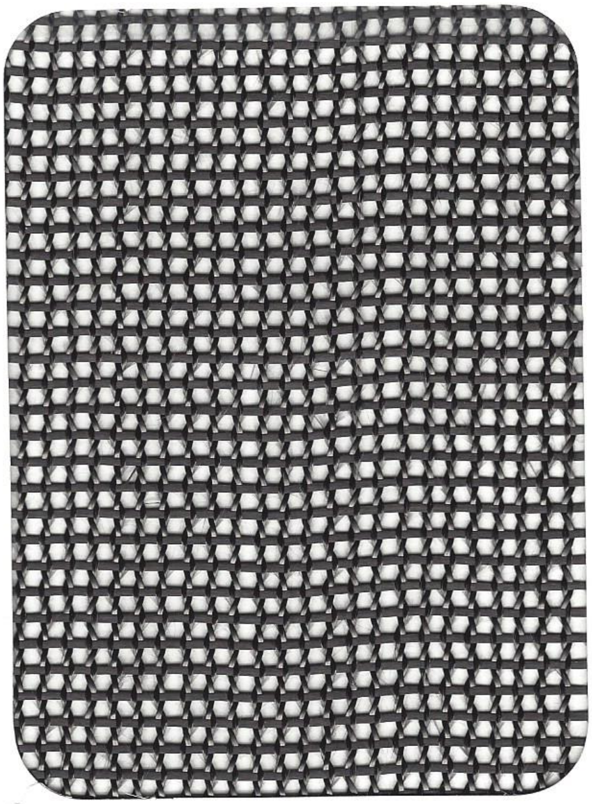
Appendix C: Material Technical Data Sheets (MTDS)

Product Name	Type	Applicable Standard	URL/Link to Datasheet
CEMENTITIOUS MATERIALS AND POZZOLANS			
SRMG Type II Phoenix Cement®	Type II	ASTM C150	Phoenix Ordinary Portland Cement®
SRMG Class F Fly Ash	Class F Pozzolan	ASTM C618	Phoenix Fly Ash, Class F Pozzolan
Chemstar Type S Lime	Hydrated Lime	ASTM C207	Chemstar Type S Lime
Eucon Silica Fume	Micro-Silica	ASTM C1240	Eucon MSA
AGGREGATES			
Utelite Crushed Clay Shale	Recycled Concrete Aggregate	ASTM C330	Utelite Crushed Clay Shale
Utelite Fine Clay Shale	Recycled Concrete Aggregate	ASTM C330	Utelite Fine Clay Shale
Utelite 10 Mesh Clay Shale	Recycled Concrete Aggregate	ASTM C330	Utelite 10 Mesh Clay Shale
Agsco® 0.1-0.3mm	Lightweight Aggregate	ASTM C330	Foamed Glass Spheres
Agsco® 0.25-0.5mm	Lightweight Aggregate	ASTM C330	Foamed Glass Spheres
Agsco® 0.5-1.0mm	Lightweight Aggregate	ASTM C330	Foamed Glass Spheres
FIBERS			
Grace MicroFiber™	Micro-Fibers	ASTM C1116	SINTA M2219 Synthetic Fibers
Euclid Tuf-Strand	Macro-Fibers	ASTM C1116	TUF-STRAND Macro Synthetic Fiber
ADMIXTURES			
Euclid Plastol 6400	Superplasticizer	ASTM C494/C1017	Plastol 6400
Euclid AEA-92	Air Entrainer	ASTM C260	AEA-92
SOLIDS AND SEALANT			
Color-Crete	Powdered Pigment	ASTM C979	Increte Color-Crete
Euclid Everclear 350	Sealing Compound	ASTM C309	Euclid Everclear 350
REINFORCEMENT			
Carbon Fiber Mesh	Reinforcement	N/A	See attached product data sheet

TEXTILE PRODUCTS INC.

2512 Woodland Drive • Anaheim, California 92801

(714) 761-0401



STYLE # 4004

WEIGHT 197 G/M2 OZ./SQ.YD

WARP FIBER: G30-500-3K ST

FILL FIBER: AS4C-GP-3K

COUNT: WARP 8

FILL 8

CONSTRUCTION Leno

THICKNESS .026

TEXTILE PRODUCTS INCORPORATED

TELEPHONE: (714) 761-0401
FAX: (714) 761-2928

2512 - 2516 W. WOODLAND DRIVE • ANAHEIM, CA 92801

PRODUCT DATA SHEET

FABRIC STYLE #4004

WEAVE STYLE:	**LENO**
WARP & FILL FIBER:	**3K CARBON**
YARN COUNT:	**16 X 8 (NOMINAL)**
AREAL WEIGHT:	**192 G/M2 (NOMINAL)**
WIDTH:	**23”**

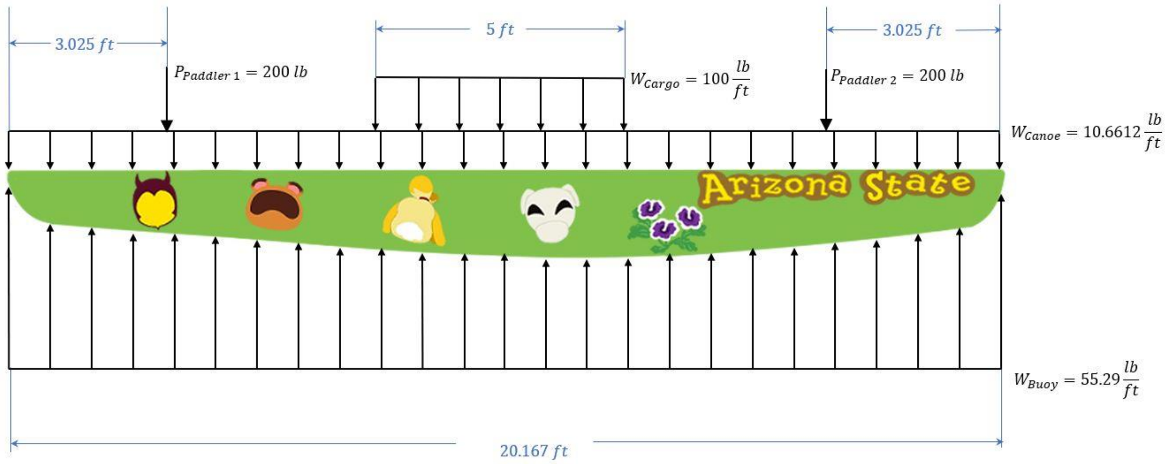
INTERNAL STRESSES OF TWO-PADDLERS WITH CARGO LOAD:

Given:

1. Total length of the canoe: 242 inches
2. Geometric center of the canoe 121 inches
3. Theoretical weight of the canoe: 215 lbs
4. Thickness of the canoe: 0.5625 inches
5. Two 200 lb. paddlers treated as point loads, each one located at 15% and 85% of the length of the canoe
6. A 100 lb./ft distributed load applied along a 5-ft length of the canoe and acts along the longitudinal centerline and centered at the midpoint of the canoe

Assume:

- Neglection of all reinforcement
- No load factors or factors of safety were applied to the given loads or resulting computed stresses
- Canoe analyzed a 2D beam parallel to the ground
- Simplification of buoyancy force into uniformly distributed load pointing upward and at equilibrium with loads acting on canoe
- Self-weight of the canoe modeled as uniformly distributed load



Compute:

- The internal stresses for the cross-section at the point of maximum **moment** under these conditions, shear (V) and bending moment diagrams (M), and cross-sectional properties.

The shear forces and bending moments are calculated below.

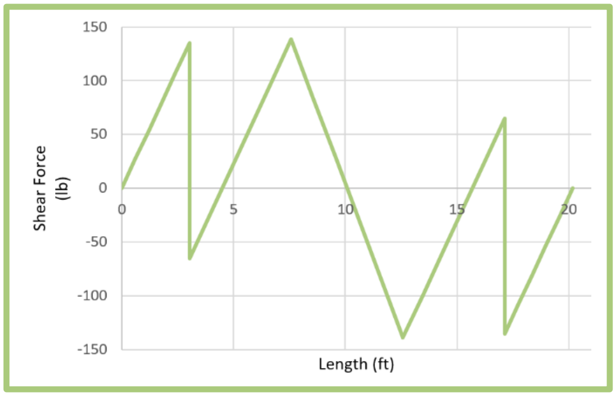
Force Equations		
Segments (ft)	$V(x)$	$M(x) = \int V(x)\,dx$
$0\text{ ft} < x_1 < 3.025\text{ ft}$	$44.627x$	$22.31x^2$
$3.025\text{ ft} < x_1 < 7.58\text{ ft}$	$44.627x - 200$	$22.31x^2 - 200x + 605$
$7.58\text{ ft} < x_1 < 12.58\text{ ft}$	$-55.37x + 558.35$	$-27.68x^2 + 558.35x - 2270.76$
$12.58\text{ ft} < x_1 < 17.142\text{ ft}$	$44.627x - 200$	$22.31x^2 - 200x + 605$
$17.142\text{ ft} < x_1 < 20.17\text{ ft}$	$44.627x$	$22.31x^2$

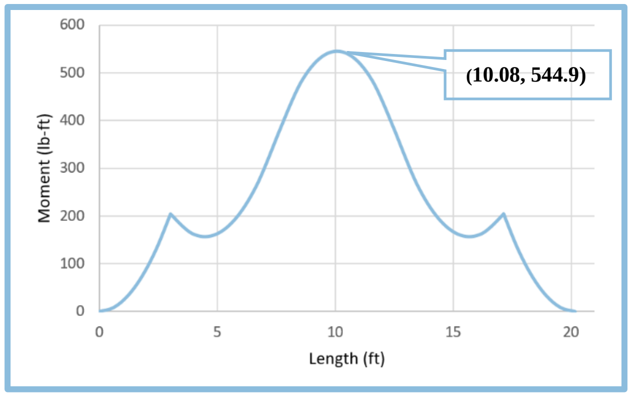
<u>Singularity Function for Loading Case:</u>

$V(x) = 44.627 < x >^1 - 200 < x - 3.025 >^0 - 100 < x - 7.58 >^1 + 100 < x - 12.58 >^1 - 200 < x - 17.142 >^0$

$M(x) = 22.31 < x >^2 - 200 < x - 3.025 >^1 - 50 < x - 7.58 >^2 + 50 < x - 12.58 >^2 - 200 < x - 17.142 >^1$

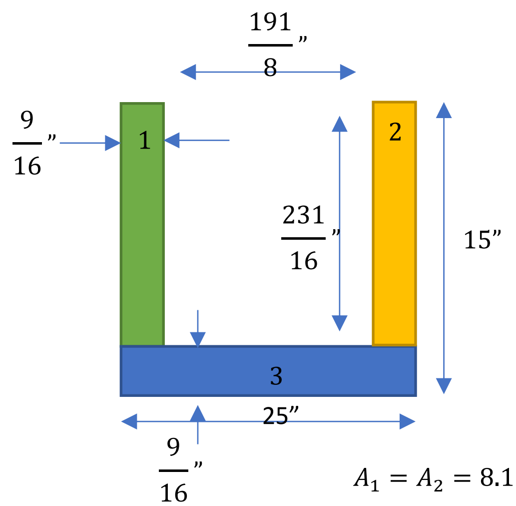
Using the equations listed in the table above, the shear force and bending moment diagrams can be drawn.

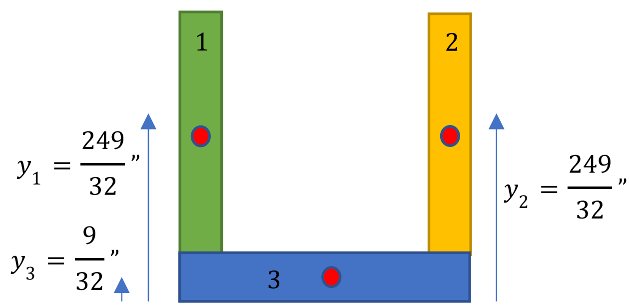




The point of maximum moment is at the geometric center of the canoe, **10.08 ft**, the maximum moment at this point is **544.9 lb-ft**. The maximum shear is 138.2 lbs located at 7.58 ft and 12.58.

The cross section for the canoe section was simplified to that of 3 rectangles arranged in a U shape. This was done as the moment of inertia calculation can be found using the equation $\left(\frac{1}{12}\right) bh^3$. While this is not 100% accurate the main differences come in areas close to the centroid, which do not contribute as much to the moment of inertia as pieces of the cross section farther away.



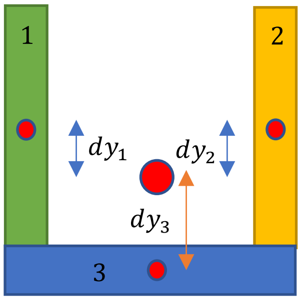


$A_1 = A_2 = 8.12\ in^2,\ A_3 = 14.06\ in^2$

$\bar{x} = 12.5"$

$$\bar{y} = \frac{\Sigma A_i y_i}{\Sigma A_i} = \frac{\left((8.12)\left(\frac{249}{32}\right) + (8.12)\left(\frac{249}{32}\right) + (14.06)\left(\frac{9}{32}\right)\right)}{8.12 + 8.12 + 14.06} = \frac{130.3}{30.3} = 4.30 \text{"}$$

Appendix D: Structural Calculations



$$I_1 = I_2 = \left(\frac{1}{12}\right)\left(\frac{9}{16}\right)\left(\frac{231}{16}\right)^3 = 141.06\ in^4, \quad I_3 = \left(\frac{1}{12}\right)(25)\left(\frac{9}{16}\right)^3 = 0.371\ in^4$$

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

$$d_1 = d_2 = \bar{y} - y_1 = 4.3 - \left(\frac{249}{32}\right) = -3.48 \qquad d_3 = \bar{y} - y_3 = 4.3 - \left(\frac{9}{32}\right) = 4.02$$

$$I = (2)\big(141.06 + (8.12)(-3.48^2)\big) + (0.371 + (14.06)(4.02^2) = 706.4\ \text{in}^4$$

Notation	Definition	Notation	Definition
A_i	Area of a specific rectangular section	y_i	Vertical distance to the centroid of a rectangular section
$\bar{x}$	Horizontal distance to centroid of entire cross section from origin	$\bar{y}$	Vertical distance to centroid or entire cross section from origin
I_i	Moment of inertia (about the centroid) of a rectangular section	d_i	Vertical distance from the centroid of the whole cross section to the centroid of a rectangular section
I	Moment of inertia of the entire cross section		

INTERNAL STRESSES OF FOUR PERSON CO-ED:

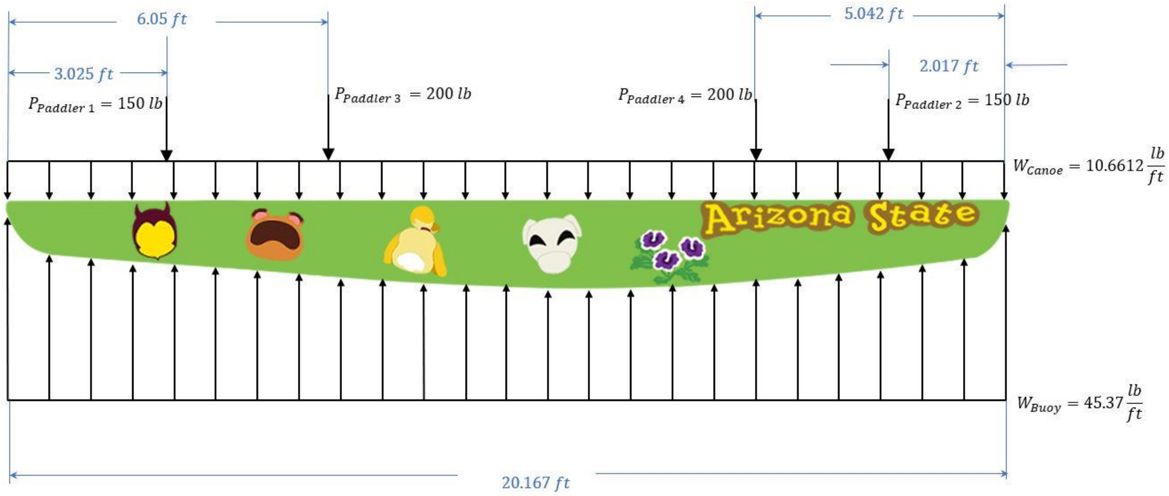
Given:

1. Total length of the canoe: 242 inches
2. Geometric center of the canoe 121 inches
3. Theoretical weight of the canoe: 0.5625 inches
4. Thickness of the canoe: 0.5625 inches
5. Two 150 lb. paddlers treated as point loads, each one located at 15% and 90% of the length of the canoe
6. Two 200 lb. paddlers treated as point loads, each one located at 30% and 75% of the length of the canoe

Assume:

- Neglection of all reinforcement
- No load factors or factors of safety were applied
- Canoe analyzed a 2D beam parallel to the ground
- Simplification of buoyancy force into uniformly distributed load pointing upward and at equilibrium with loads acting on canoe
- Self-weight of the canoe modeled as uniformly distributed load

Appendix D: Structural Calculations



Compute:

- The internal stresses for the cross-section at the point of maximum **shear** under these conditions, shear (V) and bending moment diagrams (M), and cross-sectional properties.

The shear forces and bending moments are calculated below.

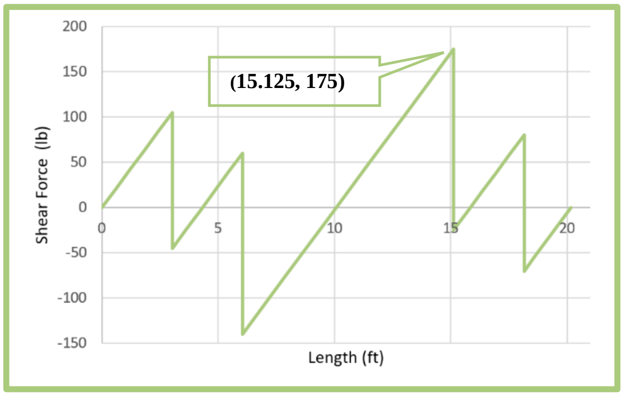
Force Equations		
Segments (ft)	$V(x)$	$M(x) = \int V(x)\,dx$
0 ft $< x_1 <$ 3.025 ft	$34.71x$	$17.36x^2$
3.025 ft $< x_1 <$ 6.05 ft	$34.71x - 150$	$17.36x^2 - 150x + 453.75$
6.05 ft $< x_1 <$ 15.125 ft	$34.71x - 350$	$17.36x^2 - 350x + 1663.75$
15.125 ft $< x_1 <$ 18.15 ft	$34.71x - 550$	$17.36x^2 - 550x + 4688.75$
18.15 ft $< x_1 <$ 20.17 ft	$34.71x - 700$	$17.36x^2 - 700x + 7411.25$

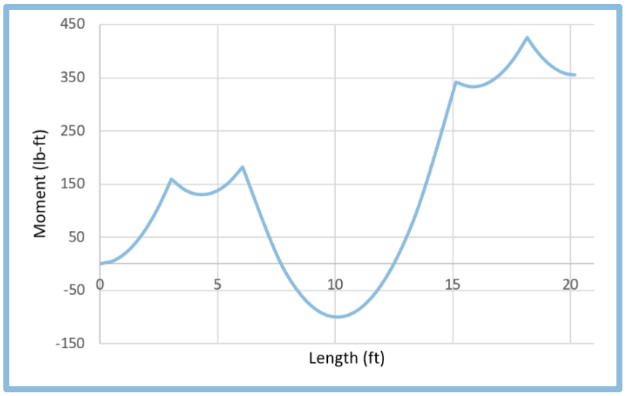
Singularity Function for Loading Case:

$V(x) = 34.71 < x >^1 - 150 < x - 3.025 >^0 - 200 < x - 6.05 >^0 - 150 < x - 15.125 >^0 - 200 < x - 18.15 >^0$

$M(x) = 17.36 < x >^2 - 150 < x - 3.025 >^1 - 200 < x - 6.05 >^1 - 150 < x - 15.125 >^1 - 200 < x - 18.15 >^1$

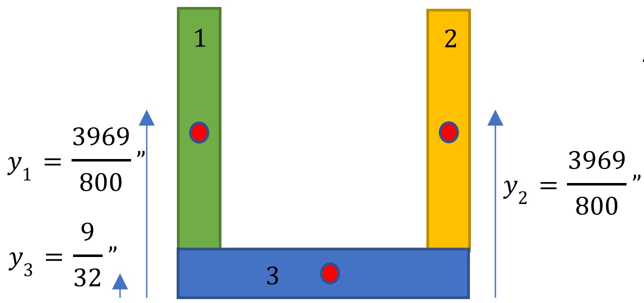
Using the equations listed in the table above, the shear force and bending moment diagrams can be drawn.

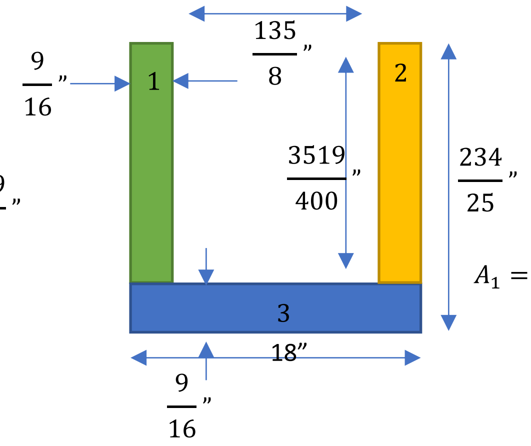




The point of maximum shear is at **15.125 ft**, the maximum shear force at this point is **175 lbs**. The point of maximum moment is 425.05 lb-ft located at 18.15 ft.

Appendix D: Structural Calculations



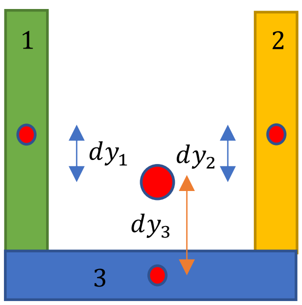


$\bar{x} = 12.5''$

$A_1 = A_2 = 4.95\ in^2,\ A_3 = 10.125\ in^2$

$$\bar{y} = \frac{\Sigma A_i y_i}{\Sigma A_i} = \frac{\left((4.95)\left(\frac{3969}{800}\right)+(4.95)\left(\frac{3969}{800}\right)+(10.125)\left(\frac{9}{32}\right)\right)}{4.95+4.95+10.125} = \frac{51.96}{20.025} = 2.69\ in$$

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



$$I_1 = I_2 = \left(\frac{1}{12}\right)\left(\frac{9}{16}\right)\left(\frac{3519}{400}\right)^3 = 31.7\ in^4,\quad I_3 = \left(\frac{1}{12}\right)(18)\left(\frac{9}{16}\right)^3 = 0.267\ in^4$$

$$d_1 = d_2 = \bar{y} - y_1 = 2.69 - \left(\frac{3969}{800}\right) = -2.27$$

$$d_3 = \bar{y} - y_3 = 2.69 - \left(\frac{9}{32}\right) = 2.41$$

$$I = (2)\left(31.7 + (4.95)(-2.27^2)\right) + (0.267 + (10.125)(2.41^2) = 173.5\ \text{in}^4$$

Notation	Definition	Notation	Definition
A_i	Area of a specific rectangular section	y_i	Vertical distance to the centroid of a rectangular section
$\bar{x}$	Horizontal distance to centroid of entire cross section from origin	$\bar{y}$	Vertical distance to centroid or entire cross section from origin
I_i	Moment of inertia (about the centroid) of a rectangular section	d_i	Vertical distance from the centroid of the whole cross section to the centroid of a rectangular section
I	Moment of inertia of the entire cross section		

CRACKING AND ULTIMATE BENDING MOMENTS CROSS SECTIONAL PROPERTIES:

Given:

1. All canoe properties from earlier load cases consistent

Assume:

- Cross-section corresponding to the maximum beam of the canoe
- Simplification of canoe shape to U-shaped beam

Compute:

- The bending moment at which cracking begins to occur
- The ultimate bending moment, neglecting the effects of carbon fiber mesh reinforcement
- The internal stress at the point of maximum bending moment and maximum shear for their respective scenarios.

Notation	Definition	Notation	Definition
A_i	Area of a specific rectangular section	y_i	Vertical distance to the centroid of a rectangular section
$\underline{x}$	Horizontal distance to centroid of entire cross section from origin	$\bar{y}$	Vertical distance to centroid or entire cross section from origin
I_i	Moment of inertia (about the centroid) of a rectangular section	d_i	Vertical distance from the centroid of the whole cross section to the centroid of a rectangular section
I	Moment of inertia of the entire cross section	NA	Axis in the cross section of a beam that has no stress or strains in the longitudinal direction
Q	Measures the distribution of a beam section's area relative to an axis	τ	Internal shear stress of a beam that is caused when a shear force is applied externally to a beam
σ_t	Normal force per area that causes a beam to increase in length	σ_c	Normal force per area that causes a beam to decrease in length
M_{max}	Maximum moment of a beam	V_{max}	Maximum shear force of a beam
t	Thickness of cross section	$f'c$	Compressive strength of concrete
f_r	Modulus of rupture	y_t	Distance from center of beam to the extreme fiber of the tension side
M_{cr}	Cracking moment	M_u	Ultimate bending moment
A_c	Total area of cross section	y_b	Lever arm of the moment

Appendix D: Structural Calculations

Scenario 1

Cross Section Properties:

$$y_1 = 7.5\ in \qquad y_2 = 7.78\ in$$

$$A_1 = 15\ in * 25\ in = 375\ in^2 \qquad A_2 = 14.44\ in * 23.88\ in = 344.83\ in^2$$

$$Neutral\ Axis: NA = \frac{y_1A_1 - y_2A_2}{A_1 - A_2} = \frac{(7.5)(375) - (7.78)(344.83)}{375 - 344.83} = 4.30\ in$$

First Moment of Area:

$$Q = \Sigma yA = y_1A_1 - y_2A_2 = 7.5(375) - (7.78)(344.83) = 129.73\ in^3$$

Second Moment of Area:

$$I = \frac{b_1(h_1)^3}{12} + A_1d_1^2 - \left(\frac{b_2(h_2)^3}{12} + A_2d_2^2\right), \qquad where\ d = yi - NA$$

$$I = \left(\frac{(25)(15)^3}{12}\right) + (375)(7.5 - 4.3)^2 - \left(\left(\frac{(23.88)(14.44)^3}{12}\right) + (344.83)(7.78 - 4.3)^2\right)$$

$$I = 703.46\ in^4$$

Stresses:

$$M_{max} = 544.90\ lb * ft, \qquad V_{max} = 138.20\ lb$$

$$\sigma_t = -\frac{Mc}{I} = -\frac{(544.90)\left(\frac{12in}{1ft}\right)(0 - 4.30)}{703.46} = 39.97\ psi$$

$$\sigma_c = -\frac{Mc}{I} = -\frac{(544.90)\left(\frac{12in}{1ft}\right)(12 - 4.30)}{703.46} = -71.57\ psi$$

$$\tau = \frac{VQ}{It} = \frac{(138.2)(129.73)}{(703.46)\left(\frac{9}{16}\right)} = 45.31\ psi$$

The compressive stress is **71.57 psi**, tensile stress is **39.97 psi**, and shear stress is **45.31 psi**.

Cracking Moment:

To begin with, the modulus of rupture, fr, must be calculated:

$$f_r = 7.5\sqrt{f'c} = 7.5\sqrt{1454\ psi} = 285.99\ psi$$

As the canoe is lightweight, a modifier must be used to account for the difference:

$$0.75f_r = 0.75(285.99) = 214.49\ psi$$

Next, yt must be found:

$$y_t = \frac{h}{2} = \frac{25}{2} = 12.5\ in$$

Finally, cracking moment can be calculated:

$$M_{cr} = \frac{(f_r)(I)}{y_t} = \frac{(214.49)(703.46)}{12.5} = 12{,}070.81\ lbf * in = 1005.9\ lb * ft$$

Ultimate Bending Moment:

Ultimate bending moment can be calculated using the total area of the cross section, the compressive strength of the concrete, and the lever arm of the moment:

$$M_u = (A_c)(f'c)(y_b)$$

$$M_u = (30.17in^2)(1454\ psi)(12.5in) = 548{,}339.75\ lbf * in = 45694.98\ lb * ft$$

Scenario 2

Cross Section Properties:

$$y1 = 4.68\ in \qquad y2 = 4.96\ in$$

$$A1 = 9.36\ in * 18\ in = 168.48\ in^2 \qquad A2 = 8.80\ in * 16.88\ in = 148.54\ in^2$$

$$Neutral\ Axis: NA = \frac{y1A1 - y2A2}{A1 - A2} = \frac{(4.68)(168.48) - (4.96)(148.54)}{168.48 - 148.54} = 2.59\ in$$

First Moment of Area:

$$Q = \Sigma yA = y1A1 - y2A2 = (4.68)(168.48) - (4.96)(148.54) = 51.728\ in^3$$

Second Moment of Area:

$$I = \frac{b1(h1)^3}{12} + A1d1^2 - \left(\frac{b2(h2)^3}{12} + A2d2^2\right), \qquad where\ d = yi - NA$$

$$I = \left(\frac{(18)(9.36)^3}{12}\right) + (168.48)(4.68 - 2.59)^2 - \left(\left(\frac{(16.88)(8.80)^3}{12}\right) + (148.54)(4.96 - 2.59)^2\right)$$

$$I = 173.04\ in^4$$

Stresses:

$$Mmax = 425.05\ lb * ft, \qquad Vmax = 175.00\ lb$$

$$\sigma t = -\frac{Mc}{I} = -\frac{(425.05)\left(\frac{12in}{1ft}\right)(0-2.59)}{173.04} = 76.34\ psi$$

$$\sigma c = -\frac{Mc}{I} = -\frac{(425.05)\left(\frac{12in}{1ft}\right)(12-2.59)}{173.04} = -277.37\ psi$$

$$\tau = \frac{VQ}{It} = \frac{(175.00)(51.728)}{(173.04)\left(\frac{9}{16}\right)} = 93.00\ psi$$

The compressive stress is **277.37 psi**, tensile stress is **76.34 psi**, and shear stress is **93 psi**.

Cracking Moment:

To begin with, the modulus of rupture, fr, must be calculated:

$$fr = 7.5\sqrt{f'c} = 7.5\sqrt{1454\ psi} = 285.99\ psi$$

As the canoe is lightweight, a modifier must be used to account for the difference:

$$0.75fr = 0.75(285.99) = 214.49\ psi$$

Next, yt must be found:

$$yt = \frac{h}{2} = \frac{18}{2} = 9\ in$$

Finally, cracking moment can be calculated:

$$Mcr = \frac{(fr)(I)}{yt} = \frac{(214.49)(173.04)}{9} = 4123.93\ lbf * in = 343.66\ lb * ft$$

Ultimate Bending Moment:

$$Mu = (Ac)(f'c)(yb)$$

$$Mu = (19.94\ in^2)(1454\ psi)(9\ in) = 260934.84\ lbf * in = 21744.57\ lb * ft$$

Appendix E: Hull/Reinforcement and Percent Open Area Calculations

THICKNESS OF CARBON FIBER REINFORCEMENT

The thickness of the carbon fiber was found using information given to the team by the manufacturer, further verification was conducted by pressing the thickness of three layers between two wooden panels with known thickness. The layers were then measured using a caliper and subtracted from the known thickness of the wooden panels and divided by three to get the thickness of a single carbon fiber layer. The theoretical and experimental value produced similar values, ensuring quality assurance.

REINFORCEMENT CALCULATIONS

Thickness of Canoe Hull:

Two structural layers of Carbon Fiber Mesh reinforcement: $2(0.026\ in) = 0.052\ in$

Thickness of Hull: $3(0.1875\ in) = 0.5625\ in$ or $\frac{9}{16}\ in$

Total Wall Thickness: $0.5625\ in + 0.052\ in = 0.6145\ in$

Hull Thickness Ratio:

$$Percent\ of\ Hull\ Thickness\ composed\ of\ Carbon\ Mesh\ Reinforcement: \left(\frac{0.052\ in}{0.6145\ in}\right)(100)$$

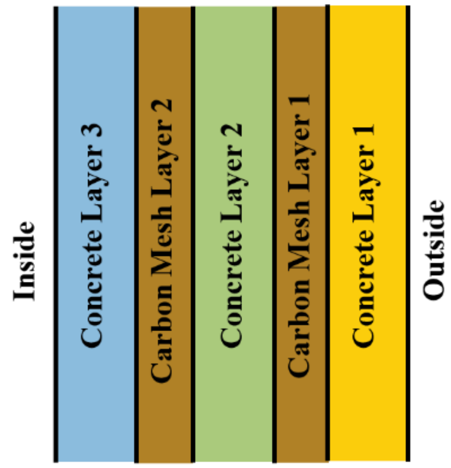
$$\mathbf{8.46\% < 50\%\ Acceptable\ Ratio}$$

Bulkhead:

$$Percent\ of\ Bulkhead\ \ Thickness\ composed\ of\ Carbon\ Mesh\ Reinforcement: \left(\frac{0.052\ in}{0.6145\ in}\right)(100)$$

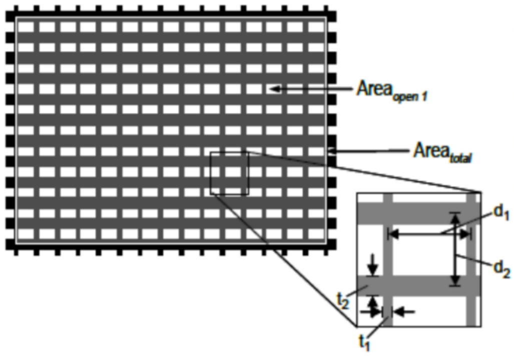
$$\mathbf{8.46\% < 50\%\ Acceptable\ Ratio}$$

CROSS SECTIONAL LAYER VIEW



Appendix E: Hull/Reinforcement and Percent Open Area Calculations

PERCENT OPEN AREA



Annotation:

n_1: Number of apertures along sample length
n_2: Number of apertures along sample width
d_1: Spacing of reinforcing (center-to-center) along the sample length
d_2: Spacing of reinforcing (center-to-center) along the sample width
t_1: Thickness of reinforcing along sample length
t_2: Thickness of reinforcing along sample width

Equations:

$$d_1 = aperature\ dimension + 2\left(\frac{t_1}{2}\right)$$
$$d_2 = aperature\ dimension + 2\left(\frac{t_2}{2}\right)$$
$$Length_{sample} = n_1 d_1$$
$$Width_{sample} = n_2 d_2$$
$$\sum Area_{open} = n_1 * n_2 * Area_{open\ 1}$$
$$POA = \frac{\sum Area_{open}}{Area_{total}} * 100\%$$

Carbon Fiber Mesh:

$t_1 = 1.0\ mm \quad t_2 = 1.5\ mm$

$d_1 = 2.5\ mm + 2\left(\frac{1.0\ mm}{2}\right) = 3.5\ mm$

$d_2 = 2.0\ mm + 2\left(\frac{1.5\ mm}{2}\right) = 3.5\ mm$

$$Length_{sample} = 15(3.5\ mm) = 52.5\ mm$$
$$Width_{sample} = 11(3.5\ mm) = 38.5\ mm$$
$$\sum Area_{open} = 15 * 11 * 5.0\ mm^2 = 825\ mm^2$$
$$Area_{total} = 52.5\ mm * 38.5\ mm = 2970\ mm^2$$
$$POA = \frac{825\ mm^2}{2970\ mm^2} * 100\% = 40.8\% > 40\% \rightarrow \boldsymbol{Compliant}$$

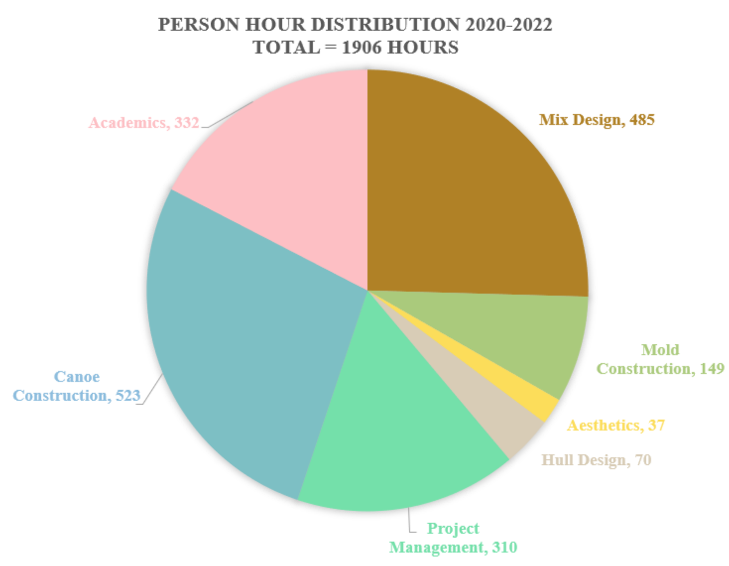
Appendix F: Detailed Fee Estimate

ITEMIZED FEE SUMMARY SHEET

BILL OF MATERIALS				
Material	**Quantity**	**Units**	**Unit Price**	**Total**
Cementitious Materials				
Ordinary Portland Cement	48.78	lbs	$0.03	$1.46
Class F Fly Ash	16.62	lbs	$0.02	$0.33
Type S Hydrated Lime	10.16	lbs	$0.15	$1.52
Silica Fume	6.10	lbs	$0.44	$2.68
Aggregates				
Clay Shale (Fine)	10.82	lbs	$0.05	$0.54
Clay Shale (Crushed Fine)	7.21	lbs	$0.05	$0.36
Clay Shale (10 Mesh)	3.61	lbs	$0.05	$0.18
Agsco® 0.1-0.3mm	14.43	lbs	$1.00	$14.43
Agsco® 0.25-0.5mm	10.82	lbs	$1.00	$10.82
Agsco® 0.5-1.0mm	25.24	lbs	$1.00	$25.24
Admixtures				
Plastol 6400	0.07	gal	$8.79	$0.60
AEA-92	0.04	gal	$3.34	$0.13
Non-Carbonated Water	4.73	gal	$0.03	$0.14
Solids				
Direct Colors Pigment	5.74	lbs	$5.00	$28.72
Concrete Fibers				
Grace MicroFiber™	0.407	lbs	$0.93	$0.38
Tuf-Strand Maxten	0.525	lbs	$0.93	$0.49
Reinforcement				
Carbon Fiber Mesh	130	sq ft	$6.32	$821.60
Finishing				
Vinyl Lettering	Lump Sum		$124.00	$124.00
Everclear 350	130	sq ft	$0.50	$65.00
Styrofoam	1.05	cu ft	$25.00	$26.25
TOTAL				**$1,125.88**

BILL OF LABOR (BY POSITION)			
Job Description	**Total Hours**	**Unit Price**	**Total**
Labor Costs			
Principal Design Engineer	780	$50	$39,000.00
Design Manager	55	$45	$2,475.00
Project Construction Manager	52	$40	$2,080.00
Construction Superintendent	30	$40	$1,200.00
Project Design Engineer (P.E)	25	$35	$875.00
Quality Manager	34	$35	$1,190.00
Graduate Field Engineer (EIT)	10	$25	$250.00
Technician/Drafter	5	$20	$100.00
Laborer/Technician	860	$25	$21,50.00
Clerk/Office Admin	50	$15	$750.00
TOTAL			**$69,420.00**

BILL OF LABOR (BY DISCIPLINE)			
Discipline	**Total Hours**	**Unit Price**	**Total**
Labor Costs			
Mix Design	485	Varies	$13,525
Mold Construction	149	Varies	$4,925
Aesthetics	37	Varies	$1,720
Hull Design	70	Varies	$2,750
Project Management	310	Varies	$14,500
Canoe Construction	523	Varies	$15,755
Academics	332	Varies	$16,245
TOTAL			**$69,420**



LUMP SUM, MULTIPLIERS, AND EXTERNAL CITATIONS

Lump Sum for Mold Construction			
Material	**Quantity**	**Unit Price**	**Total**
Mold Construction			
Foam Mold	Lump Sum	$1,017.00	$1,017.00
TOTAL			**$1,017.00**

Lump Sum for Transportation			
Material	**Quantity**	**Unit Price**	**Total**
Shipping (Gas, Labor, Lodging)			
Transportation from Tempe, AZ to Platteville, WI	Lump Sum	$3,450.00	$3,450.00
TOTAL			**$3,450.00**

Direct Labor:

$$DL = \left[\sum (RLR * HRS)\right] * (DEC + IEC) * (I + P)$$

$$DL = \$70{,}420 * (1.50 + 1.30) * (1 + 0.18)$$

$$DL = \$232{,}667.68$$

Expenses:

$$E = \left(\sum MC + \sum DE\right) * (1 + M)$$

$$E = (\$1{,}125.88 + (\$1{,}000 + \$69{,}420)) * (1 + 0.10)$$

$$E = \$78{,}700.47$$

A majority of the material costs were obtained from *Attachment 4* of the *2020 Concrete Canoe Request for Proposal*. The team assumed that any fluctuation in market value prices would be negligible since only one year has elapsed. All other material unit prices were taken from either the material manufacturer's website or local hardware store website. All prices were taken from the same day and the team is not liable for any fluctuation with future prices changes. Unit prices taken from external sources are cited below, taxes and shipping were omitted for simplification.

*Direct Expenses calculations ($\sum DE$) were found by taking the costs of outside consultants and other direct expenses related to either the research and development or construction phases of the project.

Material Unit Prices					
Name	**Material Classification**	**Total Price (TP)**	**Total Unit (TU)**	**Unit Price**	**Linked URL**
Hydrated Type S Lime	Cementitious Material	$14	50 lbs.	$0.28	Chemstar Type S Organic Hydrated Lime 50 lb.
Clay Shale (Fine)	Recycled Aggregate	$5	100 lbs.	$0.05	Utelite Clay Shale
Clay Shale (Crushed Fine)	Recycled Aggregate	$5	100 lbs.	$0.05	Utelite Clay Shale
Clay Shale (10 Mesh)	Recycled Aggregate	$5	100 lbs.	$0.05	Utelite Clay Shale
Agsco® 0.1-0.3mm	Recycled Aggregate	$40	40 lbs.	$1.00	Foamed Glass Spheres
Agsco® 0.25-0.5mm	Recycled Aggregate	$27	27 lbs.	$1.00	Foamed Glass Spheres
Agsco® 0.5-1.0mm	Recycled Aggregate	$25	25 lbs.	$1.00	Foamed Glass Spheres

Pre-Qualification Form (Page 1 of X)

Arizona State University
(school name)

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

The requirements of all teams to qualify as a participant in the Conference and Society-wide Final Competitions as outlined in Section 2.0 and Exhibit 3.	EA KW
The requirements for teams to qualify as a potential Wildcard team including scoring in the top 1/3 of all Annual Reports, submitting a Statement of Interest, and finish within the top 1/2 of our Conference Concrete Canoe Competition (Exhibit 3)	EA KW
The eligibility requirements of registered participants (Section 2.0 and Exhibit 3)	EA KW
The deadline for the submission of *Letter of Intent* and *Pre-Qualification Form* (uploaded to ASCE server) is October 22, 2020.	EA KW
The last day to submit *ASCE Student Chapter Annual Reports* to be eligible for qualifying (so that they may be graded) is February 1, 2021.	EA KW
The last day to submit *Request for Information* (RFI) to the C4 is January 22, 2021.	EA KW
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.	EA KW
The submission date of *Technical Proposal* and *Enhanced Focus Area Report* for Conference Competition (uploading of digital copies to ASCE server) is Friday, February 19, 2021.	EA KW
The submission date of *R. John Craig Presentation* for Conference Competition (uploading of presentation to ASCE server) is Friday, February 19, 2021.	EA KW
The submission date of *three (3) Peer Reviews* to the respective teams' folders (uploading of digital copies to ASCE server) is Friday, March 12, 2021.	EA KW
The submission date of *Technical Proposal* and *Enhanced Focus Area Report* for Society-wide Final Competition (uploading of digital copies to ASCE server and mailed hard copies to ASCE Headquarters) is Thursday, May 20, 2021.	EA KW

Edward Apraku 10/19/2020
Team Captain *(date)*

Edward Apraku
(signature)

Kristen M Ward 10/19/2020
ASCE Student Chapter Faculty Advisor *(date)*

Kristen Ward
(signature)

Pre-Qualification Form (Page 2 of X)

Arizona State University
(school name)

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

Currently, ASU is conducting classes in a hybrid method for classroom instruction. However, an overwhelming majority of students have opted to attend classes strictly online. After Thanksgiving break, the hybrid option will stop, and all classes will be strictly online. In conjunction with this change, the academic semester has been reduced by one week with finals week being canceled and final exams occurring the last week of classes in the fall semester. The core members of the team currently have access to laboratory space and Urban System Engineering building for concrete mix construction and testing.

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

The team's health and safety program was adapted by the team and is enforced by the project manager in conjunction with the ASU EH&S team. This includes long pants, close-toed shoes, face masks, and goggles utilization for all work done in the concrete and construction lab. All team leaders have completed requisite online and in-person training including fire safety, dust inhalation training, and hazardous waste disposal. The project manager also has a direct line of communication with the university lab manger and has meetings with them to approve material acquisitions, project activities, and to update the health and safety guidelines depending on the phase the project is on and the materials being considered. The team will be following COVID safety regulations imposed by the university while in any lab spaces. This includes monitoring the individuals entering the lab spaces, ensuring all participants complete their ASU daily health check, limiting capacity of lab space to less than 10 people, etc.

COVID-19 will greatly decrease the amount of people we can have working on the project at any given time. A detailed schedule will be created for each lab space where members will need to sign up in advance to enter. All captain and team meetings will be conducted over Zoom. Ultimately, the health and safety of the team will be the utmost importance throughout the project.

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?

For quality control, the mix design team has multiple tests, such as cylinder testing, slump testing, and buoyancy testing after every mix is made to ensure that each mix meets the requirements stipulated by the team. The construction team constantly tests the depth of concrete placed on the mold using tread-depth gauges and strips of shelf-liners to control the accuracy of concrete placement. Mix designs will be tested against previous years to ensure consistency. For quality assurance, the team has started using KitchenAid mixers to achieve the same quality every time. The construction team has changed mold preparation procedures regarding the shaping of the bulkhead to ensure a final product that is consistent with the original design. The team has also implemented a new shelf-liner system to aid volunteers in placing the proper thickness of concrete.

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

Yes, the team has completed multiple safety and testing trainings regarding using face masks, respirators, compression testing equipment, hazardous waste collection, and in sample preparation. The team is in constant communication with the EH&S team for the engineering school, meets with the EH&S team about once a week, has a dedicated Facilities Manager through ASCE, works with multiple professors for use of the machines and constantly ensures that the work is being conducted safely. The team has used a fume extractor, has updated procedures regarding ventilation, and prioritizes safety over efficiency.

The anticipated canoe name and overall theme is – *(please provide a brief description of the theme. The intent is to allow ASCE to follow up to determine if there may be copyright or trademark issues to contend with, as well as to provide insight). Note: teams may re-use past themes.*

The theme for this year's canoe is *Sun Devil Crossing,* a spin-off of the popular game Animal Crossing. The theme would incorporate elements from across the Animal Crossing universe with an emphasis on artwork from the recent adaptation, New Horizons.

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

Yes

The core project team is made up of 7 of people.

RFP Addendum No.1
Correction to Submission Date

4.2.1 Letter of Intent & Pre-Qualification Forms

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

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

Correction

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

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

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

Edward Apraku — 10/19/2020

Team Captain (print name) — *(date)*

Edward Apraku

(signature)

Kristen Ward — 10/19/2020

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

Kristen Ward

(signature)

Enhanced Focus Areas

Arizona State University

Tempe, AZ

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Selection Process and Value Added

Team Selection Process

The COVID-19 pandemic allowed for the ASU Concrete Canoe Team (ASUCCT) to use the 2020-2021 academic year to improve the foundation, both in methods and our virtual infrastructure. Certain aspects of the canoe-making process had been blurred throughout the years and the knowledge gap between alternating Project Managers (PMs) was a prevalent issue that plagued the team. From MATLAB code explanation to fundraising efforts, the team often had to start over each academic year due to emails being lost and members graduating and not passing on their knowledge and expertise. Thus, to help the current and future teams, the outgoing PM created a comprehensive document detailing the entire ASU canoe-making process. The current team decided to continue this embrace of history and leadership and began looking at ways to improve our canoe framework during this unprecedented time where our members are ever eager to help, even as they log on from across the nation. The team decided our chosen areas will include new explorations that will help future teams with their canoe design and professional development all while being completed entirely online due to university shutdowns. Ultimately, the chosen enhanced focus areas incorporate new computer methods into hull design analysis and improve our digital presence.

For the past six years, the ASUCCT has used a Microsoft Excel/MATLAB code combination for canoe hull design and structural analysis. This was created by a dedicated alumnus and has saved ASUCCT weeks by designing multiple models and analyzing their stresses quickly and accurately. The code had been designed to give coordinate outputs for software like AutoCAD™, Shopbot CNC, and DELFTship, making the link from online to 3D mold effortless. However, due to software updates and hesitation in altering the code outputs, the DELFTship program was never incorporated for hull analysis. The team allotted additional time this year to learn the program and update the coordinate outputs to give 3D views of the designs without the need for external CAD drawings and CNC mold creation. This was the first year that DELFTship was used for the advanced hull design and the team was able to analyze speed scenarios, anticipate resistance, and calculate the prismatic coefficient through the program.

During the first university shutdown caused by the pandemic, all ASU clubs were forced to transition to online platforms to conduct their meetings and events. The canoe team was left in limbo as our construction space was closed and members were barred from further helping in all remaining categories prior to our regional competition. The 2019-2020 team had recruited their highest number of student volunteers and wanted to keep the momentum alive into the next academic year despite the unpredictability of the pandemic and the entirely new executive team. The current team cooperated with the ASU ASCE Student Chapter to improve their virtual presence. The student chapter created a club Instagram account (@asceasu) to reach out to new members and showcase competition teams. ASUCCT initially wanted to create a separate account but felt the student chapter account was doing a stellar job at highlighting all events and could serve as an initial point of contact for the team. Thus, a team website (https://asuconcretecanoe.github.io/) was chosen to be our second enhanced focus area and could improve our relations with industry sponsors and streamline our improved communication efforts. The 2018-2019 ASUCCT had previously created a team website, but it fell apart shortly after the conclusion of PSWC 2019. Similarly, the website did not include current contact information and could not be easily edited due to ownership by a third-party individual. The team was able to recruit a computer science student to aid in its creation and will have complete ownership to update it through the years.

Summary of Value Added

The inclusion of these enhanced focus areas will help to reduce time spent on hull design and can bring a more analytical approach to test potential resistance during a time where paddling cannot occur. The website will help to update industry sponsors and interested students on our progress while allowing members to learn how to code.

While it's difficult to quantify their immediate impacts, the team felt that the personal growth and knowledge gained by our current team will aid future teams in their competitions. Members gained new insight on computational fluid mechanics and HTML coding that had not been explored previously, allowing for a diverse and holistic development that will have direct results on the future years.

DELFTship Software

Problem Statement

The pandemic proved to be a challenge for the team as it rendered all of our typical meetings and recruiting events impossible to do in-person. In addition to casting day, the team's annual paddling tryouts were one of the most anticipated and well-attended events, garnering interest from a wide range of eager ASU ASCE members. The paddling tryouts allowed students to experience firsthand how to maneuver a concrete canoe in open water, and the ample wave resistance that came with it. In the past, this was typically how paddlers trained to overcome the resistance they experienced at faster speeds. Not much finite analysis was taken into consideration and hull design was only reliant on canoe geometry, structural analysis, and anticipated maneuverability.

Figure 1. 2020 Paddling Tryouts on Tempe Town Lake with 2011 Canoe *Devils Du Soleil*

The team wanted to incorporate a similar design to *Legacy* to *Sun Devil Crossing* but since abrupt closure never allowed members to practice with *Legacy*, new methods had to be explored to test potential resistance given speed scenarios. The team had previously explored the software DELFTship as an analysis tool but could not alter the team MATLAB code to successfully transfer the spline coordinates to surface coordinates. The team felt the advancement and personal knowledge gained from the program was worth the risk of altering the alumnus code. The ASUCCT knew future teams would benefit greatly from its addition and the program became increasingly attractive during hull design.

The use of DELFTship was an ambitious project to take on as an enhanced focus area, requiring members to make sense of 18 MATLAB code files, 8 output files, 3000 lines of 3D coordinates, and an entirely new program that had never been used before in ASUCCT history. In terms of quantifiable time, the team saw a 22% decrease in total hull design time. The team anticipates this statistic to widen as future captains become more familiar with the program.

DELFTship Background

DELFTship Maritime Software is a program that allows users to model hull forms for vessels including canoes, boats, ships, and yachts. The program began as a code to assist naval architects in designing hull designs, developers then decided to add computer-aided design to their program. Once they created an appropriate hull, the hydrostatic data, resistance, and other hull characteristics could be obtained. Since its start, DELFTship has had frequent updates to optimize the user experience, add problem-solving for real-life issues, and create beautiful software.

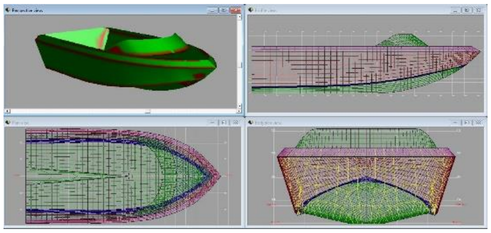


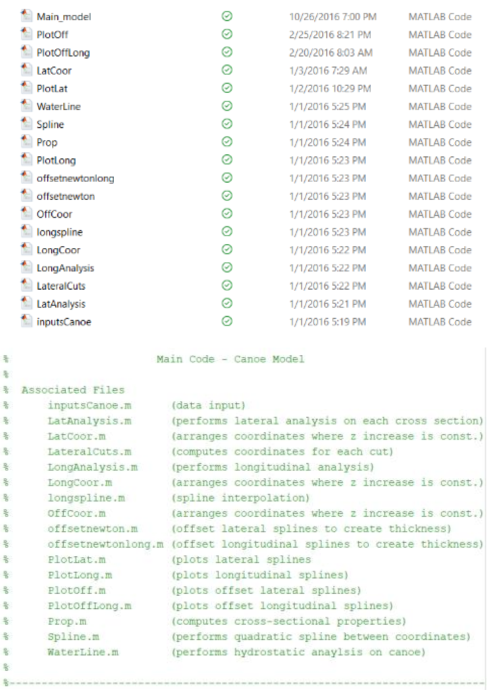
Figure 2. Hull Modeling Example

DELFTship can create 3D vessel designs providing hydrostatic details with a variety of extensions, including but not limited to, Bending Moment and Shear Forces, Floodable Length, Inclined Hydrostatics, and Load Cases/Intact Stability. The load case extensions apply different load cases to vessel models to ensure the model is efficient and appropriate for whatever load cases it will take on.

DELFTship can be used by anyone interested in advanced ship design, whether that be individuals at home, naval engineers, or students participating in ASCE's Concrete Canoe competition. The 3D modeling features, hydrostatic calculation capabilities, and report outputs allowed for the team to have an easy transition from 2D design to 3D view for *Sun Devil Crossing*. DELFTship was an extremely helpful tool for those trying to create a vessel and believe future ASUCCT can utilize this program to blueprint and calculate their hull design.

Reasoning and Exploration

Due to turbulent transportation from conferences and recycled concrete efforts, previous team canoes were made unavailable for paddling practice. This forced the team to continually use the 2011 canoe, *Devils Du Soleil*, making this the 10th year it has been in use for paddling. While the canoe has held up through the years and shows little damage, the team knew that retirement would need to occur soon and believed 2020's *Legacy*, once completed, would serve as an excellent replacement. Since *Legacy* never made it to open waters, the team conducted trial runs using old uncompleted DELFTship surface coordinates. This way, the design of *Sun Devil Crossing* could be completed independent of the progression of this exploratory topic. The hull design team was extremely reluctant of altering large portions of the team MATLAB code and consistently ensured backup files were created in the event the endeavor failed. Similarly, the project managers were prepared to create a canoe model without the use of the program, believing they could instead use the prismatic coefficient and Froude's number to anticipate wave resistance. The team lacked the technical knowledge required for computational fluid mechanics and recruited several faculty members to aid with this project but to no success. Ultimately, hard coding was the chosen route and the team contacted the alumnus to aid in the project.



Main_model	✓	10/26/2016 7:00 PM	MATLAB Code
PlotOff	✓	2/25/2016 8:21 PM	MATLAB Code
PlotOffLong	✓	2/20/2016 8:03 AM	MATLAB Code
LatCoor	✓	1/3/2016 7:29 AM	MATLAB Code
PlotLat	✓	1/2/2016 10:29 PM	MATLAB Code
WaterLine	✓	1/1/2016 5:25 PM	MATLAB Code
Spline	✓	1/1/2016 5:24 PM	MATLAB Code
Prop	✓	1/1/2016 5:24 PM	MATLAB Code
PlotLong	✓	1/1/2016 5:23 PM	MATLAB Code
offsetnewtonlong	✓	1/1/2016 5:23 PM	MATLAB Code
offsetnewton	✓	1/1/2016 5:23 PM	MATLAB Code
OffCoor	✓	1/1/2016 5:23 PM	MATLAB Code
longspline	✓	1/1/2016 5:23 PM	MATLAB Code
LongCoor	✓	1/1/2016 5:22 PM	MATLAB Code
LongAnalysis	✓	1/1/2016 5:22 PM	MATLAB Code
LateralCuts	✓	1/1/2016 5:22 PM	MATLAB Code
LatAnalysis	✓	1/1/2016 5:21 PM	MATLAB Code
inputsCanoe	✓	1/1/2016 5:19 PM	MATLAB Code

```
%                       Main Code - Canoe Model
%
% Associated Files
%     inputsCanoe.m       (data input)
%     LatAnalysis.m       (performs lateral analysis on each cross section)
%     LatCoor.m           (arranges coordinates where z increase is const.)
%     LateralCuts.m       (computes coordinates for each cut)
%     LongAnalysis.m      (performs longitudinal analysis)
%     LongCoor.m          (arranges coordinates where z increase is const.)
%     longspline.m        (spline interpolation)
%     OffCoor.m           (arranges coordinates where z increase is const.)
%     offsetnewton.m      (offset lateral splines to create thickness)
%     offsetnewtonlong.m  (offset longitudinal splines to create thickness)
%     PlotLat.m           (plots lateral splines
%     PlotLong.m          (plots longitudinal splines)
%     PlotOff.m           (plots offset lateral splines)
%     PlotOffLong.m       (plots offset longitudinal splines)
%     Prop.m              (computes cross-sectional properties)
%     Spline.m            (performs quadratic spline between coordinates)
%     WaterLine.m         (performs hydrostatic anaylsis on canoe)
%
%--------------------------------------------------------------------
```

Figure 3. Associated MATLAB Code Files with Function Descriptions

The team was able to seamlessly incorporate the given coordinates into the program and create a 3D representation of the hull model. This was a challenging task that involved creating additional lines of code to incorporate the "closing" of the canoe at the bow and stern. The code gave two surface outputs based on interior and exterior thickness, exterior was utilized, and the final product is shown in Figure 4.

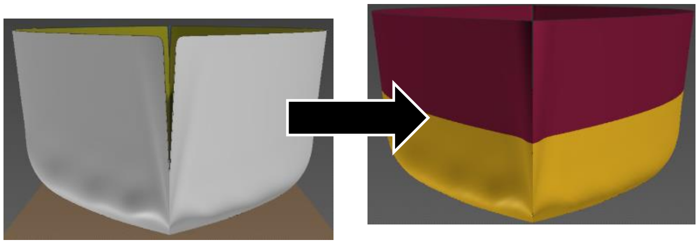


Figure 4. 2020's *Legacy* in DELFTship Before and After Code Alteration

Previously, this roadblock meant the program would interpret the canoe as "open" and was unable to conduct any calculations since the leak points would drive the design and cause flooding. This closing meant that the program could begin to perform a myriad of calculations such as wave resistance using the Delft Series ('98) and John Winters' KAPER method, hydrostatics, midship area, block coefficient, prismatic coefficient, and much more. Design parameters included the anticipated weight of the canoe taken from the code output, a conservative density estimate of 62 pcf to ensure flotation, and co-ed races as point loads.

The hull design team was able to create multiple models in Excel, analyze structural analysis in MATLAB, and finally calculate resistance in DELFTship achieving a coordinated effort resulting in a competitive hull design. The team used *The Maroon Machine* race-day performance from PSWC 2019 to compare the calculated resistance with actual performance and estimated about a 72% consistency between the two results.

Impact on Future Race Performance

This addition will propel ASUCCT to new heights and improved competition rankings. The team normally ranks in the top 1/3rd of our regional student competition, but increased model testing believe will allow us to break through the leaderboard of multiple races. Furthermore, future team paddling practices will alter their methods to anticipate the increased resistance at higher speeds while prioritizing maneuverability with unstable canoes. Paddling with *Legacy* will be the final test of our hypothesis and the team believes the DELFTship values will be consistent yet again, enhancing our hull design and aiding future teams.

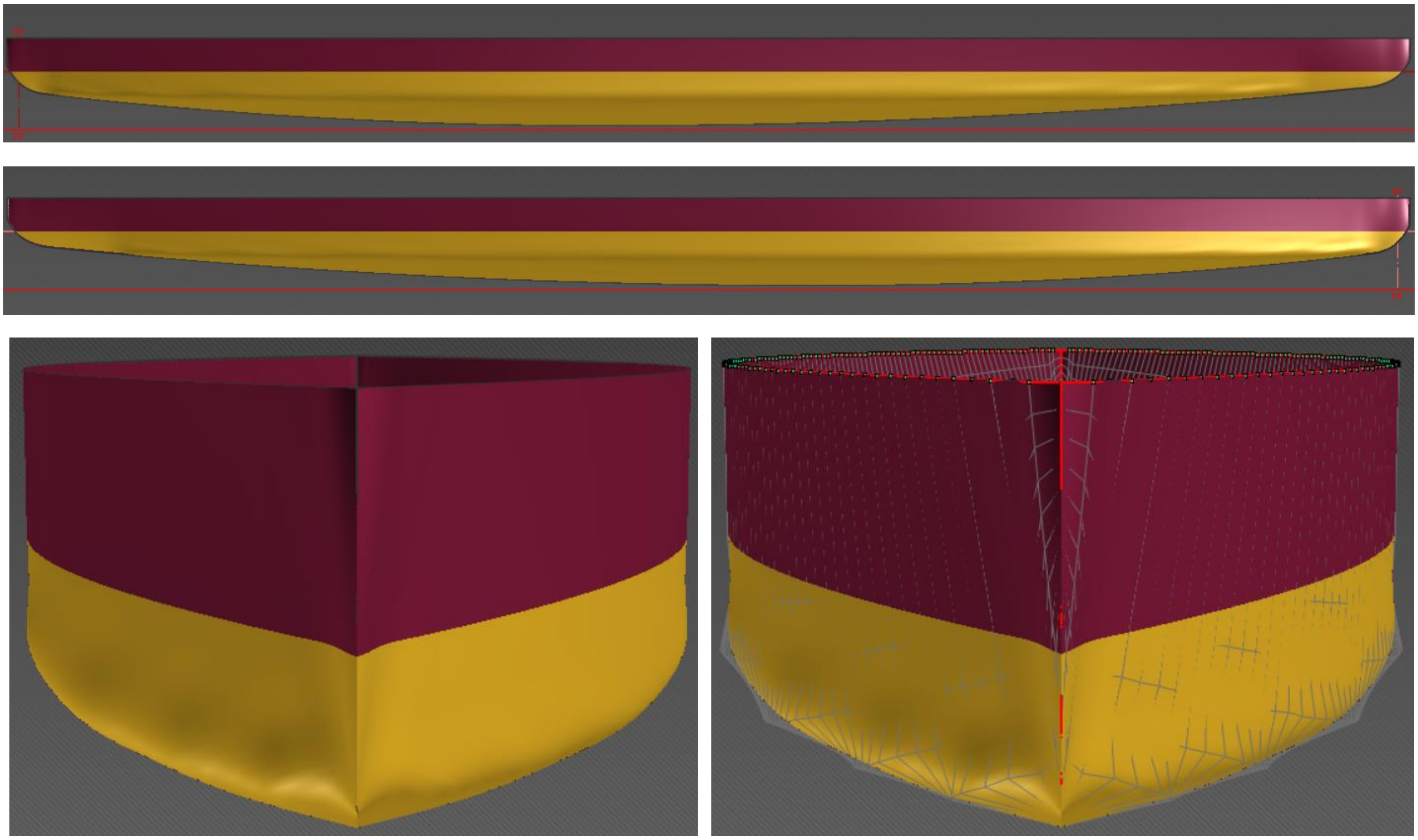


Figure 5-8. Top and bottom images showing *Sun Devil Crossing* in elevation view, bottom right shows plan view, bottom right shows plan view with leak points (gunnels). Gold indicates the waterline

Race Results		
Rank	**University**	**Points**
1	Cal Poly San Luis Obispo (CPSLO)	25.00
2	University of Hawai'i at Manoa (UHM)	22.40
3	University of California, Los Angeles (UCLA)	18.00
4	University of California San Diego (UCSD)	13.90
5	Cal State University, Northridge (CSUN)	13.70
6	Arizona State University (ASU)	12.90
7	San Diego State University (SDSU)	11.10
8	University of Nevada, Las Vegas (UNLV)	6.00
9	University of Southern California (USC)	5.20
10	University of California, Irvine (UCI)	2.70
11	California Baptist University (CBU)	1.60
12	University of Arizona (UofA)	1.50
13	Loyola Marymount University (LMU)	1.20
14	Cal Poly Pomona (CPP)	0.90
14	Northern Arizona University (NAU)	0.90
16	Cal State University, Fullerton (CSUF)	0.00
16	Cal State University, Long Beach (CSULB)	0.00
16	Cal State University, Los Angeles (CSULA)	0.00

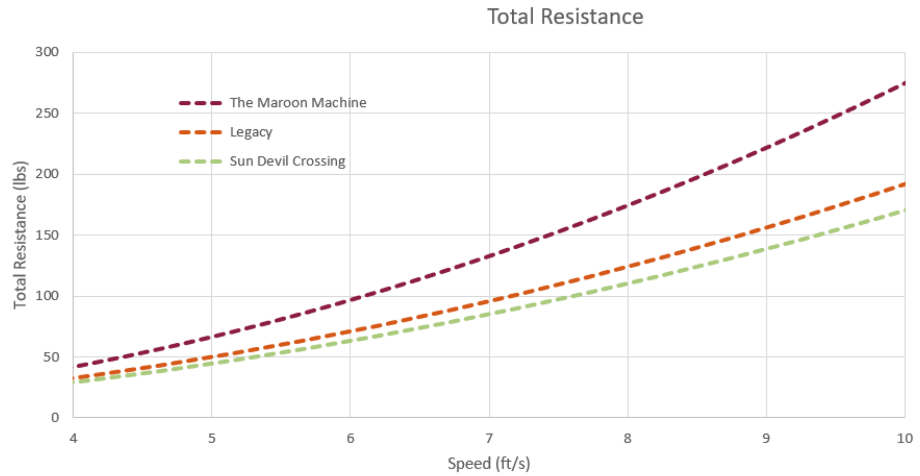


Figure 9. Overall PSWC 2019 Race Results and Total Resistance Testing Against ASUCCT Canoes

Concrete Canoe Website

Problem Statement

Due to the COVID-19 pandemic, most elements of school and clubs are now completely virtual. The ASU ASCE chapter had created an Instagram page to better facilitate membership announcements for the current members and spark interest with incoming freshman class. Rather than going for a similar page, the team shot for a more personalized and engaging project to better their virtual infrastructure. For an activity like the planning, building, and presenting of a canoe, this presents a huge challenge in maintaining community engagement and attracting sponsorship. Although ASU had experimented with two forms of a website for concrete canoe--one a page on a club website provided by ASU and the other a highlight of one year of concrete canoe--there was no homepage for information about the organization and how to support it. To address this gap in information dissemination, the team leaders decided to create an official and professional website to highlight the club's work and more effectively promote the club in the community.

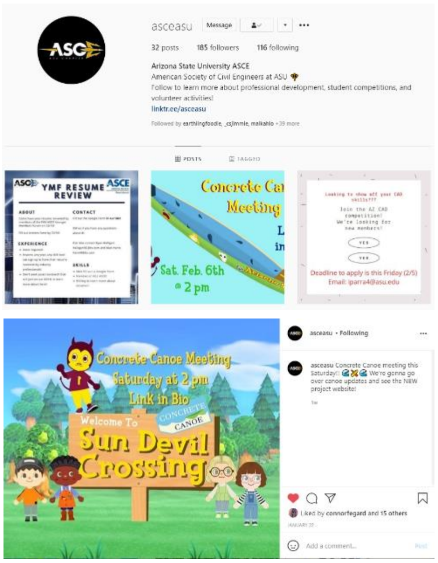


Figure 10. ASCE ASU Instagram Page with ASUCCT Events

The new website would be unique from previous attempts in both depth and breadth. A homepage for the club would need to include elements to highlight the team members working on the canoe--in the form of photos, a team highlight, and examples of previous work--as well as pages describing the organization and best methods to contact leadership. Previous websites either only had overviews of concrete canoe as one portion of the ASU ASCE chapter or a deep dive on one specific year of concrete canoe. The challenge was creating something with the best of these two approaches to create a place to showcase the team and provide information to those looking to learn more. The last key component would be the requirement that the website would be simple to maintain and update for future years. ASU ASCE chapter does not boast many members studying computer science, so creating something that could be easily understood by all members was key.

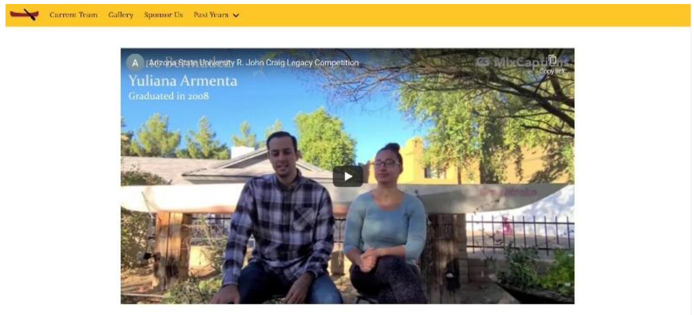


Figure 11. Front Page of the Website with R. John Craig Legacy Competition Video Submission

Technical Solution and Work Conducted

There were two options for creating the concrete canoe website: using a website builder service or building the website from scratch. Using website building services was initially appealing because of the ease of use and lack of technical requirements. However, these services cost a fee and require further payment for custom domains. Building a website from scratch has a much higher initial work threshold but can be completely customized and then easily maintained with the correct setup. This does not come with fees and can be hosted for free with GitHub using a custom domain. The team decided to pursue the custom website option and reached out to ASU computer science students to gauge interest in collaborating with ASCE to create such a website. One student volunteered to create the website as a side project and was especially interested in creating a website that would be easy to maintain for the club in future years. This student, the webmaster, collaborated with canoe leadership to determine the aesthetic layout, content, and platform for the website.

The website was written in HTML, CSS, and JavaScript using the popular web framework Bulma. These tools were chosen to create a low barrier of entry to any member of ASCE who would want to play with the website's formatting in future years, as each of these languages is extensively documented. The framework Bulma was chosen because of the robust documentation including examples and the ease of creating a website that would maintain aesthetic cohesiveness on all device sizes. The website would be hosted on GitHub as this allows a custom URL using the club's free GitHub account username.

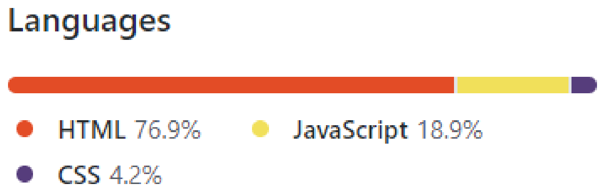


Figure 12. Coding Language Breakdown

Creating the website was a process that lasted 5 months and depended on frequent discussions with the team about the direction of the website, assets, and ideas for new information to include. Technically, the website rests on a few HTML documents that are filled in using JavaScript scripts. All of the custom content for each year is put into CSV documents, which can easily be done using Excel, and the JavaScript code will grab all of this data to update the website. This means that each year's ASUCCT needs to only upload 6 things: the photos they would like in the gallery, the CSV file of the names of these photos, the photos they would like of their team, the CSV file of the descriptions for the members, the sponsors for their canoe team, and the canoe report from the previous year. Not a single line of code needs to be modified, which eliminates the coding barrier that a website built from scratch usually entails.

name	pronouns	role	photo
Alejandro Muñoz	He/Him	Project Manager and Mix Design Captain	"2020.2021_team/Alejandro Munoz.jpeg"
Alexandra Plukis	She/Her	Coding Captain	"2020.2021_team/Alexandra Plukis.jpg"
Arely Lopez	She/Her	Construction Captain	"2020.2021_team/Arely Lopez Cortez.jpeg"
Caleb Siff	He/Him	Support	"2020.2021_team/Caleb Siff.jpeg"
Edward Apraku	He/Him	Project Manager	"2020.2021_team/Edward Apraku.jpg"
Gabriella Stadler	She/Her	Aesthetics Captain	"2020.2021_team/Gabriella Stadler.jpg"
Janelle Miguel	She/Her	Team Member	"2020.2021_team/Janelle Miguel.jpeg"
Joseph Todsen	He/Him	Team Member	"2020.2021_team/Joseph Todsen.jpeg"
Maya Elliott	She/Her	Team Member	"2020.2021_team/Maya Elliott.jpeg"
Peter Nguyen	He/Him	Hull Design Captain	"2020.2021_team/Peter Nguyen.jpg"
Susanna Westersund	She/Her	Team Member	"2020.2021_team/Susanna Westersund.jpg"
Valentina Rivera	She/Her	Team Member	"2020.2021_team/Valentina Rivera.jpeg"
Zane Monell	He/Him	Team Member	"2020.2021_team/Zane Monell.jpg"

Figure 13. Image Submission by Team Captains and Volunteers on Excel

Team Approach and Knowledge Transfer

Throughout the website building process, there was constant contact between the webmaster and the ASUCCT team. The initial brainstorming for the content and appearance of the site happened with the

Figure 14. Transfer from Excel to Website with Members Listed Alphabetically by Column

entire concrete canoe team during a biweekly meeting, where a committee for the website was created. This committee had a larger role within the creation of the website, creating surveys for gathering team member information for the website, providing ideas for the specific page content and aesthetics, and creating assets for the galleries on the site. In addition, this committee created a video that would be showcased on the website. All of these elements for the website were stored in a Google Drive folder that shared access with the entire team and the webmaster so that everyone could contribute to the site.

Since the website requires that documents be uploaded with specific names, a straightforward knowledge transfer between years is critical. To this end, there is a Readme document explaining how to update the website yearly on the GitHub account where the code is stored. Keeping all of the information and code stored in one place reduces the chance that information will be lost between years and improves the likelihood of consistent website maintenance. In addition, a video accompanies the Readme document to further improve the quality of the tutorial for those who have limited experience with website maintenance.

alexandra-plukis Merge branch 'main' of https://github.com/ASUCCT/asuconcretecan...	✓ a25f59b 3 days ago	16 commits
2020.2021_team	website v1	15 days ago
canoe_reports	website v1	15 days ago
website_images	updating for better search results, removing duplicated image	3 days ago
.gitattributes	added large video	15 days ago
README.md	Initial commit	15 days ago
current_team.html	updating for better search results, removing duplicated image	3 days ago
current_team.js	web docs version 1	15 days ago
google07a0be8328a07ec2.html	adding google verification file	3 days ago
homepage.js	web docs version 1	15 days ago
image_gallery.html	updating for better search results, removing duplicated image	3 days ago

Figure 15. GitHub Account with Several Main Files

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