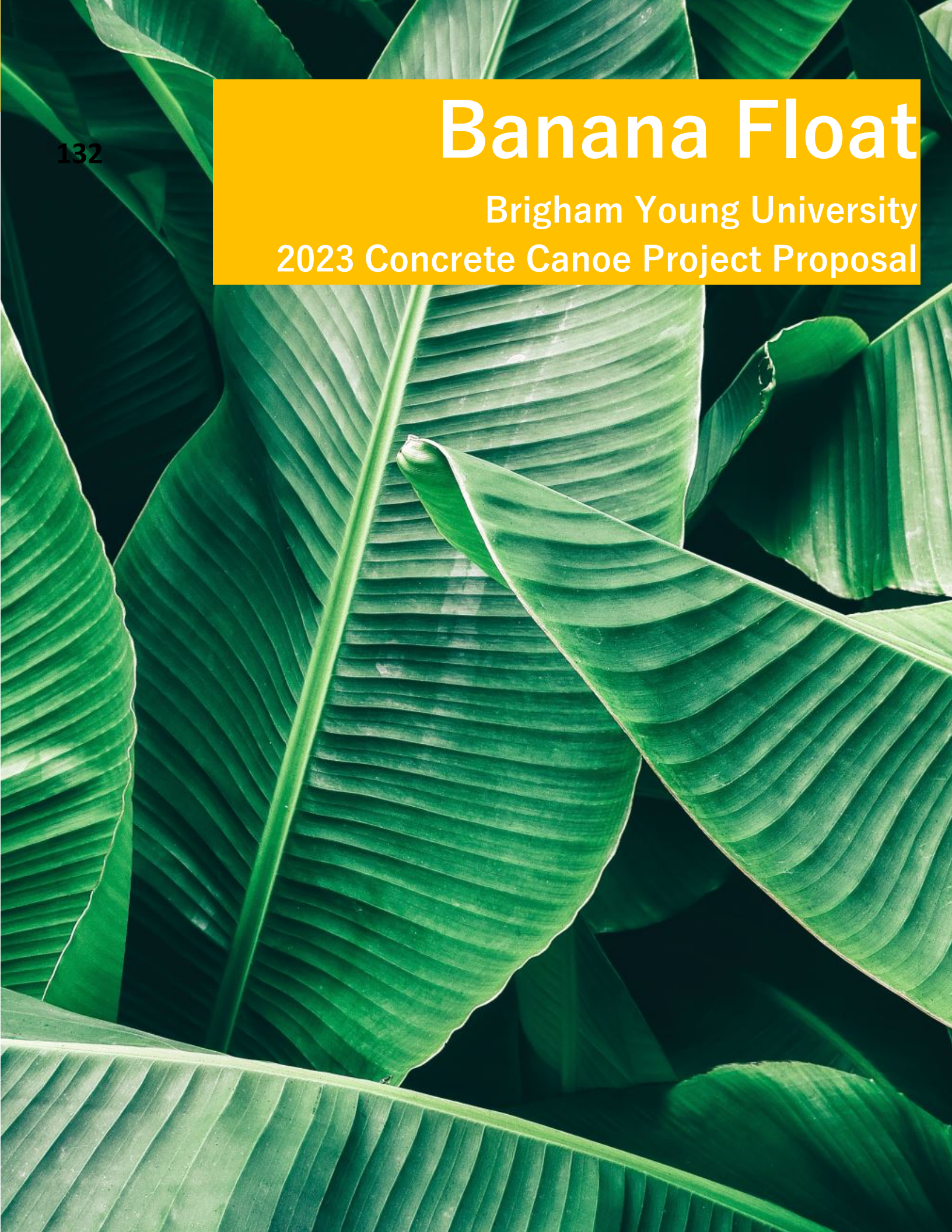


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Banana Float

Brigham Young University
2023 Concrete Canoe Project Proposal



Brigham Young University Concrete Canoe Team

February 17, 2023
Committee on Concrete Canoe Competitions
ASCE Student Services
1801 Alexander Bell Drive
Reston, VA 20191
Attn: 2021 Concrete Canoe Competition

Subject: Response to Request for Proposal -- 2022-2023 Concrete Canoe

The Brigham Young Concrete Canoe Team (BYUCCT) is excited to present our project proposal for the 2022-2023 competition year. The BYUCCT has competed in the Concrete Canoe Competition for many years and is proud to present the culmination of our work during a year faced with the challenges caused by the ongoing COVID-19 pandemic. The team has thoroughly reviewed the 2022-2023 Request for Proposals (RFP) and has checked that the C4 that our submission complies with the rules and specifications. All registered participants listed below are qualified student members and Society Student Members of ASCE that meet all eligibility requirements detailed in Section 3.0 of the 2022 RFP.


Participant	ASCE Society Member ID Number
Mason Millard	000012228220
Sam Oldham	000012232723
Ivy Stout	000012218104
Brindalynn Darby	00001237
Lauren Buer	000011950951
Emily Walmer	000012218090
Steven Wright	000012218106
Pablo Harline	000012269743
Tate Baird	

Additionally, the BYUCCT hereby certifies that:

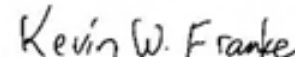
- The proposed hull design, concrete mixture design, reinforcement scheme, and construction of the prototype canoe has been performed in full compliance with the specifications outlined in the Request for Proposal.
- Material Technical Data Sheets (MTDS) and Safety Data Sheets (SDS) have been reviewed by the team.
- The team acknowledges receipt of the Request for Information (RFI) Summary and that their submissions comply with responses provided.
- The anticipated registered participants are qualified student members and Society Student Members of ASCE and meet all eligibility requirements.

The following signatures by the team captains and ASCE Student Chapter Faculty Advisor certify that the NCCT's 2022 submission Azure and the information presented in this Project Proposal and MTDS Addendum is true.

Sincerely,



Team Captain

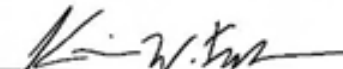


ASCE Student Chapter Faculty Advisor



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Executive Summary

A fun fact many don't know is that bananas float in water. This is since they are less dense than water. Many fruits including apples, oranges and even watermelon float for this same reasoning. A fun fact that even fewer know is that concrete can be made to float in water. Though initially substantially denser than a banana, this team, along with 200+ other teams across the US, set out to attempt to make a concrete mix and canoe that could not only float, but can also participate in races and maneuverability challenges (UNR ASCE Student Chapter, n.d.). A banana's density is 58.68 pounds/cubic foot (IjPPHT, 2012); with our final concrete mix weighing in with a density of 45 pounds per cubic foot, we managed to make a canoe less dense than a banana. Table 1 shows the specifications of the affectionately named, "The Banana Float," canoe. This project has tested the teams' understanding of concrete, ingenuity, and at times, resilience.

Table 1: Specifications

Specifications	
Maximum Length	19 ft
Maximum Width	24 in
Maximum Depth	16 in
Average Hull Thickness	0.75 in
Weight (estimated)	lbsf
Structural Mix Proportions (28-day)	
Moist Unit Weight	52.1 pcf
Dry Unit Weight	45 pcf
Compressive Strength	1325 psi
Tensile Strength	210 psi
Composite Flexural Strength	260 psi
Air Content (%)	13.8

The BYU ASCE Student Chapter has a living legacy of learning and service. For more than 50 years, BYU's ASCE student chapter has been a place for civil engineering students to learn, grow, and serve, while preparing for their careers in the engineering

industry. Individually, and as a whole, the students are proud to be a part of this organization. The chapters' purpose is, "to enable civil engineering students to learn, grow, gain leadership skills, and serve in meaningful ways, while gaining valuable insights into their future as professionals and citizens." This purpose is fulfilled through weekly seminar meetings, service projects, activities, and club meetings.

For the seminar the student chapter meets to hear from working professionals to learn about the industry and get practical advice. Each semester the students hear from a variety of speakers from all disciplines of civil engineering as well as from across the country and even internationally. The BYU ASCE Student Chapter also provides a place for students to socialize and build friendships. Every semester there are a myriad of activities that help students network amongst their peers such as volleyball and basketball tournaments, and club meetings. Students that represented BYU at 2022 ISWS are shown in Figure 1.



Figure 1: BYU's 2022 ISWS Attendees

Service is also a large part of the student chapter. Every member of BYU's ASCE chapter is required to attend three ASCE activities and spend at least three hours performing service to their communities. Students have done a variety of services with one of this year's favorites including volunteering at an engineering fair for local middle schoolers. This is just



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one of the many service opportunities that have allowed the students to be involved in the community and have a positive impact.

As the students strive to learn, grow, and serve as a student chapter they have left an ever-growing legacy. The Robert Ridgeway Student Chapter Award recognizes “the single most outstanding Student Chapter of the American Society of Civil Engineers” (Robert Ridgeway Student Chapter Award, n.d.). BYU’s ASCE chapter has won this award eight times, with the first being in 1973. Throughout the last 50 years, the students have strived to live up to the legacy established by past students. In the past ten years the student chapter has won the Ridgeway award a total of three times, with the most recent being in 2019. This is a great accomplishment and something the students are extremely proud of.

Beyond awards however, we are proud of who we are as individuals and as a student chapter. BYU ASCE has helped, and continues to help us, be the future engineers and leaders that our world needs. We are grateful to have a place where we can learn, grow, and serve together.

Key Team Roles

This is the first year BYU’S concrete canoe was approved to be a capstone project. The capstone team was comprised of four civil engineering seniors. Each Monday a capstone class was held for team meetings as well as short lectures. In the winter semesters, class lectures were presentations by those in the work force speaking on their company and the projects they were working on.

Capstone is a consecutive year long class that is required for each civil engineering student as they prepare to graduate. By the time this class ends, all junior core classes must have been taken. This is to prepare the students for the issues they will work to solve in their projects.

As part of capstone, there were two capstone teachers/advisors: Dr. Harold Mitchell and Dr. Rollin Hotchkiss. The team was also advised by Dr. Kevin Franke and Dr. Spencer Guthrie. Dr. Franke leads and advises BYU’s ASCE chapter. Dr. Guthrie is the professor of BYU’s elementary concrete class, multiple design and graduate level courses, and the manager of the Highway and Materials Laboratory on campus. He was consulted about ideas for mixes, as well as potential solutions to some of the issues encountered. The Highway and Materials lab was used for all concrete work including designing, batching, testing, and casting the canoe.



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Organization Chart

Capstone Member




**BRINDALYNN
DARBY**
Senior
Lead hull design
process, structural
analysis

Captain/Capstone
Member




MASON MILLARD
Senior
Oversaw all aspects of
the project, especially
the mix design

Capstone Member



SAM OLDHAM
Senior
Managed the schedule,
CAD drafting

Capstone Member



IVY STOUT
Senior
Managed aspects of
physical construction,
curing, and paper

Club Members



LAUREN BUER
Junior




EMILY WALMER
Junior



STEVEN WRIGHT
Senior



PABLO HARLINE
Senior



THOMAS ANDREWS
Senior

Additional Club Members:
Andrew Harline
Haidee Armstrong
Sierra Stewart
Tate Baird

Advisors and Consultants:
Dr. Spencer Guthrie
Dr. Kevin Franke
Dr. Harold Mitchell
Dr. Rollin Hotchkiss



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Hull design

To design Banana Float extensive research was done using several of BYU's past canoes namely Inviscid (2019), Phoenix (2018), and North Star (2017). The partial designs of the canoes Sakura (2020) and White Dragon (2021) were also used. These two designs were not finished as BYU didn't compete in the competition these years. The end design of Banana Float took much of its inspiration from Phoenix (2018) and Inviscid (2019).

Two main goals were decided upon by the team. Which were then used as guidelines for altering the geometry and overall design of the previous canoes. As no one on the team had previous experience with competing in concrete canoeing, it was decided that the design needed to be as stable as possible to avoid additional stresses to the canoe. Phoenix (2018) was designed with a high stability which made it easier for the racers to get in and out of the canoe as well as for them to not fall out of the canoe while racing. Inviscid (2019) was designed with maneuverability in mind. As such, the canoe featured a rounded chine. The square shaped chine of Phoenix (2018) and the rounded chine of Inviscid (2019) were combined to make a highly stable yet maneuverable canoe.

The team determined to use a symmetrical rocker instead of an asymmetrical rocker. An asymmetrical rocker would drastically complicate the construction of the canoe without providing any main benefits as the hull width had purposefully been designed to account for stability. It would also contribute to poor maneuverability.

To decrease the drag forces on the canoe the team decided to shorten the length of the canoe to 18 feet as compared to the roughly 19 feet sported by both Inviscid (2019) and Phoenix (2018). The depth of the canoe was also extended to ensure the necessary buoyancy.

Structural Analysis

Once the canoe was designed a structural analysis was performed to determine the necessary concrete specifications as well as the required reinforcement strength and quantity. The team decided that the canoe would not be pretensioned. The canoe was idealized as a beam for all structural calculations and a simple beam analysis was performed. The weight of the canoe and the buoyant force of the canoe on the water were estimated first to determine the maximum possible density of the concrete mix. This number was used solely as a safety checking precaution to ensure the canoe would float.

The weight added by racers was idealized, for both genders, as two 200-pound point loads, one 20% and the other 80% of the overall length. This ended up being at the 3.6-foot and 14.4-foot marks respectively. A second set of point loads of 140-pounds were added at 40% and 60% of the overall length. Putting them at 7.2-feet and 10.4-feet respectively. A shear diagram was created for the canoe dividing the force of the weight of the canoe and the buoyancy force evenly over the 5 sections created between the 4-point loads. The Moment diagram was created by calculating the area under the curves created by the shear diagram.

Once it was determined that the canoe would float with riders, the forces on the canoe during transportation were estimated. Once again, the canoe was idealized as a beam and a simple beam analysis was performed. The canoe's traveling trailer was inspected, and it was learned that the canoe would be held up by two straps for transport. The point loads created by the straps were determined and shear and moment diagrams were created.

A simple punching stress analysis was performed, as this was one of the largest concerns the team had with the low density of a few of the mix designs. The canoe was idealized as a non-prestressed non reinforced two-way slab and the Building Code Requirements for Structural Concrete (ACI 318-19) Punching Stress for



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a Two-Way Slab was utilized to verify the mix designs in question posed a low risk of failing in this manner.

Material Selection and Testing

The main objectives of the development and testing processes were to create a concrete mixture that maximized strength while maintaining a unit weight less than that of water (62.4 lb./ft³). The team typically made and tested 2 mixes a month changing one factor each time such as lime, an admixture concentration, the aggregate gradation, or the balance of the cementitious materials. This allowed for more direct comparisons between each mix and provided the team with time to design and carefully change each aspect of the mix. Compression tests were run following the American society of testing and materials (ASTM) standard C39 (Standard Test Method for Compressive Strength of Cylindrical Concrete Specimens). The concrete was cast in 6-inch cylinders that were 4-inches in diameter and allowing a separate set to cure in a fog room for each of 7, 14, or 28 days. These cure lengths were selected because they allowed the team to test more samples during each testing period and to calculate the theoretical 28-day strength of each cylinder with more accuracy compared to just testing once. This provided appropriate data on how to better change the mix design to maximize the design criteria. During this curing process, the cast cylinders were put in the fog room after one day. The cylinders were removed from the fog room after the appropriate length of time and air dried for 2-3 days before testing. Samples can be seen being batched in Figure and tested in Figure 3.



Figure 2: Sample Being Batched

Cylinders were allowed to cure for 28 days before being tested to determine the final strength and properties of our concrete more accurately as the tested mixes utilized many pozzolanic reactions. Other properties of the concrete, such as the flexure strength, were extrapolated from the measured compressive strengths.



Figure 3: Testing Sample Batches

Fly ash (type f) was selected as the primary pozzolanic material in the mix due to its availability and its



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performance. A large portion of the mix development focused on maximizing the amount of lower density cementitious materials (such as fly ash) as the pozzolanic reactions help increase the strength of the concrete without the use of as much cement. The team decided on fly ash as the main pozzolan because of its low unit weight compared to cement. Fly ash has a unit weight of approximately 144 lb./ft³ while cement has a unit weight of 196 lb./ft³. Other pozzolans such as metakaolin (calcified clay, class n) and lime were also used.

As part of the mix experimentation, the amount of lime used varied. Lime was added to equal 10%, 15%, and 20% of the dry weight of the cement to determine which percentage yielded the highest strength and weight benefits for the mix. Blue and red pigment were added to the 15% and 20% lime batches respectively to help in identifying the three mixes during and after curing. A picture of the three samples at varying concentrations can be seen in Figure . Hydrated lime was chosen as a pozzolan for the mix as it has a lower unit weight than cement. Hydrated lime has a unit weight of 150 lb./ft³ as compared to cement which has a unit weight of 196 lb./ft³. Metakaolin was added to the mix for the same reason as the hydrated lime. Metakaolin has a unit weight of 156 lb./ft³. By using these light weight pozzolans in replace of some of the heavier pozzolans (such as slag and cement) the strength could be maximized while minimize the final unit weight.



Figure 4: Lime concentrations of 10%, 15%, and 20% (left to right).

Poraver was used as one of the primary aggregates because of its availability and eco-friendliness. The concrete canoe team had a large amount of Poraver left over from previous years which meant no aggregates needed purchased this year. Poraver is an extremely light-weight glass product used in many concretes because of its strength and inertness. It is produced by crushing and refining recycled glass that is primarily silicide-based which makes it chemically stable. It is nontoxic and can safely be combined with several substances. Its main variable that changed was the aggregate gradation of the concrete mix to make the gradation of the mix match the Fuller curve as closely as possible.

The Fuller Curve, also known as the Fuller-Schettler-Gleason grading curve, is a graph that represents the cumulative percentage of a sample that passes through each sieve size. It is commonly used to evaluate the particle size distribution of aggregates and can help optimize the amount of cement and water needed for a given concrete mixture. When creating a concrete mixture, it is important to have a well-graded aggregate that contains a range of particle sizes. If the aggregate is too coarse or too fine, it can result in poor workability, reduced strength, and increased permeability. The Fuller Curve can be used to determine the ideal gradation of the aggregate by plotting the percentage of the sample that passes through each sieve size on a logarithmic scale.

The Fuller Curve assumes that the volume of each particle is proportional to its surface area, and therefore the mass of the particles can be distributed in a logarithmic manner. This allows for a more accurate representation of the particle size distribution of the sample and can help identify any gaps or clusters in the distribution. The Fuller Curve was applied to the concrete and aggregate gradations by performing a basic sieve gradation on a sample of the aggregate and then plotting the results on a graph. The resulting curve was used to determine the ideal gradation of the aggregate. However, due to the rules and regulations of the ASCE conference this aggregate gradation did not meet the requirements. Therefore, aggregate sizes



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were manipulated to both meet the required gradation while matching the Fuller curve as close as possible.

The team also experimented with the use of fibers in the mix. It was found that fibers reduced the workability of the concrete which was beneficial in applying the concrete to vertical surfaces such as the walls of the canoe. The fibers also improved the strength while very minimally affecting the final weight of the concrete. For these reasons the team added a small number of fibers into the mix.

One major problem encountered by the team was how the entrained air in the mix reacted to the change of cementitious materials. At first the admixtures were not enough to lower the unit weight of the concrete to make it usable despite it having an impressive compressive strength and workability. This problem was resolved by doubling the number of admixtures used and making sure to increase the saturation water so the air entrainer would properly mix into the entire batch. This did cause a reduction in strength, but it was deemed necessary for the flotation of the final product as it lowered the final unit weight substantially.

The final concrete mix used for Banana Float had a 28-day compressive strength of approximately 1000 psi, which is near the predicted desired strength needed for the canoe, and a measured unit weight of 45.0 pcf, which also satisfies the teams desired density. The concrete was workable enough to consolidate through the layers of reinforcement that were picked which allowed the full potential maximization of the metal reinforcement.

The patch mix used was a previously designed batch for the hull. The patch mix consists of fines mixed with cementitious materials and chemical admixtures to produce a flowable mortar that can fill in small cracks. This mix was used to touch up the hull of the canoe and add a design to the inside of the hull as discussed in the construction portion of the report.

Construction

In preparation to cast the concrete canoe, a form needed made. As the team researched how to best make the form, using foam was decided upon as BYU had used Expanded Polystyrene (EPS) foam in the past. Further foam research showed companies such as Universal Foam Products, suggest and use EPS forms when making concrete molds for the ASCE competition. EPS is often used for construction applications and in uses where a low compressive strength is acceptable (Insulation Corporation of America, n.d.). In addition to liking the strength, cost, sustainability, and stability benefits (Universal Foam Products, 2019), the club had a large inventory of foam from previous years.

With the completion of the canoe design, a male mold was created. The foam was pre-cut into 4' x 8' x 2" sheets. A couple of different ways of shaping the foam were used. The initial plan was to work with BYU's prototyping Lab which has a Computer Numerical Control (CNC) machine. A consultation meeting with one of the lab assistants determined that the CNC machine would not be a feasible option. The next option explored was using a hot wire or hot knife to manually cut each foam board as this had been done in previous years. However, the hotwire used in previous years had been attached to a homemade frame. It was disassembled due to the dangerous hazards it presented. From here, the team met again with the prototyping lab, later moving on to consult with Bryant Brown, BYU's engineering occupational health and safety specialist, to find a solution. At this meeting, approval was given to work with a store-bought hot knife with safety measures in mind. Each piece would be manually cut and then once put together, it would be sanded and shaped. By switching from our original idea of using BYU's CNC machine to a manual method, the schedule was altered to allow more time for the creation of the canoe's form.

In compliance with the team's safety measures as well as the school's safety rules, sanders, electric saws, and hot knives were used to mold the foam. Because the canoe is 18 ft long and each sheet was 2" wide, the mold had 108 cross sections. For each cross section,



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the foam was cut into a square with a half inch margin and then marked with the width, height, and points where the canoe would curve. Once all the pieces were cut, they were glued together with a silicone adhesive. Figure shows squares cut and glued together.



Figure 5: Cross-sections cut and glued together.

To make removing the form from the concrete after construction easier, rebar, wooded dowels, and nylon string were added. Three pieces of rebar were placed through the centers of the three largest cross sections as shown in Figure. In the smaller cross sections, wooden dowels were placed. The string was wrapped around the rebar which created an additional point to help pull out the form. When ready to remove the form, the strings attached to the rebar will be pulled on which will help separate the form from the concrete.



Figure 6: Rebar enforced form shaping with curry comb.

With a full mold glued together, curry combs and sanders were used to shape the foam. Using USG sheetrock all-purpose joint compound, two layers of drywall mud were applied to the form. With each layer being sanded and smoothed. Figure 7 shows the last steps to prepare the canoe for the concrete which included sealing the sheetrock with RedGuard Waterproofing and Crack Prevention Membrane once the final layer of drywall mud was dry to help the form pop out of the canoe. Weather stripping, in the shape of banana leaves, was also added to form a design on the inside of the canoe.



Figure 7: RedGuard sealant on canoe form.

With the mold fully prepped and ready, we gathered members from BYU'S concrete canoe club, friends,



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and others to help begin our casting day. To allow the concrete to stick to the mold better, chicken wire was added to the mold.

Finally, concrete was ready to be added to the canoe. Knowing that casting would take several hours, steps were taken to prevent non-uniform joints in the concrete. These would occur if the concrete cured too fast before the next part was added. To prevent this, those who came to help were separated into groups. One group managed the concrete mixing. They oversaw timing the mixing with the rate others were able to place the concrete on the mold. To make this easier, the materials that went into our mix were weighed out before the casting day. This included weighing out the aggregates, add-mixtures, and water for each batch of concrete.

Aspects of concrete mixing that were considered included the specific mixing time required for each admixture. By following the recommended mixing time for each admixture, we hoped to increase the effectiveness of each admixture as well as make each batch uniform. By having one group managing the concrete mixing, it allowed the concrete to be cast in one lift.

When the mix was ready, the canoe was cast starting at one end. The concrete was placed on the mold with a $\frac{3}{4}$ inch thickness. To help us gauge how thick our layer was, the weather stripping we placed for the design was $\frac{1}{2}$ inch thick. With some parts being a bit rougher than others, the rough spots would be corrected in the sanding phase after the canoe had cured. Once the main body of the canoe is cast, the weather stripping was removed, and a different color of patch mix was added in the gaps for the design.

The canoe will be left for 28 days to allow the concrete to cure. To help with proper curing of the concrete, hydration is essential. To facilitate this, the team created a DIY fog room for the canoe. It was made by placing plastic over and around the canoe and using misters and placing buckets of water in the plastic. This allowed us to seal the moisture in with the canoe.

Following curing, the mold will be removed by pulling the rebar, wooden dowels, and strings that were added to aid the removal. Any foam that was not removed was manually taken out. It will then be sanded down to create a smooth surface. Foam will be placed in the first three feet in each of the ends which is in accordance with the competition rules. Finally, any final touches to the canoe will be made including patching or designing.

Quality Control and Quality Assurance

Attention to detail and awareness of safety were critical attributes that were needed as students were heavily involved in the development and construction of the canoe. Many potential hazards were presented, especially with the mixing and construction. Many materials that are involved in the concrete mix can be dangerous such as cement or lime. Construction materials included electrical and hand saws.

To prevent injuries, materials were ordered, stored in a specified area of the university lab space, and labeled so that they were not confused with other similar materials. All materials were returned to their appropriate storage space once measurements and usage were completed. Proper Personal Protective Equipment (PPE) was given to each student when needed.

When our club gathered in the lab, a safety moment was taken before heading into the lab. These moments included an overview of the work that would be done that day, the tools that would be used, as well as the safety measures that should be taken.

Document Compilation and Review

To ensure that this report included all appropriate information, teammates were assigned sections to write. During the writing process, sections of the



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report as well as competition rules and regulations were reviewed to verify that the proper formatting was used, and the designated information included. The paper was written within a reasonable timeframe because of said delegation and editing.

Health and Safety

Concrete Mixing

When creating the concrete, teammates wore glasses and gloves to protect eyes and hands from harmful particles. The amount of each material needed to create the mixture was calculated prior to the mixing. This created a focused mixing environment which allowed teammates to avoid distractions or any hindrance to the process. Different bowls were weighed, scaled, and used to separate and measure materials to avoid any possible error in mixture composition. A timer was set to ensure each liquid was stirred into the powder mixture with accurate setting time and teammates switched often to aid in the mixing process.

Team Member Training

Before any teammate was admitted to the lab, they were required to complete a series of lab trainings relating to the usage of machinery, chemicals, materials, proper dress, lab hazards, emergency protocol, etc. Once the tests were passed members of the team were allowed to enter the lab space and participate in mixing, molding, compression testing, and all other competition-related procedures. New members to the project were always accompanied by senior members and given instructions on what task would be completed and the steps would be performed to carry out said task. Teamwork and trust in each other were key in the design, creation, and writing processes which all contributed to the final product.

Sustainability

Construction of a concrete canoe takes a lot of time and materials. With any recurring project,

sustainability should be a consideration of a conscious engineer. As we want this to continue to be an ongoing project at BYU, we took care to create a sustainable program and set up future students' teams for success.

Social

Isaac Newton once said, "If I have seen further, it is by standing on the shoulders of giants." We have benefitted greatly from learning from previous teams at our university and are immensely grateful for the efforts they put into social sustainability and setting us up for success. To continue this, we worked to build meaningful relationships between this program and the professors and advisors that have helped moved us through this process. As an impact of the COVID-19 pandemic, this has been the first year that BYU has produced a concrete canoe since 2019. We quickly discovered the gaps in our knowledge and preparation, with no one from that last team remaining. As such, we took steps to document progress, acknowledge mistakes, and leave resources for teams' future years.

This year concrete canoe became a capstone project, meaning it is mostly run by Seniors in conjunction with graduation requirements. This creates high yearly turnover in club and project leadership. To combat this, we sought to strengthen campus relationships and student connections. This included club recruitment to get other students involved in the production and design. Club meetings and activities were held every other Tuesday for most of the year with the couple weeks of molding and casting requiring more participation. For the remainder of the semester, activities will include sanding the canoe once it has cured, adding our patch mix where needed, building a frame for canoe transport and rowing practices. During these activities, a goal was to increase student excitement for the design and construction process as well as maintain retention in the students. We hosted activities with open-invites and reached out to other engineering-adjacent student groups and invited them to assist with steps like the casting of our canoe. This was in hopes of getting higher levels of campus involvement and getting exposure to a wider body of students, helping more understand the process and



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potentially sparking a passion and interest in students, allowing them to know of the opportunity and be prepared to get more involved future years. In doing this, we also hope to prepare students who are interested in being in leadership for next year.

In addition to preparing students for next year, we also wanted to encourage our community youth. BYU hosted an engineering fair for local Junior High students. Many students were given tours of the different engineering labs, buildings, and majors. Several engineering clubs, including our Concrete Canoe club were given the opportunity to set up an interactive booth. Students were shown different light weight concrete batches and compare them to a typical mix that would be used for a concrete slab used in their driveway. They were shown scaled down concrete canoes that had been made by the club in 2021. This booth allowed these students to learn more about how concrete can be altered to meet different creative needs and club leadership was able to present concrete canoe and the unique applications of engineering.

Economic

As students at BYU, our goal was to be contributing members of our Provo and Utah County community. To support local businesses, they were prioritized when purchasing and finding materials we needed. This was most prevalent when choosing the materials for our concrete mix and materials for construction. We were blessed with the donation of the white cement and Utelite used for design and testing. Because BYU has not competed in the competition in the last couple years, we were able to use some left-over material. This allowed us to preserve our budget for this year. These materials included all the foam, Poraver, some cementitious materials and a couple of admixtures. A lot of the costs that we had this year were tools or materials needed for the canoe form. We bought all our tools locally.

Environmental

We sought to remain conscious of our environmental impact throughout the selection of materials and design process. We built our canoe form material

chosen using EPS. EPS is engineered foam and is comprised of 98% air (Altor Solutions, n.d.). It's durable nature also. It is also very recyclable if taken to the correct places. It can be reused for packaging, insulation, or other construction processes. While it is recyclable, finding a place to recycle it presented a challenge. Many of the foam boards were preserved and will be reused next year. The smaller pieces will be taken to a couple different shipping and packing companies to see if they can take them and use them.

Value and Innovation

Our team believes that value means providing a benefit or solution that meets or exceeds the needs and expectations of our stakeholders. This includes our team members, the judges, the ASCE organization, and our community at large. Our goal is to create a concrete canoe which not only meets project deliverables but is also innovative, functional, and efficient. We hoped to achieve all this while also demonstrating the highest level of technical and engineering excellence.

To provide value to our canoe, our team incorporated several innovations that set us apart from other teams. For example, we focused on creating a lightweight, durable, and hydrodynamic canoe that would perform well in both speed and maneuverability. To achieve this, we used advanced materials (such as admixtures and Poraver) and construction techniques that improved the strength-to-weight ratio of our canoe. We did all this while also reducing drag and improving buoyancy with our design by slightly lifting the ends of the canoe. We also incorporated these unique design features such as a curved hull and strategically placed steel reinforcements that further improved our canoe's performance.

Throughout the project, our team was very conscious of the need to provide value in all our deliverables, including the project proposal, prototype display, technical presentation, and the competition. In the project proposal, we emphasized the unique features of our design and the potential benefits it would



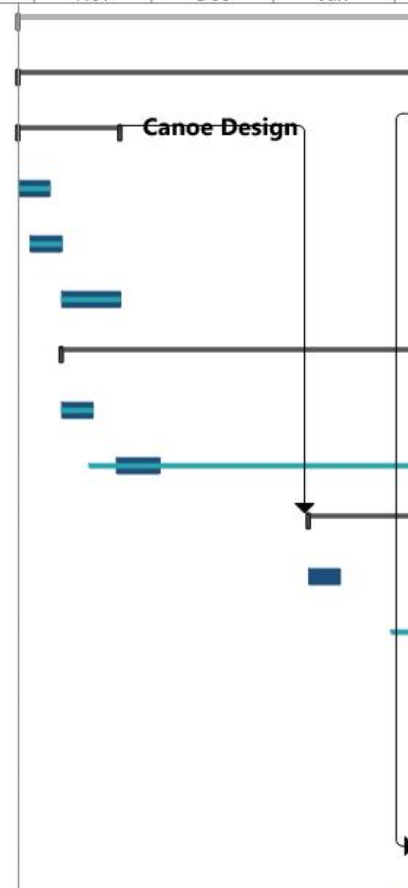
BANANA FLOAT

provide. In the prototype display, we highlighted the innovations we incorporated and how they contributed to our canoe's overall performance. In the technical presentation, we explained the technical details of our design and construction process, including the specific materials and techniques we used. Finally, in the competition, we hope to demonstrate the superior performance of our canoe compared to other teams, showcasing the value our team has added to the competition this year.

To ensure that our value was present from the concept of innovation to the final product, our team followed a rigorous and thorough design and development process. We started by identifying the specific needs and goals of the project, and then brainstormed and evaluated multiple design options to find the most promising approach. We then used computer-aided design (CAD) and simulation software to model and test our design, making refinements as needed to optimize performance and functionality. Finally, we constructed and tested multiple mix designs, making further improvements based on our testing results until we had a final product that met or exceeded our original objectives.

In conclusion, we believe that our team has provided value in all aspects of the ASCE concrete canoe competition. Our team made every effort to incorporate innovation that would contribute to the overall value of the project. By focusing on unique features that set us apart from other teams and using advanced materials and construction techniques, we were able to create a canoe prototype that was both innovative and highly functional. Our team was committed to providing value in all our deliverables, as we follow our rigorous and thorough design and development process. We do this to ensure that what we present comes from a place of innovation and ends in a final product which can be referenced and admired in future years.

	Duration	Baseline Start	Actual Start	Baseline Finish	Actual Finish	Sep	Qtr 4, 2022 Oct	Nov	Dec	Qtr 1, 2023 Jan
	121 days	Fri 10/28/22	Fri 10/28/22	Sat 4/15/23	NA					
	81 days	Fri 10/28/22	Fri 10/28/22	Tue 1/31/23	NA					
	18 days	Fri 10/28/22	Fri 10/28/22	Tue 11/22/22	Tue 11/22/22					
	6 days	Fri 10/28/22	Fri 10/28/22	Fri 11/4/22	Fri 11/4/22					
Rule	6 days	Mon 10/31/22	Mon 10/31/22	Mon 11/7/22	Mon 11/7/22					
Structural Design	11 days	Tue 11/8/22	Tue 11/8/22	Tue 11/22/22	Tue 11/22/22					
	66 days	Tue 11/8/22	Tue 11/8/22	Tue 12/20/22	Tue 2/7/23					
	6 days	Tue 11/8/22	Tue 11/8/22	Tue 11/15/22	Tue 11/15/22					
	61 days	Tue 11/22/22	Tue 11/15/22	Fri 12/2/22	Tue 2/7/23					
	29 days	Tue 1/10/23	Tue 1/10/23	Tue 1/31/23	NA					
	6 days	Tue 1/10/23	NA	Tue 1/17/23	NA					
	11 days	NA	Tue 1/31/23	NA	Tue 2/14/23					
	9 days	Tue 2/7/23	Tue 2/7/23	Fri 2/17/23	Fri 2/17/23					
	9 days	Tue 2/7/23	Tue 2/7/23	Tue 2/14/23	Fri 2/17/23					
DUE	1 day	Fri 2/17/23	Fri 2/17/23	Fri 2/17/23	Fri 2/17/23					
	34 days	Tue 1/31/23	Tue 2/7/23	Tue 2/7/23	Fri 3/24/23					
	6 days	Tue 1/31/23	Tue 2/7/23	Tue 2/7/23	Tue 2/14/23					
	2 days	Fri 2/3/23	Fri 2/24/23	Sat 2/4/23	Sat 2/25/23					
	21 days	Fri 2/3/23	Fri 2/24/23	Fri 3/3/23	Fri 3/24/23					
	29 days	Tue 2/28/23	NA	Sat 4/15/23	NA					
	6 days	Tue 2/28/23	NA	Tue 3/14/23	NA					
n Details	6 days	Tue 3/14/23	NA	Tue 3/21/23	NA					
	6 days	Tue 3/21/23	NA	Thu 4/13/23	NA					
Presentation Details	6 days	Tue 3/28/23	NA	Tue 4/4/23	NA					
	6 days	Tue 4/4/23	NA	Tue 4/11/23	NA					
	2 days	Tue 4/11/23	NA	Wed 4/12/23	NA					
	3 days	Thu 4/13/23	NA	Sat 4/15/23	NA					

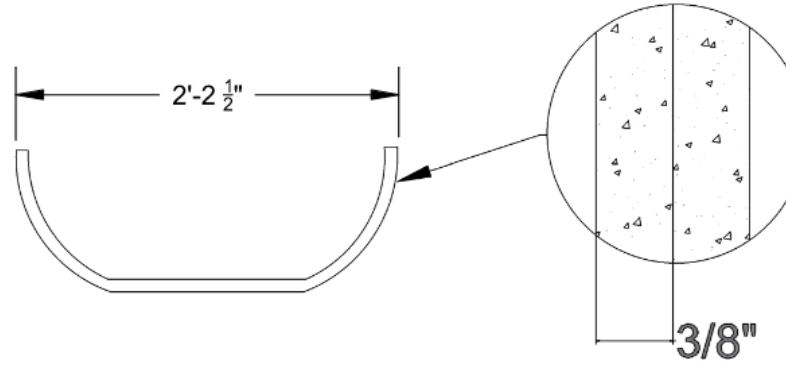
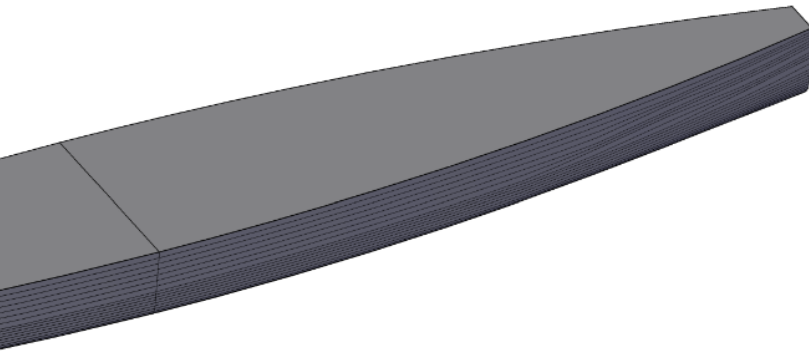
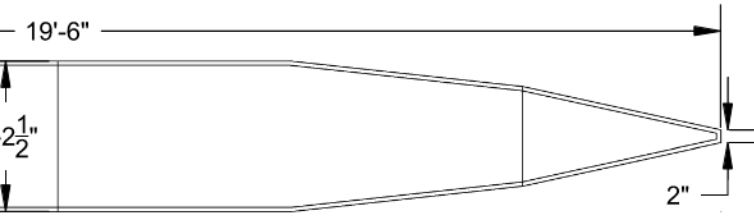


Summary

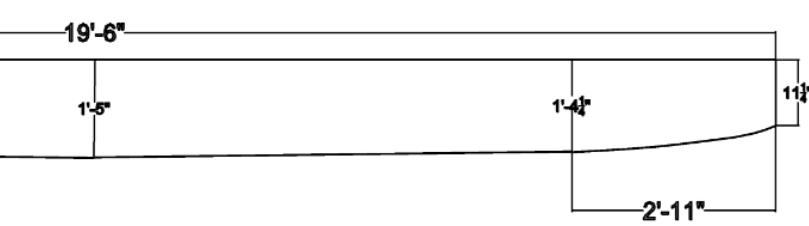
Project Summary

Planned Task
Time

Construction Drawings



Cross Sectional View of Canoe



Material	Quantity	Units	Unit Cost	Total
<i>Cementitious Materials</i>				
Portland Cement, Type 1/2	1	Bag	\$20.00	\$20.00
Metakaolin	6	lbs	\$50.00	\$50.00
<i>Tools</i>				
Hand saw	2	EA	\$50.00	\$50.00
Hot Knife	4	EA	\$25.00	\$100.00
<i>Reinforcing Materials</i>				
Chicken wire	1	roll	\$100.00	\$100.00
<i>Mold System</i>				
USG Sheetrock All Purpose Joint Compound	10	Gal	-	\$60.00
Weather Stripping	10	17 ft Roles	\$4.48	\$44.80
Misting System	1	-	\$35	\$35
RedGaurd Weatherproofing and Crack Prevention Membrane	1	Gal	\$60	\$60
Painters Tape	1	75 ft Role	\$5	\$5
<i>Member Hours</i>				
Principle Design Engineer	1	60	\$50.00	3000
Design Manager	1	60	\$45.00	2700
Project Construction Manager	1	65	\$40.00	2600
Construction Superintendent	0	0	\$40.00	0
Project Design Engineer	1	10	\$35.00	350
Quality Manager	2	5	\$35.00	350
Graduate field Engineer	0	0	\$25.00	0
Technician/Drafter	2	5	\$20.00	200
Laborer/Technician	6	15	\$25.00	2250
Clerk/Office Admin	1	40	\$15.00	600
Consultants	1	5	\$200.00	10000
Total Maned hours to Date	-	-	-	350
Total Production Cost				\$22,574.80

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Appendix B: Mixture Proportions and Primary Mixture Calculation

Structural Mix

Cementitious Material							
Component	Specific Gravity	Volume (ft ³)	Amount of CM (mass/volume)(lb/yd ³)				
Portland Cement	3.15	0.509	100			Total Amount of cementitious materials <u>337.5</u> lb/yd ³ c/cm ratio <u>0.296</u>	
Fly Ash Class F	2.3	0.74	106.25				
Metakaolin	2.5	0.60	93.75				
Lime	2.3	0.26	37.5				
Fiber s							
Component	Specific Gravity	Volume (ft ³)	Amount of Fibers (mass/volume)(lb/yd ³)				
Grace Fibers	0.91	0.027	1.53			Total Amount of Fibers <u>1.53</u> lb/yd ³	
Aggr eg at es							
Aggregates	ASTM C330	Abs (%)	SGOD	SGSSD	Base Quantity (lb/yd ³)		Volume (ft ³)
					OD	SSD	
Utelite (Expanded Shale)	Y	0%	1.78	1.78	26.6	26.6	0.24
Size: 2-4	Y	23%	0.37	0.46	56.8	69.9	2.46
Size: 1-2	Y	20%	0.41	0.49	40.7	48.8	1.59
Size: 0.5-1	Y	20%	0.45	0.54	50.8	61.0	1.81
Size: 0.25-0.5	Y	28%	0.68	0.87	31.9	40.8	0.75
Size: 0.1-0.3	Y	35%	0.85	1.15	36.1	48.7	0.68
Size: 0.04-0.125	Y	25%	0.80	1.00	30.1	37.6	0.60
Admix t ures							
Admixture	lb/gal	Dosage (fl.oz/cwt)	% Solids	Amount of Water in Admixture (lb/yd ³)			
MasterGlenium 3030	8.8	5.5	6.73%	1.880			Total Water from Admixtures <u>8.339</u> lb/yd ³
MasterSet DELVO	9.0	6.9	13.50%	2.229			
MasterAir AE 90	8.5	15.0	20.25%	4.230			
So l id s							
Component	Specific Gravity		Volume (ft ³)	Amount (mass/volume)(lb/yd ³)			
Yellow dye	2		0.055	6.94			
W at er							
	Amount (mass/volume)(lb/yd ³)			Volume (ft ³)			
Water, lb/yd ³				165.9			
Total Free Water from All Aggregates, lb/yd ³				-105.5			
Total Water from All Admixtures, lb/yd ³				8.34			
Batch Water, lb/yd ³				263.0			
Densities, Air Content, Ratios and Slump							
	cm	fibers	aggregates	solids	water	total	
Mass of Concrete, M, (lb)	337.5	1.53	272.9	6.94	165.9	ΣM: 784.77	
Absolute Volume of Concrete, V, (ft ³)	2.11	0.027	8.1	0.055	2.7	ΣV: 12.99	
Theoretical Density, T, (=ΣM/ΣV)	60.4	lb/ft ³	Air Content = [(T - D) / T x 100%]			13.8%	
Measured Density, D	52.1	lb/ft ³	Air Content = [(27-ΣV)/27 x 100%]			13.8%	
Total Aggregate Ratio (=V _{agg, SSD} / 27)	63%		Slump, Slump Flow (in.)			4.50	
Water/Cement Ratio, w/c:	1.66		water/cementitious material ratio, w/cm:			0.49	

Patch Mix

Cementitious Material							
Component	Specific Gravity	Volume (ft ³)	Amount of CM (mass/volume)(lb/yd ³)				
Portland Cement	3.15	1.44	155.68	Total Amount of cementitious materials <u>531.51</u> lb/yd ³			
Fly Ash Class F	2.3	1.152	205.86				
Slag	2.9	0.288	105.55				
Lime	2.3	0.216	64.42				
c/cm ratio <u>0.293</u>							
Fiber s							
Component	Specific Gravity	Volume (ft ³)	Amount of Fibers (mass/volume)(lb/yd ³)				
Grace Fibers	0.91	0.057	3.24	Total Amount of Fibers <u>3.24</u> lb/yd ³			
Aggregates							
Aggregates	ASTM C330	Abs (%)	SGOD	SGSSD	Base Quantity (lb/yd ³)		Volume (ft ³)
					OD	SSD	
Utelite (Expanded Shale)	Y	0%	1.78	1.78	487.6	487.6	4.39
Size: 2-4	Y	23%	0.37	0.46	93.3	114.7	4.04
Size: 1-2	Y	20%	0.41	0.49	62.9	75.5	2.46
Size: 0.5-1	Y	20%	0.45	0.54	64.0	76.8	2.28
Size: 0.25-0.5	Y	28%	0.68	0.87	81.9	104.8	1.93
Size: 0.1-0.3	Y	35%	0.85	1.15	83.8	113.1	1.58
Size: 0.04-0.125	Y	25%	0.80	1.00	43.9	54.9	0.88
Admixtures							
Admixture	lb/gal	Dosage (fl.oz/cwt)	% Solids	Amount of Water in Admixture (lb/yd ³)			
MasterGlenium 3030	8.8	2	6.73%	0.682	Total Water from Admixtures <u>2.82</u> lb/yd ³		
MasterSet DELVO	9.0	4	13.50%	1.293			
MasterAir AE 90	8.5	3	20.25%	0.844			
Solids							
Component	Specific Gravity		Volume (ft ³)	Amount (mass/volume)(lb/yd ³)			
Green dye	2		0.017	2.09			
Water							
	Amount (mass/volume)(lb/yd ³)			Volume (ft ³)			
Water, lb/yd ³	169.9			2.7			
Total Free Water from All Aggregates, lb/yd ³	-161.8						
Total Water from All Admixtures, lb/yd ³	2.56						
Batch Water, lb/yd ³	329.2						
Densities, Air Content, Ratios and Slump							
	cm	fibers	aggregates	solids	water	total	
Mass of Concrete, M, (lb)	531.86	2.75	1027.6	2.09	169.9	ΣM: 1732.1	
Absolute Volume of Concrete, V, (ft ³)	3.10	0.057	17.6	0.017	2.7	ΣV: 23.4	
Theoretical Density, T, (=ΣM/ΣV)	74.0	lb/ft ³	Air Content = [(T - D) / T x 100%]			6.8%	
Measured Density, D	69.0	lb/ft ³	Air Content = [(27-ΣV)/27 x 100%]			6.8%	
Total Aggregate Ratio (=V _{agg, SSD} / 27)	75%		Slump, Slump Flow (in.)			2.50	
Water/Cement Ratio, w/c:	1.09		water/cementitious material ratio, w/cm:			0.32	

Appendix C: Hull Thickness, Reinforcement, and Percent Open Area Calculations

Assumptions:

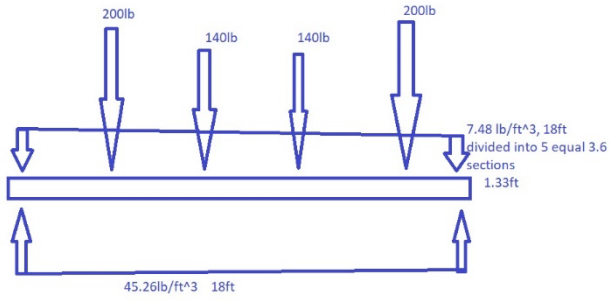
The structural calculations are based on the assumptions that the canoe is an equivalently weighted rectangular prism based off the length, height, and thickness dimensions. For the buoyancy calculations, a conservative estimate of half the total width of the canoe was used. This is a conservative estimate because half the total width is less than the average width of the canoe.

Pre-Determined Values:

Length (L) = 18 ft
Width (w) = 2.1666 ft
Height (H) = 1.333 ft
Effective Width (EFW) = 0.125 ft
Effective Volume (EFV) = 2.9925 ft³
Unit Weight of the Canoe (γ_c) = 45 lb/ft³
Unit Weight of Water (γ_w) = 62.4 lb/ft³
Thickness (t) = 0.0625 in

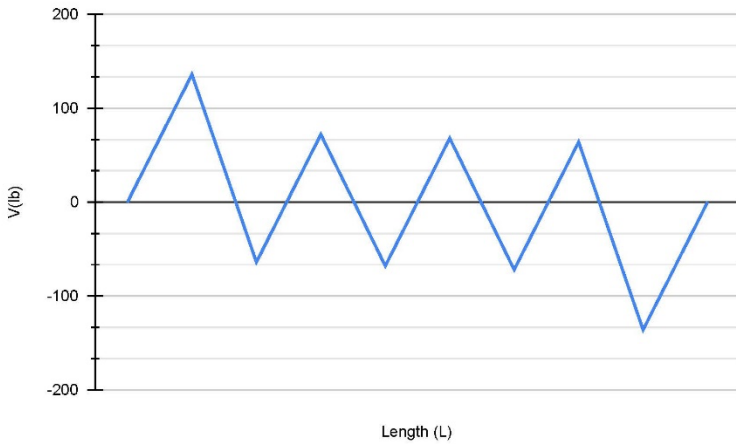
Free Body Diagrams:

Total Weight (TW) = $\gamma_c \cdot \text{EFV}$
= 45 lb/ft³ * 2.9925 ft³
= 134.66 lb
Distributed Load From Self Weight (DLSW) = TW/L
= 134.66 lb / 18 ft
= 7.48 lb/ft
Point Loads from Riders: 200 lb point loads at 3.6 ft (20%) and 14.4 ft (80%); and, 140 lb point loads at 7.2 ft (40%) and 10.8 ft (60%)
Point Loads During Transportation = TW/2
= 134.66 lb / 2
= 67.333 lb
Buoyancy Force (BF) = (TW) + 2 * point load + 2 * other point load
= 134.66 lb + 2(200 lb) + 2(140 lb)
= 814.66 lb
Height of Water on Canoe (HW) = (BF) / ($\gamma_w \cdot L \cdot (W/2)$)
= 814.66 lb / (62.4 lb/ft³ * 18 ft * (2.1666 ft / 2))
= 0.67 ft = 8.0366 in
Distributed Boyant Load (DBL) = (HW) * (W/2) * γ_w
= 0.67 ft * (2.17 ft / 2) * 62.4 lb/ft³
= 45.26 lb/ft

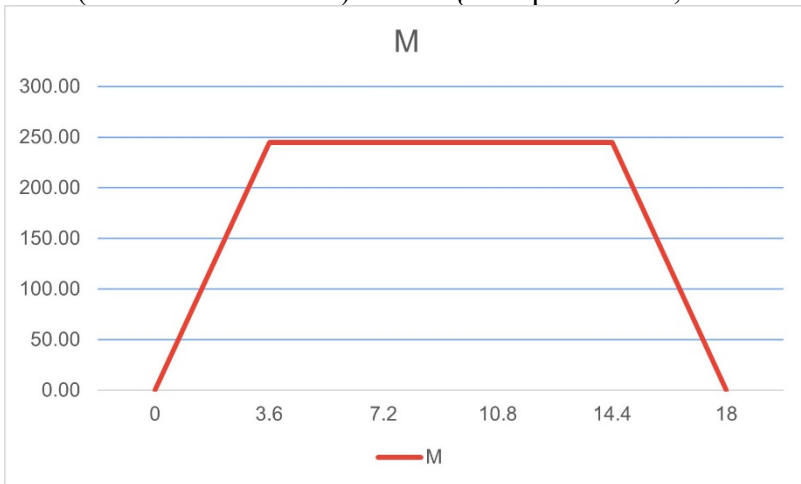


Co-Ed Shear/Bending Moment Diagrams Highly Simplified:

$V = (45.26 \text{ lb/ft} - 7.48 \text{ lb/ft}) * x \text{ lb}$ {with point loads, as indicated}



$M = (45.26 \text{ lb/ft} - 7.48 \text{ lb/ft}) * x^2 / 2 \text{ lb}$ {with point loads, as indicated}



Transportation Shear/Bending Moment Equations:

$V = -7.48 \text{ lb/ft} \cdot x$ {With point Loads as indicated}

$M = -7.48 \text{ lb/ft} \cdot x^2 / 2$ {With point Loads as indicated}

Punching Failure in accordance with ASCE 318 22.6.5.2

ACI 318-14
 V_n (least of a, b, c)

(a) $4\lambda\sqrt{f'c}$

(b) $(2 + \frac{4}{\beta})\lambda\sqrt{f'c}$

(c) $(2 + \frac{\alpha_s d}{b_o})\lambda\sqrt{f'c}$

λ	0.75			
f_c	900	lb/in ²		
β	1			
a_s	20			
d	0.03	ft	->	0.375 in
l	4	in		
w	4	in		
b_o	17.50			
λ_s	1.39	if > 1 $\lambda_s = 1$	1	
eq a	90			
eq b	135			
eq c	54.64			
v_n	22.86			
f_s	2.39	Fs=factor of safety		

Percent open area:

Hull thickness = 0.5 in

Chicken wire= 0.035in

=0.035in/0.5in

=0.07

7%<50% max therefore compliant

Appendix D: Detailed Fee Estimate

Material	Quantity	Units	Unit Cost	Total
<i>Cementitious Materials</i>				
Portland Cement, Type 1/2	1	Bag	\$20.00	\$20.00
Metakaolin	6	lbs	\$50.00	\$50.00
<i>Tools</i>				
Hand saw	2	EA	\$50.00	\$50.00
Hot Knife	4	EA	\$25.00	\$100.00
<i>Reinforcing Materials</i>				
Chicken wire	1	roll	\$100.00	\$100.00
<i>Mold System</i>				
USG Sheetrock All Purpose Joint Compound	10	Gal	-	\$60.00
Weather Stripping	10	17 ft Roles	\$4.48	\$44.80
Misting System	1	-	\$35	\$35
RedGaurd Weatherproofing and Crack Prevention Membrane	1	Gal	\$60	\$60
Painters Tape	1	75 ft Role	\$5	\$5
<i>Member Hours</i>				
Principle Design Engineer	1	60	\$50.00	\$3,000.00
Design Manager	1	60	\$45.00	\$2,700.00
Project Construction Manager	1	65	\$40.00	\$2,600.00
Construction Superintendent	0	0	\$40.00	\$0.00
Project Design Engineer	1	10	\$35.00	\$350.00
Quality Manager	2	5	\$35.00	\$350.00
Graduate field Engineer	0	0	\$25.00	\$0.00
Technician/Drafter	2	5	\$20.00	\$200.00
Laborer/Technician	6	15	\$25.00	\$2,250.00
Clerk/Office Admin	1	40	\$15.00	\$600.00
Consultants	1	5	\$200.00	\$1,000.00
Total Maned hours to Date, HRS	-	-	-	350
Total Materials Cost, MC				\$524.80
Raw Labor Rates, RLR				\$13,050.00
Direct Labor Expenses, DE				\$1,000.00
Markup, M				10%
Expenses, E = $[\sum MC + \sum DE]*(1+M)$				\$1,677.28
Direct Employee Costs, DEC				1.5
Indirect Employee Costs, IEC				1.3
Profit Multiplier, P				18%
Direct Labor, DL = $[\sum(RLR*HRS)]*(DEC + IEC)*(1+P)$				\$43,117.20
Grand Total to date, GT = DL + E				\$44,794.48

Appendix E: Supporting Documentation

Material Technical Data Sheets (MTDS)

<i>CONSTITUENT</i>	<i>BRAND NAME (COMPANY NAME)</i>	<i>INTENDED USE</i>	<i>APPLICABLE ASTM STANDARDS</i>
<i>Cementitious Materials</i>			
Portland Cement	Lehigh White Cement	Cementitious material	ASTM C150
Class F Fly Ash	Boral Resources	Pozzolanic; improved workability	ASTM C618
Metakaolin	Lehigh Hanson (Heidelberg Cement Group)	Pozzolanic; improves sustainability by decreasing portland cement use	ASTM C618
Slag Cement	Lehigh Hanson (Heidelberg Cement Group)	Cementitious material; improves sustainability by decreasing portland	ASTM C989
Type S Hydrated Lime	Lhoist North America (Lhoist Group)	Pozzolanic; long-term strength gain	ASTM C206; C207
<i>Aggregate</i>			
Structural Fine Lightweight Aggregate	Utelite Corporation	Stability and strength; long-term	ASTM C330
Expanded Glass Bubbles	Poraver	Stability and strength; decrease	ASTM C330; C331; C332
Grace Fibers	GCP Applied Technologies	Increase tensile and flexural capacity	ASTM C1116
<i>Pigment</i>			
Concrete Pigments	Direct Colors Inc.	Aesthetics	ASTM C979
<i>Chemical Admixtures</i>			
Air-entrainer	MasterAir AE 90 (BASF)	Decrease density; increase watertightness; reduced segregation	ASTM C260
Full-range Water Reducer	MasterGlenium 3030 (BASF)	Flexible dosage; reduce water content; increase compressive and flexural	ASTM C494/C 494M
Hydration Reducer	MasterSet DELVO (BASF)	Retard setting time; reduce water content while maintaining workability	ASTM C494/C 494M

Appendix F: Related Issues and addition to Sustainability

This appendix is supplemental information to the following sections: Quality Control and Quality Assurance, Health and Safety, and Sustainability.

The design, construction, and competition of Concrete Canoe contained and addressed several related issues including safety, public health, and cultural, social, environmental, and economic factors.

Activities from construction to the actual racing of the canoe introduced safety hazards, necessitating the implementation of precautions and safety trainings. Before working in the lab, Dr. Spencer Guthrie held and led an activity which went over the potential dangers of working in the lab and the steps to take to prevent any injury. In addition to the lab safety training, safety plans from past years were reviewed, updated, and implemented for the current year. This included reviewing proper lab attire including long pants, safety glasses, hearing protection, eye protection, gloves, and long hair tied back. Some of the large health hazards presented in the lab were from the materials used. We used cementous materials such as Portland Cement, Hydrated Lime, Fly Ash, and Metakaolin. Several chemicals are contained in these materials and are harmful when inhaled and even with long-term contact to skin. N-95 rated face masks were used when weighing out or mixing these materials. Gloves were also used to avoid skin contact. Cementous materials are hydrophilic and when left on skin for a long time can cause chemical burns. They begin to absorb the water from any surface they are in contact with. If cement did come into contact with skin or other surfaces where it could be harmful, proper thorough washing protocols were followed. Most of the construction and mix design happened in the lab, also used by several other groups and teams of people. To prevent harm to others in there, cement was weighed out in one specific area and the lab was properly ventilated.

After the construction of the canoe, exposure to these materials was no longer a large concern but other physical dangers became prevalent. The canoe, while made from lightweight concrete, weighed around 350 pounds so caution was used when transporting, lifting, and working on the canoe. Because of the weight of the

canoe, it also posed a danger while in the water. To ensure the safety of each of our team members who raced in the canoe as well as the environmental factors of the reservoir we raced in, our canoe was required to pass a swamp test. A swamp test included a complete submersion of our canoe. After it was submerged, it had two minutes to come back to the surface to prove it is buoyant. This test ensures that participants are kept reasonably safe even in the event of the canoe capsizing during a race. In addition to the safety of our team members, it also prevents the canoe from sinking and remaining at the bottom of the reservoir. If it breaks or fails, it can easily be removed from the lake.

Unique to this year was the availability of material from previous years. Because BYU has not constructed a full canoe in the last three years, there was a supply of necessary materials for construction. By having this material available, the Banana Float was the cheapest canoe at the ISWS competition. Through networking connections between BYU and concrete distributors, material such as aggregate and cement were donated. The estimated cost that was calculated assumes that all materials were bought this year at full price with no donation. The actual cost was much lower due to the materials that we already had.

The concept and competition aspect of concrete canoe influences the culture of engineering students and observers. Engineers are geared to solve problems and often unique ones. Building a canoe from concrete is not a common thought to most. This competition inspires many young engineers to find a creative solution to a specific issue. Since BYU has been involved with Concrete Canoe, it has involved many undergraduate engineering students from different disciplines. This year, we had both civil engineers and mechanical engineers working together on this project.