University of Southern Indiana
Pott College of Science, Engineering, and Education
Engineering Department

8600 University Boulevard
Evansville, Indiana 47712

Concrete Canoe
Second Generation

Isaac Pampe & Hanna Simmons
ENGR 491 – Senior Design
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Approved by: ____
Faculty Advisor: Kerry Hall, Ph.D. Date

Approved by: ____
Department Chair: Paul Kuban, Ph.D. Date

ACKNOWLEDGEMENTS

In this section, we would like to acknowledge:

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Justin Amos for his help getting tools necessary for the alterations the mold was set to take on. Justin also used the water jet to cut out a piece of Lexan that was used to flatten out the entire table for the concrete canoe to sit on within the concrete lab.

ABSTRACT

The purpose of this project was to become project engineers to create a plan for the construction of a concrete canoe, assemble several mixture designs that follow all rules and regulations, design a suitable mold along with a structural analysis, and finally produce a final project prototype that is appropriate to race. The *2023 American Society of Civil Engineers Concrete Canoe Competition Request for Proposals* was heavily reviewed for this project to ensure the final product met all criteria without any deductions of points. With all pages carefully reviewed by members of the Student Chapter, the final project prototype was fully constructed and transported to Bowling Green, Kentucky for the 2022-2023 Student Symposium. Here, the University of Southern Indiana got the canoe, *Second Generation*, into the water. It succeeded in the fact it floated but it failed another test as well as suffered an extensive break in the endcap. Therefore, *Second Generation* was unable to race on competition day.

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1 BACKGROUND

1.1 AMERICAN SOCIETY OF CIVIL ENGINEERS

The American Society of Civil Engineers (ASCE) is an organization that recruits and represents the civil engineering profession all around the world. To aid in the recruitment of younger members as well as support the generation of future engineers, ASCE Student Chapters can be found throughout many colleges in the United States. One way to get colleges involved within the society is to host an annual student symposium for various regions. For Indiana schools specifically, they fall under the Region 4 category which represents members from Arkansas, Kentucky, North Carolina, South Carolina, Tennessee, Virginia, and West Virginia. To minimize travel distance, the conference was open to Indiana and Kentucky colleges only unless otherwise approved. There are originally 11 schools that can compete within this symposium while having the ability to compete at nationals. These 11 schools are:

- Purdue University Fort Wayne
- Purdue University Northwest
- Purdue University West Lafayette
- Rose-Hulman Institute of Tech
- Trine University
- University of Evansville
- University of Kentucky
- University of Louisville
- University of Notre Dame
- University of Southern Indiana
- Western Kentucky University

1.2 STUDENT CHAPTER

University of Southern Indiana (USI) Pott College of Science, Engineering, and Education was founded in 1998. The American Society of Civil Engineers (ASCE) Student Chapter was created in hopes to improve interest and encourage the engineering majors within the University to pursue additional approaches to structural design and concrete design outside of the classroom. In addition to the concrete canoe, other competitions were implemented to encourage other focuses of engineering such as surveying, environmental engineering, and estimating.

The USI ASCE student chapter is overseen by academic advisor and professor, Dr. Kerry Hall. Like the University, the ASCE chapter strives to encourage growth within its members while also instilling properties common to most engineers' post-graduation. Because of this, all engineering majors are encouraged to join and help on different projects, building on skills such as teamwork, communication skills, and hands-on experience. Throughout the years ASCE has had a student chapter at USI, there have been electrical engineering majors, manufacturing engineering majors, mechanical engineering majors, business majors, and even art majors participating within the club. The USI chapter has been recognized by the University for outstanding service both in the community as well as to the campus of the University of Southern Indiana. The ASCE student chapter works with multiple professors, students, practitioner advisors, Evansville's professionals, other student organizations on campus, among many others to develop different opportunities for the members. USI ASCE received the Pott College Student Campus Community Excellence in Service Award in 2021. The organization continues to build upon this honor and aspires to improve each year. By doing so, the organization shall have an exemplary student president, vice president, secretary, and treasurer. The roles for the 2022-2023 leadership positions at USI for the ASCE Student Chapter are listed below.

President(s): Hanna Simmons and Corrie Grubb

Vice President: Cole Cooper

Secretary: Teryn Stanley

Treasurer: Vince Wilhelmus

1.3 KEY MEMBERS

The following are the main members of the Student Chapter that took on major roles within the process of constructing a final project prototype.

Isaac Pampe – Project Manager/Construction Manager/Structural Engineer

The project manager takes control of the project and oversees many of the tasks. The project manager is the lead decision maker and works to keep the rest of the group on task and on schedule. Construction drawings are and specifications are created by the project manager in accordance with the design. Analysis is performed to ensure the design is feasible and practical. Managing the budget is another crucial aspect, ensuring that the project meets both labor and material requirements to stay on or under budget. Lastly, the project manager aids when needed. The construction manager oversees the construction process, ensuring quality, and assisting when needed. The structural engineer performs calculations that determine whether or not a project will meet the structural demands that are present.

Hanna Simmons – Mix Manager/QC Manager

The mix manager works to create the most practical mix for the concrete canoe while considering the stresses placed upon the structure with loading weight and buoyant forces. The mix manager is responsible for ordering any necessary mix materials and communicates all findings with other team members for various analyses. The quality control manager ensures safety for all team members and ensures proper procedures and safety standards are used as well as assisting when needed. This is most necessary during all aspects of the construction of the concrete canoe.

Corrie Grubb – Rowing Manager

The rowing manager recruits paddlers for the canoe and works with them to teach proper form and paddling techniques. Throughout this process, old canoes shall be utilized for practice out on Reflection Lake on the USI campus.

Dr. Kerry Hall – Academic Advisor

The academic advisor serves as a source of knowledge and wisdom for the team, giving guidance when needed. The several years of experience in the program is also valued.

1.4 *STUDENT SYMPOSIA*

The 2022-2023 Student Symposia for Indiana and Kentucky was hosted by Western Kentucky University which was in Bowling Green, Kentucky. This took place from April 13th to April 15th, 2023, and more than 11 schools participated including out of conference schools, University of Illinois, and Michigan Technological University. There were several competitions that schools could participate in including concrete canoe, steel bridge design, balsa wood bridge, surveying, mystery design, concrete cornhole and more. Each of the competitions had a set of rules that had to be reviewed prior to participating in each one. After the rules were reviewed, all national competitions had to have a letter of intent turned in. The smaller competitions that USI competed in were balsa wood bridge, mystery design, concrete cornhole, concrete lawn darts, surveying, and construction institute. Although the University of Southern Indiana participated in many of the smaller competitions, the main focus for the students was the concrete canoe.

The race is set up in the manner displayed in the figure below. There are four races that have a mixture of both male and female paddlers as well as two different types of races. There are sprints which are straight line races and slalom races which are longer and depend more on maneuverability. In addition to these, there is also a co-ed race where both males and females work together to complete a course.

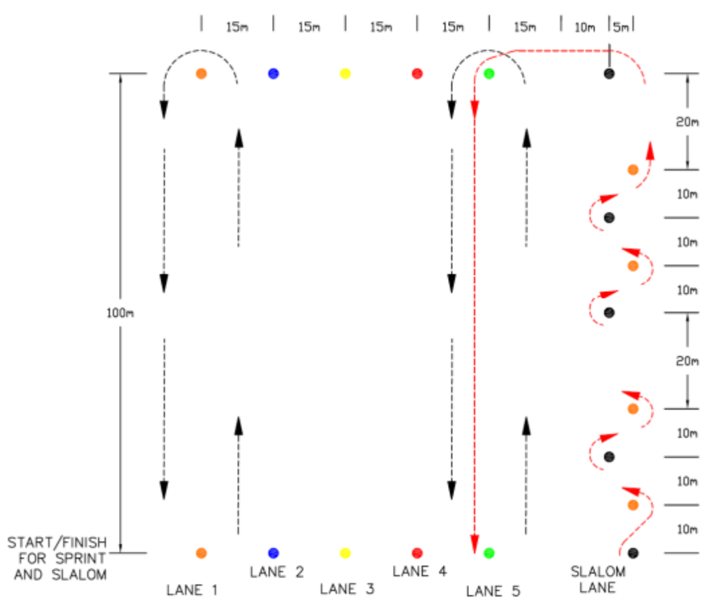


Figure 1. Racing Lane Setup (ASCE 2023).

1.5 CONCRETE CANOE BACKGROUND

The University of Southern Indiana Student Chapter constructed the concrete canoe called *Second Generation* for the 2022-2023 school year which shall be under consideration as the team best suited to provide a standardized design for manufacturing and building canoes for possible consumers. The name *Second Generation* was derived from the use of two previous canoes which were pulverized into an aggregate that was utilized in the mix design. These two previous canoes can be seen below in Figure #. Throughout the report, the pulverized concrete is referred to as Recycled Concrete Aggregate (RCA). The two canoes were from 2019 and 2022 and were named *Smiley* and *Supercrete* respectively. Not only were these canoes turned into material for the *Second Generation*, but a former mold was also utilized from a canoe that was constructed years ago. This mold was made of fiberglass and had alterations that were necessary before construction. But before anything can begin, project management has to be taken into consideration to ensure the project is completed on time and setbacks can be accounted for.

Figure 2. Concrete Canoes Smiley (Yellow) and Supercrete (Red and Blue).

2 REQUIREMENTS

2.1 MIX DESIGN REQUIREMENTS (ASCE)

A maximum of three mixture designs shall be utilized while the various mix designs may warrant a multitude of colors.

A maximum of 30% of the total cementitious materials may be utilized within one mix design. The cementitious materials shall follow the following American Society of Testing Materials (ASTM) standards and the ones within *Second Generation* can be seen below.

- Hydraulic Cement (ASTM Standard(s) C150, C595, or C1157, C845)
- Fly Ash (ASTM Standard(s) C618 Class C or F)
- Silica Fume (ASTM Standard(s) C1240)

At a minimum, the total aggregate volume shall exceed 30% of the total volume of any mix design. In addition to this, the aggregate mixture shall pass the ASTM C33 gradation which can be seen below.

Table 1. ASTM C33 Standard Based on Gradation (ASTM).

Sieve	Percent Passing
9.5-mm (3/8-in.)	100
4.75-mm (No. 4)	95 to 100
2.36-mm (No. 8)	80 to 100
1.18-mm (No. 16)	50 to 85
600-um (No. 30)	25 to 60
300-um (No. 50)	5 to 30
150-um (No. 100)	0 to 10

Regarding wet materials, all admixtures shall follow certain ASTM standards as outlined below.

- Water-Reducing & Set-Control (ASTM Standard(s) C494)
- Air-Entraining (ASTM Standard(s) C260
- Specialty Admixtures (ASTM Standard(s) C494 Type S)

There shall be a maximum of two coats of clear, non-pigmented concrete sealers that may be applied to *Second Generation*.

2.2 *STRUCTURAL DESIGN REQUIREMENTS (ASCE)*

Dimensional wise for the design of the hull, *Second Generation* may not exceed a total length of 22 feet. Other dimensions based on the height, width, and depth are not restricted.

The composite thickness with regards to the primary reinforcement to the total wall thickness at any point along the hull, gunwales, bulkheads, and more shall be equal to or less than 50% of the total thickness.

All reinforcement shall be encased within the concrete and shall not have any post-manufacturer applied coatings. All reinforcement materials shall be less than ½ inch thick wide.

A canoe cross-section shall be a full-scale model which presents both the raw and finished concrete canoe prototype. Within the cross-section, there shall be representations of the casting, finishing, and reinforcement techniques where the dimensions shall not exceed 4 feet (W) by 4 feet (L) by 7 feet (H).

All the gunwales shall be sanded and finished to be smooth to ensure no injuries are sustained while competing in the races on competition day.

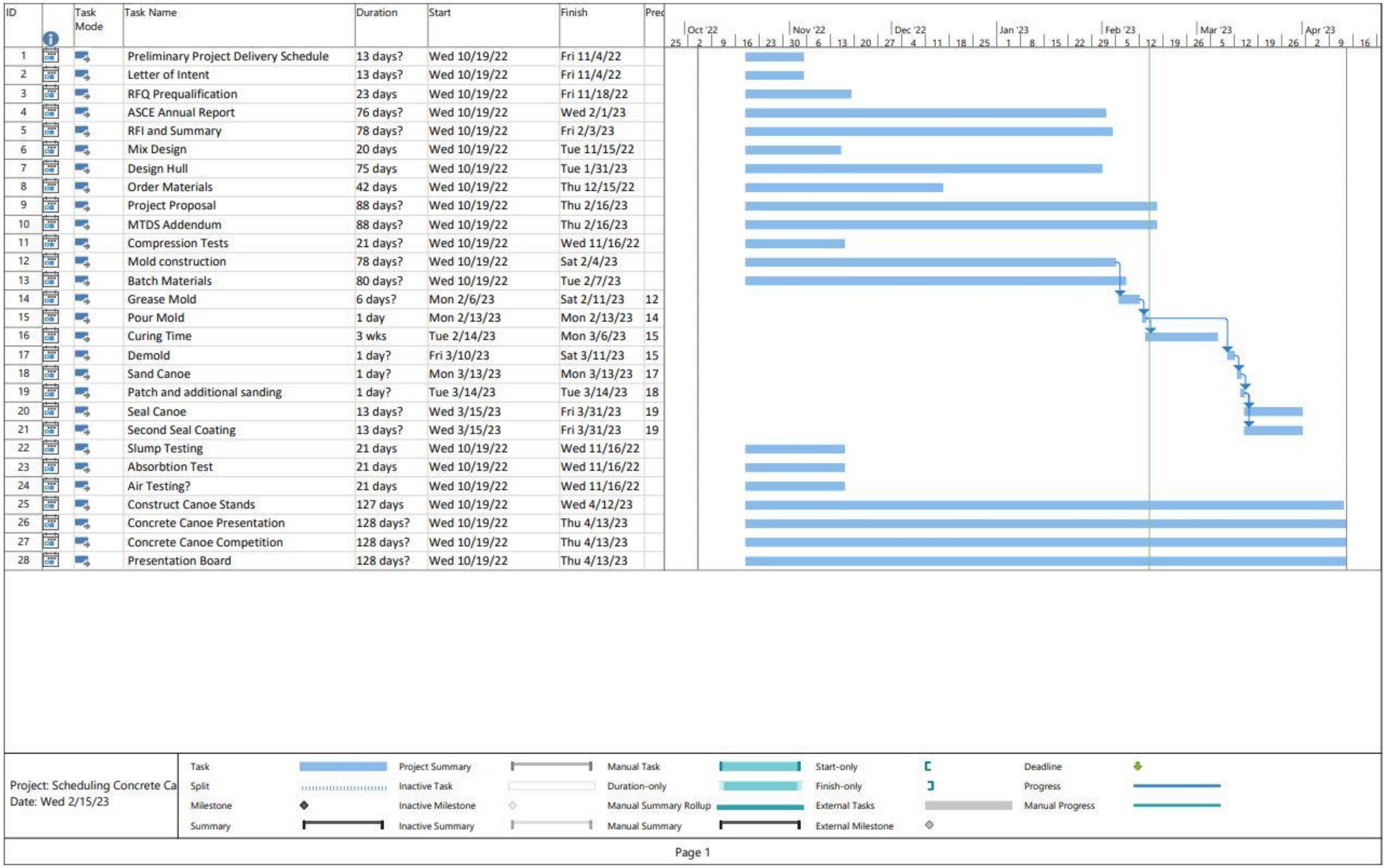
All material that aids in the floatation of the canoe shall be encased within the concrete and pass a swamp test without failure. The swamp test is based upon the buoyant design of the canoe and is where the canoe is fully submerged under the water and shall rise within a minute of being submerged. The amount of floatation is limited to within 3 feet of the bow and stern sections on the ends of *Second Generation*.

3 PROJECT MANAGEMENT

3.1 CANOE SCHEDULE

The project manager assembled a list of the various tasks necessary for the construction of the canoe and the time allotment necessary in completing said tasks. The milestones were placed in a Gantt chart, breaking up the hull/mold alterations and the mixing design before the two met into one critical path when pouring the canoe. The amount of time needed for each task was estimated based on previous years' experience and was updated as needed as the project progressed. Some of the most challenging tasks that posed the most threat to the critical path were centered around materials. Silica fume and fly ash are hard to get in small amounts without a large notice to the provider, hence putting dry batching at risk of running behind and therefore pushing back the critical path. This setback was narrowly avoided but served as a good reminder to the team to work towards getting ahead of the schedule.

3.1.1 *Gantt Chart*



ID	Task Mode	Task Name	Duration	Start	Finish	Pred
1		Preliminary Project Delivery Schedule	13 days?	Wed 10/19/22	Fri 11/4/22	
2		Letter of Intent	13 days?	Wed 10/19/22	Fri 11/4/22	
3		RFQ Prequalification	23 days	Wed 10/19/22	Fri 11/18/22	
4		ASCE Annual Report	76 days?	Wed 10/19/22	Wed 2/1/23	
5		RFI and Summary	78 days?	Wed 10/19/22	Fri 2/3/23	
6		Mix Design	20 days	Wed 10/19/22	Tue 11/15/22	
7		Design Hull	75 days	Wed 10/19/22	Tue 1/31/23	
8		Order Materials	42 days	Wed 10/19/22	Thu 12/15/22	
9		Project Proposal	88 days?	Wed 10/19/22	Thu 2/16/23	
10		MTDS Addendum	88 days?	Wed 10/19/22	Thu 2/16/23	
11		Compression Tests	21 days?	Wed 10/19/22	Wed 11/16/22	
12		Mold construction	78 days?	Wed 10/19/22	Sat 2/4/23	
13		Batch Materials	80 days?	Wed 10/19/22	Tue 2/7/23	
14		Grease Mold	6 days?	Mon 2/6/23	Sat 2/11/23	12
15		Pour Mold	1 day	Mon 2/13/23	Mon 2/13/23	14
16		Curing Time	3 wks	Tue 2/14/23	Mon 3/6/23	15
17		Demold	1 day?	Fri 3/10/23	Sat 3/11/23	15
18		Sand Canoe	1 day?	Mon 3/13/23	Mon 3/13/23	17
19		Patch and additional sanding	1 day?	Tue 3/14/23	Tue 3/14/23	18
20		Seal Canoe	13 days?	Wed 3/15/23	Fri 3/31/23	19
21		Second Seal Coating	13 days?	Wed 3/15/23	Fri 3/31/23	19
22		Slump Testing	21 days	Wed 10/19/22	Wed 11/16/22	
23		Absorbtion Test	21 days	Wed 10/19/22	Wed 11/16/22	
24		Air Testing?	21 days	Wed 10/19/22	Wed 11/16/22	
25		Construct Canoe Stands	127 days	Wed 10/19/22	Wed 4/12/23	
26		Concrete Canoe Presentation	128 days?	Wed 10/19/22	Thu 4/13/23	
27		Concrete Canoe Competition	128 days?	Wed 10/19/22	Thu 4/13/23	
28		Presentation Board	128 days?	Wed 10/19/22	Thu 4/13/23	

Figure 3. ***Gannt Chart***

3.2 *DIGITAL RENDERING*

3.2.1 FARO Scans

To find the precise dimensions of the fiberglass mold, an accurate model was necessary to have an accurate representation of the dimensions the canoe would have. A FARO Scanner was used to create a point cloud using Lidar Technology. Three white orbs were placed around the concrete lab, and the scanner was placed in four separate locations around the canoe. The orbs are used in conjunction with each other and with the equipment to triangulate each individual scan and paint those points on one large surface.

The data cloud was taken from the scanner and processed using FARO software and imported into AutoCAD. From there, the point cloud had to be cropped. The scanner does not discriminate and therefore the entire room was scanned. After cutting down the room to the table and the canoe, the cloud was much more manageable. This cloud was then traced over in AutoCAD for multiple different views of the canoe. This was performed for profile views, cross sections, and top views. These traces were then used to create the plan set in the figure below.

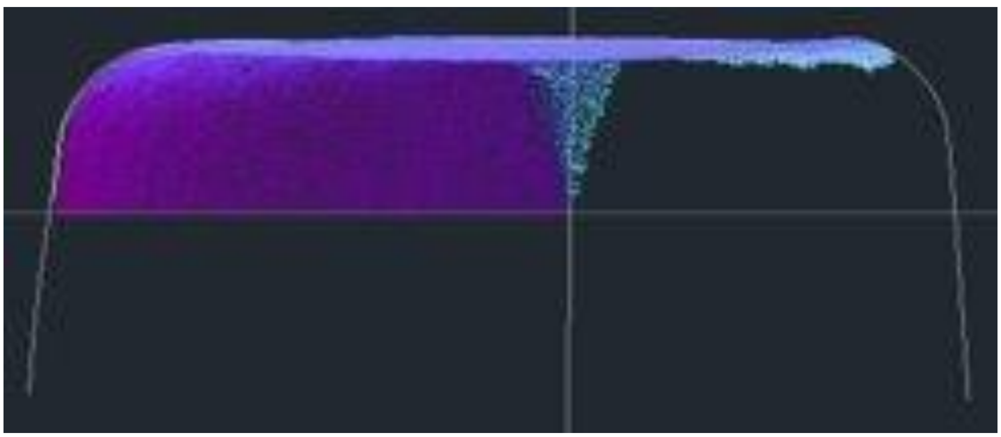


Figure 4. Point Cloud of a General Cross Section.

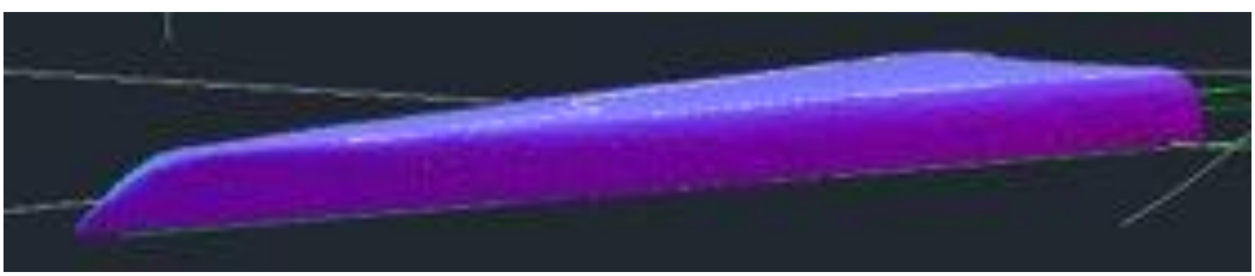


Figure 5. Point Cloud Front of Concrete Canoe.

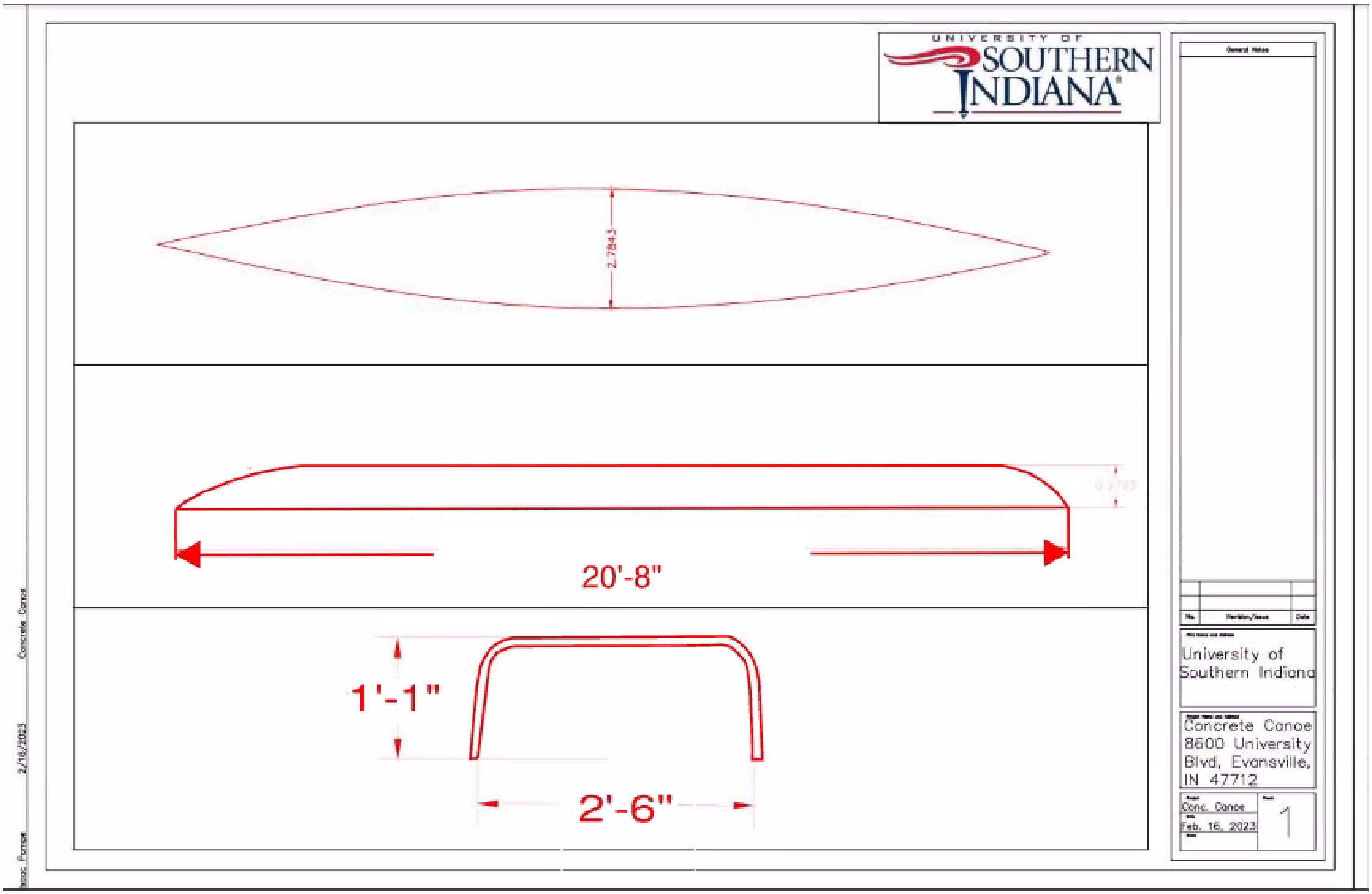


Figure 6. AutoCAD Plan Set.

3.3 BUDGET

When discussing the costs, the canoe was approached in a manner that ensured cost efficiency. The mold was reused from a previous year with some free alterations such as the removal of approximately 1.5 feet. Silica fume as well as fly ash were donated from local establishments and therefore presented no cost to the team. Fiberglass wax was purchased for $76.61 to prevent the mold and concrete from sticking together during the curing and demolding process. Arcosa Lightweight was also donated in previous years, so this aggregate along with Poraver was already provided. Other additions outside of aggregates such as the Shrinkage Reduction Agent (SRA), Glenium 3030 NS, Recycled Concrete Aggregate, and more were also within the laboratory and were at no cost to the Student Chapter or University this year. Specifically, the Recycled Concrete Aggregate was derived from old concrete and played a major role in the mix design. The only other items purchased this year were two (2) 40-pound bags of Portland Cement for $34.74 and steel reinforcement cable for $20.40. This led to a total of $131.75. A breakdown of all materials utilized along with their costs can be seen below. The items with no cost are the materials that were already present, donated, or recycled for *Second Generation.*

Table 2. Cost Breakdown for Second Generation.

Cost Breakdown		
Mold	$	-
Mesh Reinforcement	$	-
Steel Cable Reinforcement (60 ft)	$	20.40
Fiberglass Wax	$	76.61
Water	$	-
SRA	$	-
Glenium 3030	$	-
AE 90	$	-
Silica Fume	$	-
Arcosa LW	$	-
RCA	$	-
Porover	$	-
Portland Cement (94 pound bags)	$	34.74
Flyash	$	-

3.3.1 Labor Estimate

An estimate of the total man hours was assembled to reflect the total cost of labor that was put into the design and execution of constructing the concrete canoe. All of the total hours were estimated by the project manager and the hourly rates were determined after consulting with engineering advisors. It is important to note that all these costs are theoretical as all labor was donated by the ASCE student chapter as well as the project manager and mix designer.

Table 3. Estimated Value of Labor.

Projected Total Hours			
Title	Hourly Rate	Hours	Cost
Design Manager	$ 45.00	200	$ 9,000.00
Project Construction Manager	$ 40.00	100	$ 4,000.00
Construction Superintendent	$ 40.00	80	$ 3,200.00
Design Engineer	$ 35.00	100	$ 3,500.00
Quality Manager	$ 35.00	150	$ 5,250.00
Technician	$ 20.00	200	$ 4,000.00
Laboror	$ 25.00	350	$ 8,750.00
Clerk	$ 15.00	75	$ 1,125.00
Other Consultants	$ 200.00	5	$ 1,000.00
		Total	$ 39,825.00

4 MIX DESIGN

The mix design was one of the hardest things to achieve with the overall design of *Second Generation*. Obviously, one of the adopted criteria was the use of recycled concrete aggregate from two previous canoes.

4.1 MIX DESIGN PREPARATION

The starting point of creating a mix design was to determine the official length, depth, width, and heigh of the concrete canoe to ensure enough material was available for dry batching. We did not wish to exceed over an inch of thickness in order to minimize the overall weight which impacts the buoyancy. The overall typical cross section dimensions as well as rough weight estimate can be seen below. This is an estimate for a rectangular prism to be conservative with the weight of *Second Generation* and the amount of concrete necessary.

Table 4. Rough Dimensions for Second Generation.

Second Generation Dimensions	
Length	229 inches
Width	24 inches
Depth	12 inches
Thickness	1 inch
Weight	463 pounds

The rough weight estimate was considering how much Portland Cement, Lightweight Arcosa, Poraver, Silica Fume, Fly Ash, and Recycled Concrete Aggregate was utilized over the given dimensions.

To obtain an adequate mix design for *Second Generation*, the goal for a total seven (7) day strength was approximately 1,800 psi while following the ASTM sieve analysis standards. Previous mixes were referred to, but this year we strived to do something different. Something we have never done before as a Student Chapter. The use of Recycled Concrete Aggregate was highly encouraged from the previous presidents of the Student Chapter, so numerous tests were performed to see if this was a possibility. Before any mix was finalized, mix designs were thrown together to test the overall strength. After the desired strength was obtained and a good water to cement ratio was achieved, a sieve analysis was performed on an aggregate, the recycled concrete aggregate, that varied too much in size.

In total, there were three (3) aggregates utilized within the finalized mix design. Poraver, Arcosa Lightweight, and Recycled Concrete Aggregate were utilized and must pass ASTM sieve analysis standards. When batching mixes for cubes, cylinders, and shrinkage bars, the mix was very dry, so more water was added as well as Glenium 3030 NS to improve the workability of the mixture. Because of this, an adsorption test was performed on the Recycled Concrete Aggregate since those properties were not documented.

4.2 MATERIALS TESTING

4.2.1 Materials

The main material that was of concern to the Student Chapter at USI was the use of Recycled Concrete Aggregate (RCA). This material was foreign in the sense of the reactivity to water and the properties it consisted of. Thus, material testing had to take place to ensure the best possible outcome for the finalized mix design for *Second Generation*. In addition to this, it was unclear whether there would be any other reactions regarding the Portland Cement, Silica Fume, or Fly Ash. Thus, an adsorption capacity test was run along with the calculation of specific gravity to ensure the floatation for *Second Generation* can be calculated efficiently.

The finalized mix design shall be tested for strength, shrinkage, and most importantly the sieve analysis based on the C33 standard. All material calculated values can be seen in Appendix B.

4.2.2 Strength Testing

The following table displays the compressive strength for the mix design that was utilized for *Second Generation*. A total of three (3) cubes were batched and each was tested at their 7-day strengths. Unfortunately, due to a shortage of time because of continuous testing with prior mix designs and lack of material, 14 and 28-day strengths were not able to be tested before the initial report was due.

Table 5. Compressive Strength Cube Testing Results for Final Mix Design.

Compressive Strength	
Cube 1	1882 psi
Cube 2	1765 psi
Cube 3	1802 psi

All concrete canoe properties were accounted for as well during the process of creating a mixture design. These calculated values are presented within Table 6.

Table 6. Second Generation Official Concrete Properties.

Concrete Canoe Properties	
Avg. Strength (Compressive-Cubes)	1816 psi
Density (hardened concrete)	124 lb/ft
Slump, Spread	1/8 inch
Weight	463 pounds
Air Content	8.00%
Water to Cement Ratio	0.4
% Aggregate Volume	60%
% Paste by Volume	32%

The ideal compressive strength for this type of test is tested utilizing a Forney Compressive Machine with the test specimen being a 2-inch by 2-inch cube.

4.2.3 Shrinkage Testing

Due to the nature of the concrete placement over the fiberglass male mold, shrinkage was a major concern in which it had to be tested. Shrinkage bars were cast and measured within 24 hours of being poured. After 7 days, the bars were measured again in which it was seen that the bars shrank approximately 0.02 millimeters. To counter the shrinkage of the bars, more Shrinkage Reducer Agent (SRA) was added to the mix design.

4.2.4 Sieve Analysis

There were discrepancies in the sieve analysis for the recycled concrete aggregate. There were too many fines within the aggregate mix so, because of this, anything below the number fifty pan was removed from the mix design to ensure it followed ASTM C33 guidelines. All pans were massed before the analysis was run, and then all masses were recorded after ten (10) minutes of running the test. The masses retained on the pans were calculated and graphed alongside the maximum and minimum percent passing on the sieves.

4.3 FINALIZED MIX

The finalized mix design batched for smaller patching buckets can be seen below as an example on how quantities were dry batched. This does not include Glenium since this was added minimally when needed.

Table 7. Patching Bucket Mix Quantities.

Design 1	Mass (g)	Weight (lb)
Cement	1002.61	2.21
Flyash	117.95	0.26
Glenium 3030 NS	5.82	0.01
MB AE 90	2.61	0.01
Shrinkage Reducer	18.5	ml
Water	457.24	1.01
Porover	446.09	0.98
Arcosa LW	550.18	1.21
RCA	520.44	1.15
Silica Fume	58.98	0.13
Total	3161.91	6.97

Again, the aggregated were ran through a final sieve analysis to ensure the gradation passed the maximum and minimum percent passing data given by ASTM C33. The same process of running the sieve analysis was completed once more to ensure a thorough and consistent mix design was produced. The graph of the data can be seen below.

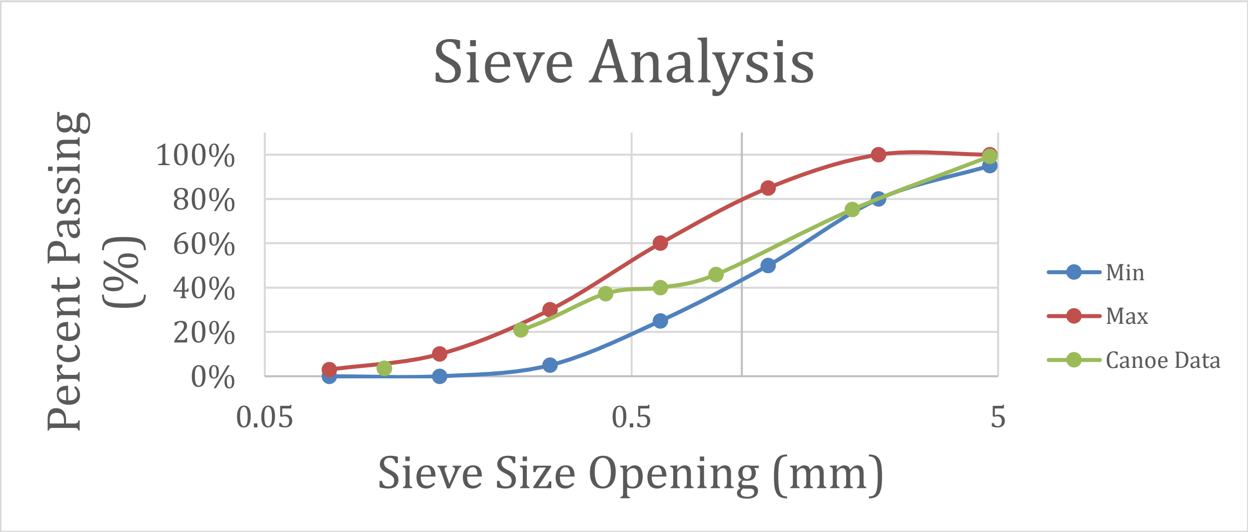


Figure 7. Sieve Analysis of Finalized Mix Design.

The final mix design with fully batched buckets were aimed for approximately 10 pounds after all materials were added. Halfway through, the value of buckets dropped from 48 to 35 to eliminate waiting time for the team members. The batching for the forty-eight (48) buckets can be seen below in the table. This also shows the approximated overall weight of the concrete canoe.

Table 8. Finalized Mix Design Showing Approximated Weight and Dry Batch Buckets.

Batch Quantities				
	Mass (g)	Weight (lb)	Per Bucket (g)	(lb)
Cement	68734.58	151.49	1431.97	3.16
Flyash	8086.42	17.82	168.47	0.37
Glenium 3030 NS	398.66	0.88	8.31	0.02
MB AE 90	178.71	0.39	3.72	0.01
SRA			23	ml
Water	31280.19	68.94	651.67	1.44
Porover	23956.05	52.80	499.08	1.10
Arcosa LW	37718.04	83.13	785.79	1.73
RCA	35679.23	78.64	743.32	1.64
Silica Fume	4043.21	8.91	84.23	0.19
Total	210075.09	463.01	4376.56	9.85

**The green values, for the most part, are wet materials while the red values are dry materials.

5 HULL DESIGN

5.1 FIBERGLASS MOLD

The hull of a boat has many design specifications. The boat must stand up to different forces like buoyancy, self-weight, and live weight loads, as well as optimizing conditions for the canoe to travel through water. The hull of a concrete canoe can be poured two ways: using female molds and using male molds. Female molds are concave, and the material is laid into the mold with the mold staying on the outside of the material. The male mold utilizes the material being laid onto the mold with the mold remaining on the inside of the material before the demolding process can begin. The fiberglass mold available will be treated as a male mold and thus concrete will be poured onto the mold.

5.1.1 Hull Profile

The fiberglass mold has a hull profile labeled as “flat bottom” which helps in the stabilization of the canoe on calm water (Canoe.com, 2023). The lack of curve along the bottom helps in the initial stabilization, but the addition of people can increase the center of gravity enough to capsize should there be enough lateral movement.

5.1.2 Canoe Profile

The mold is also straight sided, meaning that the gunwales are vertically oriented, helping both in paddling ease and water deflection (Canoe.com, 2023). Flared canoes have gunwales that taper away from paddler and come with good water deflection at the expense of paddling ease while tumblehome canoes are the opposite. They struggle to deflect water but are very easy to paddle (Canoe.com, 2023). Straight sided is a good mixture of the too that leans into the upsides of both flared and tumblehome canoes without suffering the full extent of the drawbacks.

The stems of the canoe are oriented squarely or coming to a point. This square stem helps the canoe to cut through the water but loses out on the maneuverability of a rounded stem (Canoe.com, 2023). The stems on both the bow and stern of the canoe are held together by a deck for the mold and will be removed for the pouring process to ensure a flat surface and prevent concrete from seeping underneath the mold.

5.2 *MOLD CONSTRUCTION*

5.2.1 Mold Origin

A fiberglass boat from years past was chosen to be the mold for the canoe. The fiberglass boat was an old practice boat used by ASCE members at the University of Southern Indiana ten to twelve years ago. In selecting this boat to act as a male mold, there were many steps that needed to be made to meet conditions for the ASCE Concrete Canoe Competition and to optimize travel speed as well as stability.

5.2.2 Mold Alterations

There were several modifications that were necessary to bring the canoe mold within ASCE specifications. According to ASCE Concrete Canoe Competition 6.1.1, the hull shall not be over 22 feet in length (ASCE, 2022). The fiberglass mold was not over 22 feet and therefore shortening the mold was not a necessity. However, the table in which the mold was held was slightly shorter than the canoe, meaning that pouring the concrete onto the mold would result in concrete spilling off the table. Therefore, shortening the canoe slightly became a necessity to ensure a clean pour of the mold. In total, the mold was shortened to approximately 229 inches and after 1 inch of concrete is applied to the outer surface, the result shall be approximately 231 inches in length. The lack of symmetry created minor hiccups and thus connecting the two mold sections as cleanly as possible became a vital step in the canoe building process.

Figure *8*. Fiberglass Mold Pre-Alteration.

Another step in altering the mold, though minor, was removing the endcaps from the interior of the bow and stern of the canoe. The endcaps raised the elevation of the two ends of the canoe to be slightly raised, leaving room for concrete to seep under medial edges. This causes miscalculations in the concrete necessary for the pour and poorly constructed gunwales.

Figure 9. Removed Fiberglass Cross Section.

5.2.3 Mold Waxing

Before pouring, a layer of 3M Fiberglass Wax was applied to the mold. This wax helps to smooth out any valleys and create a more consistent slope for the concrete to be poured on. In doing this, less sanding will be necessary due to the smoother nature of the concrete pour. This creates an easier process after demolding the canoe, but the wax also helps to protect the mold. The wax will have a small layer of protection, helping to keep the mold in better condition for future canoe builders.

Figure *10*. Marine Wax Used for Second Generation.

This was the first time that the USI ASCE student chapter used fiberglass wax to aid in the demolding process. After its inaugural use, it is recommended to continue using this wax when using a mold made of fiberglass as the canoe experienced minimal damage and henceforth was a success.

Figure *11*. Application of Wax to the Fiberglass Mold.

5.3 *HULL DESIGN CALCULATIONS*

Various calculations were performed to ensure the performance of the canoe throughout its 0lifecycle. These were performed with design parameters in mind and the following calculations are as follows.

5.3.1 Freeboard

Freeboard calculations show the change in elevation the canoe will undergo when subjected to the weight of the paddlers as well as buoyant forces.

$$V_w = \frac{W_D + W_P}{\gamma_w}$$

$$Draught = \frac{V_w * h_{max}}{V_c}$$

$$Draught(W_p) = \frac{(W_D + W_p) * h_{max}}{V_c * \gamma_w}$$

$$Draught\left(W_p\right) = \frac{(463 + 800) * 1.1}{55.78 * 62.4} = 4.78''$$

With a freeboard of roughly five inches, the canoe will easily be able to take on 800 pounds of canoe paddlers without the canoe capsizing. With this loading, the water level on the canoe would be right around five inches from the bottom most tip of the canoe. With the height of the canoe being slightly over a foot, this is a value much lower than that height and therefore perfectly acceptable.

5.3.2 Loading Diagram

Using RISA 2D, a diagram of all the loading was added to a concrete beam with the same length as the canoe. Two individual point loads depicting the paddlers were added as well as two separate distributed loads. The first of those two is acting downwards and acts as the self-weight of the canoe. This load was applied in the middle of the canoe where the canoe was at its widest. Though this is not wholly accurate to how the canoe will act, it is more conservative and creates a higher moment in the middle of the canoe. The last of the distributed loads acts upwards and is the buoyancy force helping to keep the canoe afloat. The buoyancy was determined by following the diagram below with basic static equations:

$$\sum F_y = 200 + 200 + 80(5) - 20(F_B) = 0$$

$$F_B = 40\ plf$$

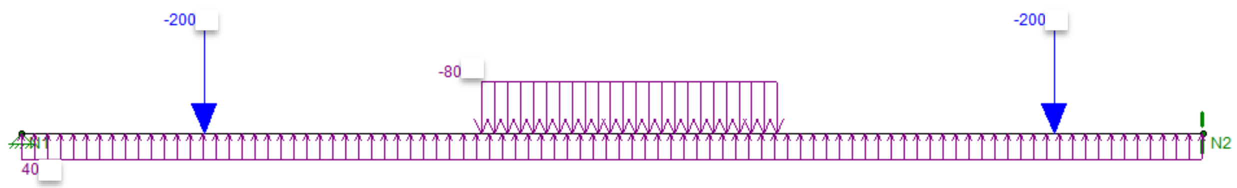


Figure *12*. RISA Loading Diagram Given Point Loads and Distributed Loads.

Twenty feet was used for the buoyancy calculation as the very tips of the canoe experience very little buoyant forces. This takes a third of a foot off of each tip and the statics equate to forty pounds per linear foot of buoyancy force being applied in the upward direction along the canoe.

5.3.3 Shear Diagram

After running an analysis on the loading diagram above, a shear diagram was generated and showed the maximum moment present throughout the canoe. It is also worth noting that because of rounding values, the shear diagram is asymmetrical by a slight margin when the canoe would be identically loaded on each side. This shear diagram determined a maximum shear force of 112 pounds.

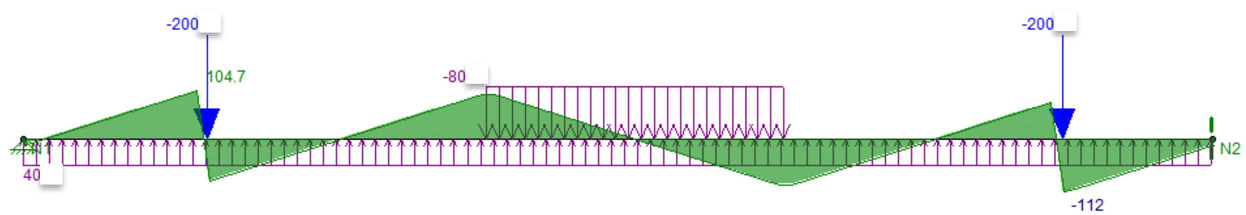


Figure *13*. RISA Shear Diagram.

5.3.4 *Moment Diagram*

Like the shear diagram, a moment diagram with the magnitudes was generated. The symmetry is more prevalent in this diagram than that of the shear diagram, though still not perfectly for the same reasons. This diagram yields a maximum moment of around 600 pound-feet.

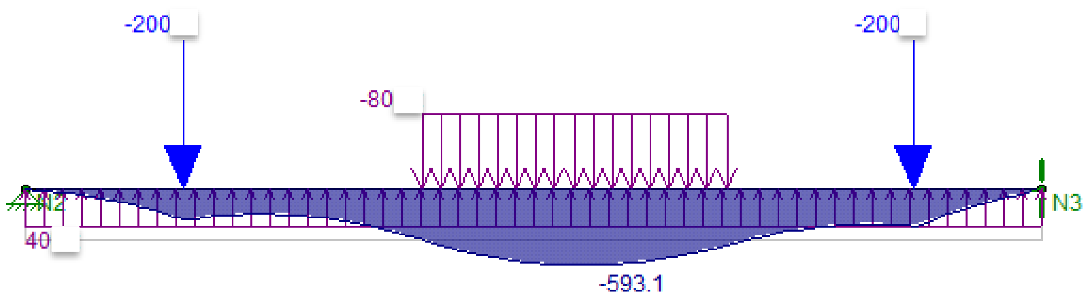


Figure *14*. RISA Moment Diagram.

5.3.5 *Moment of Inertia and Bending Moment*

The moment of inertia was found by breaking the canoe cross section into five separate entities. The first and fifth of those were the tops of the gunwales, the second and fourth being the leftover sections of the gunwales, and lastly the third being the bottom flat section of the canoe. The following table was used to determine the different factors necessary in calculating the moment of inertia and is shown below:

Table 9. Moment of Inertia Table

Segment	Area (in^2)	y (in)	Ay (in^3)	I (in^4)	d (in)	Ad^2) (in^4)
A	1.5	12.5	18.75	0.18461	-8.7	114.73255
B	13	6.5	84.5	1.08333	-2.7	98.009767
C	30	0.5	15	2.5	3.25	317.70181
D	13	6.5	84.5	1.08333	-2.7	98.009767
E	1.5	12.5	18.75	0.18461	-8.7	114.73255
Sum	59		221.5	5.03589		743.18644

Thus, using this table, a computation for the maximum bending stress is calculated using the following equations:

$$I_{total} = Ad^2 + \sum I$$

$$I_{total} = 5.03589 + 743.18644$$

$$I_{total} = 748.22\ in^4$$

$$\sigma = \frac{M_{max} * (h_{max-}c)}{I_{total}}$$

$$\sigma = \frac{593 * (13 - 2.729)}{748.22}$$

$$\sigma = 97.68\ psi$$

6 MOLD POURING

6.1 PRE-POUR

6.1.1 Dry Batching

For the canoe to be poured in an efficient fashion, concrete needed to be steadily available to those applying the concrete to the mold. To ensure that the concrete was available, the dry ingredients were all measured into buckets with their respective ratios, making it to where each bucket needed a set amount of water before mixing. This allowed more workers to be helping with other construction processes and was able to be done before "Pour Day."

6.1.2 Concrete Mixing

The buckets that had been filled with dry ingredients had the set amount of wet ingredients added to them and then mixed. Set workers used hand drills with large bits that helped to mix the concrete. This process was repeated for each bucket, with every individual bucket being checked by one of the concrete layers. This helped to verify the right consistency and slump of the concrete for application to the mold. If the concrete did not meet the concrete layer's liking, superplasticizer was added to add more slump/runniness and more mixing was performed to decrease the slump or make the concrete less workable.

6.2 POUR DAY

6.2.1 Concrete Application

Whenever each bucket had passed inspection, the concrete was placed on the mold and pressed down to a set height for each layer. Two layers of concrete were applied across the entire mold by hand, one layer being completely done before starting the second. Wooden skewers were made with set heights etched into them, making it quick and easy to check the height of each layer as the application process progressed. The top of the mold, which makes up the bottom of the canoe, was very easy to apply as gravitational forces were not a problem. The gunwales, however, struggled mightily without using the cohesive force in the concrete to help hold the concrete in place. To help keep the concrete from falling off the sides (Which happened on several occasions), the concrete was started at the very bottom and top. By building up from the top and bottom, there were cohesive forces helping to keep the concrete in place rather than just sliding off. Doing this in a slow and steady fashion was less ideal, but in the long run created less issues.

Figure *15*. Pour Day

6.2.2 Reinforcement

A reinforcement layer of mesh was added between the two layers of concrete. This provides structural stability while also helping to hold the two layers of concrete together. Also, at different points of the canoe, reinforcement steel cables were placed tangentially to the longitudinal axis of the canoe, adding strength in the concrete, and aiding in shrinkage resistance. Similarly, reinforcement rods were also placed around the canoe on the edge of the gunwale, primarily helping to prevent shrinkage and cracking at the edges of the canoe.

Figure *16*. Application of Reinforcement.

6.2.3 Curing of Canoe

After pouring the concrete, an hour was given to let the canoe settle. Plastic wrap and wet burlap were then placed on top of the canoe, creating ideal curing conditions. The burlap was changed as needed throughout the curing process, again emphasizing the importance of putting the canoe in the best circumstances for curing efficiency. The canoe remained in this ideal condition for three weeks, allowing for the concrete to close in on its maximum strength.

Figure *17*. Post Pour-Day Before Cured.

7 CANOE ALTERATIONS (POST-CURING)

7.1 PATCHING

Patching the canoe simply means filling in holes, cracks, or other parts of the canoe where there was extra concrete needed. After the curing took place, new batches of concrete were made utilizing the same mix design. This was then applied to three main locations of the canoe. First, there was a section of the toe of the canoe that was left unfinished on the second layer due to lack of concrete. This patching simply fulfilled what was initially intended to occur on pour day. Secondly, the bottom of the canoe had some areas that were not as flat as the design specifications, leading to more concrete being used to level out these sections. Lastly, concrete was intermittently used on the gunwales all around the canoe to help fill in some of the small cracks that became evident after the curing process had taken place.

7.2 SANDING

7.2.1 Sanding

Sanding the concrete canoe was a tedious yet necessary task. Sanding removes very small amounts of material and helps to smoothen out the hull. The outside of the canoe requires sanding for increased mobility as the drag forces are lesser on a smooth surface. The sanding that takes place on the inside of the canoe creates a smoother surface for the rowers, eliminating sharp edges and possible injuries. Lastly, the sanding helps to create a more aesthetically pleasing look. The outside of the hull was sanded first as the canoe had not been flipped when the canoe sanding initially began.

Figure *18*. Hand Sanding Rough Patches.

7.2.2 Flipping Canoe

After the outside of the canoe has been sanded, the canoe needs to be flipped. This grants access to the inside of the canoe and therefore allows new tasks to be completed. Some of these new tasks include sanding the opposite side of the canoe. The sanding on the inside of the canoe mentioned above takes place after the canoe is flipped. The gunwales can still be sanded need-be on the outside, if necessary, but the bottom of the canoe is not exposed and therefore must be completed before flipping.

The canoe should be flipped with care and with many hands-on deck to avoid damage to both the canoe and the mold in case it shall be reused in the future. After lifting and flipping the canoe, it was placed on a soft surface and ensure that the canoe is level to avoid tipping and any other damage.

7.3 DEMOLDING CANOE

After the canoe had been flipped, the mold needed to be removed for multiple tasks to take place. Because the mold had been cut into two separate pieces and spliced together, the mold was removed in two pieces. The fiberglass was separated from the concrete with prying devises lightly being used to separate the two pieces. Special care was taken to ensure that little pressure was put on the canoe to avoid damage. After doing this completely around the first half of the canoe, half of the fiberglass was pulled out of the canoe with minimal adhesive forces between the concrete and bottom of the mold being present. This process was then repeated for the other half of the canoe/mold, leaving the two halves of the mold separated.

7.4 END CAPS

7.4.1 Adding Foam

One of the most important tasks in the canoe making process is adding foam into the endcaps to increase the buoyancy forces acting on the boat. Rectangular foam sections were individually cut to fit the ends of the canoe. After fitting the first piece, a second piece was fitted in the area directly adjacent to the original foam slice. When this second piece was sized correctly, the two pieces of foam were adhered together and placed back in the canoe. The third slice was similarly cut, adhered to, and placed, performing this pattern until the end cap was completely filled with foam. The other end cap was done in the same fashion after the first end cap was completed.

After all the foam was placed in the canoe, expanding foam was sprayed around the edges of the foam and in the gaps under and to the side of any places big enough. This foam helped to fill the voids that were too precise for the normal foam and most importantly secured the foam to the concrete walls in which the foam was laid against.

7.4.2 Pouring End Cap Concrete

After the foam is secured in the end caps, a layer of concrete is laid to encapsulate all the foam. The original concrete mix is again batched, mixed, and laid with an emphasis on bonding the new concrete to the edges of the canoe. The concrete is given time to cure and bond whilst making sure the foam is completely covered up from all outside exposure.

Figure *19*. End Caps Post-Pour Before Sealant and Sanding.

7.5 SEALING CANOE

After all patching, sanding, and pouring has been completed, sealing must take place. The sealer prevents water from being absorbed into the concrete and foam and increasing the weight of the canoe, likely leading to the canoe capsizing. This sealant is applied like paint, being performed firstly on the inside of the canoe since the canoe was already upright. After the inside took on two coats of sealant, the canoe was then flipped and sanded to ensure a smooth finish. One layer of sealant was lathered onto the outside of the canoe to help with a smooth finish before any lettering was added to the endcaps.

7.6 FINISHING TOUCHES

After the sealant had been applied, ‘2nd Gen’ and ‘USI’ were cut out in permanent vinyl using a Cricut machine. The letters were carefully transferred from the mats to the canoe by hand and pressed on for approximately 10 seconds. Finally, a second coat of sealant was applied over the whole canoe as well as the lettering for the finishing touch.

8 QUALITY CONTROL/ASSURANCE AND SUSTAINABILITY

8.1 QUALITY CONTROL/ASSURANCE

8.1.1 Bucket Weight

When taking the suggested volume of a general shape, thirty-six (36) buckets were to be dry batched to produce the canoe. The materials list within the design spreadsheet calculated how much the dry mix shall weigh after each bucket was fully batched. The total weight per bucket for dry batching was calculated to be approximately 9.8 pounds. On pour day, after the addition of the wet materials, the total weight was calculated to be approximately 11.8 pounds. The weighing process was crucial on pour day to ensure all materials were accounted for to keep a consistent mix design that followed the competition rules. Thankfully, according to this process, a team member was able to catch a bucket that did not have Portland Cement in it.

8.1.2 Canoe Thickness

It was decided prior to pour day to keep the canoe around 1 inch thick which is the thickness that was utilized in the general calculation for total volume. To control this aspect of the canoe, depth control probes (wooden skewers) were labeled at 0.35 inches and 1 inch. The first layer was placed onto the mold and the concrete was checked to be 0.35 inches in width every six (6) inches. Laterally across the canoe, the sides were checked in the center and the bottom of the canoe was checked approximately six (6) inches off each side. After the mesh and steel cable was added, they had to be fully submersed within the concrete, but had to stay at 1 inch to ensure enough material was accounted for in the calculations. Not only was this crucial to keep track of materials being used, but it was also crucial in making sure the canoe did not weigh more than 500 pounds.

8.1.3 Mixing Dry and Wet Materials

The finalization of the mix design was also key to ensure it followed all the specifications presented within the rules. All materials were placed into five-gallon buckets and wet materials were added. To ensure mixes were sufficiently combined, hand mixers were utilized to aid in the elimination of dry mix sticking within the edges of the buckets. Along with this, each bucket was checked with rectangular trowels. Finally, *Second Generation* wanted to have a smooth finish which was completed with the rectangular hand trowels to provide physical integrity.

8.2 SUSTAINABILITY

Sustainability was heavily considered within the design and construction of *Second Generation* regarding environmental and economic impacts. *Second Generation* derived its name using two previous canoes that were designed for the 2019 to 2020 (*Smiley*) and 2021 to 2022 school years (*Supercrete*). Both canoes were broken into small pieces in May 2022 and were then pulverized into an aggregate during the 2022 to 2023 school year. By doing this, 79 pounds (17 percent) of the current canoe, *Second Generation,* is purely recycled aggregate concrete (RCA). Not only does this cause less waste, but it also is cheaper when accounting for materials for the mix design.

Regarding the design of the mold, the idea was to reuse a previous mold that was like the hull design we strived to achieve. This mold was fiberglass which was easily manipulated into the desired design. This design was shorter in length to be able to make tighter turns within the competition. To shorten the canoe, the fiberglass mold was cut to make it approximately 240 inches.

Another key aspect to the economic impact of this year's canoe was the use of donated materials and previously owned materials. All materials apart from steel reinforcement cable, Portland Cement, and fiberglass wax were either owned by the Student Chapter/University or donated by surrounding organizations within Evansville, Indiana. By doing so, new connections were made which may lead to possible job opportunities for younger/future Student Chapter members.

9 CONCLUSIONS AND RECOMMENDATIONS

9.1 CURRENT PROGRESS

There is no current progress going on with this project as it has already been completed and tested during the 2023 ASCE Student Symposium in Bowling Green, Kentucky. However, there is room for improvement for future students and faculty advisors as this is an annual competition.

9.2 RESULTS

The ASCE Student Chapter of the University of Southern Indiana successfully unloaded *Second Generation* upon the arrival at Western Kentucky University for the 2022-2023 Student Symposium. The team members of the Student Chapter can be seen below with the final product, *Second Generation*.

Figure 20. Second Generation at Bowling Green, Kentucky.

After beginning the day, the canoe was lifted from the approximately 4-foot-tall stands and set into the water. From there, a swamp test shall be performed. Team members from the University of Southern Indiana had 5-gallon buckets and started filling up *Second Generation* with water. After this, the canoe was fully submerged underneath the water surface and had to meet the criteria of rising within a minute to be able to race. Unfortunately, one end did not rise. Thus, extra foam was added and secured within the canoe to aid in the buoyancy of the end cap that did not rise. Upon swamp testing the canoe again, water started seeping into the cracks within the concrete which added more weight to the canoe and countered the buoyancy. To fix this problem, the Student Chapter decided to pull the canoe onto the beach to seal *Second Generation* with more duct tape. Upon doing so, one of the ends snapped and exposed the entirety of the foam within the end cap. This can be seen below. In result, *Second Generation* failed the swamp test and was not able to compete in the races.

Figure 21. Crack in the End Cap on Race Day.

9.3 FUTURE RECOMMENDATIONS

The following issues are left open for the ASCE student chapter to improve upon the completion of this project:

- There was an abundance of water which entered the endcaps through cracks which may have been caused by shrinkage over the expanding spray foam. Less spray foam should be utilized to ensure there is not too much expansion around these joints.
- *Second Generation* was a decently heavy canoe, so it is recommended that more lightweight aggregates should be utilized in the future. An example of this is the utilization of various gradations of Poraver.
- While the male mold had less slumping than the previous female molds, the canoe did not take shape to the male mold very well. There was sagging within the middle of the fiberglass which gave the final prototype a curve. If proper technique can be achieved as well as the workability of the concrete, a female mold may be a better approach. If not, ensure the male mold is not flexible and is properly supported structurally.
- The use of fiberglass wax was new to the USI chapter and performed very well. It is recommended the chapter continues to utilize the wax whenever using any sort of fiberglass mold to ensure minimal damage when demolding.

If these issues can be investigated and properly addressed, any future canoes through the student chapter at the University of Southern Indiana shall be more successful.

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APPENDIX

APPENDIX A

Useful formulas for the calculations regarding mix design materials.

Equation 1. Absorption Capacity

$$\boldsymbol{Abs = \frac{W_{SSD} - W_{OD}}{W_{OD}} X100\%}$$

Where…

W_{SSD} = Weight Saturated Surface Dry

W_{OD} = Weight Oven-Dry

Abs = Absorption Capacity

Equation 2. Absolute Volume

$$\boldsymbol{Abs\,Vol = \frac{m}{62.4(SG)}}$$

Where…

Abs Vol = Absolute Volume

SG = Specific Gravity

m = Mass

Equation 3. Volume of Cement

$$\boldsymbol{Vol_{Cement} = \frac{m_{Cement}}{62.4(SG_{Cement})}}$$

Where…

m_{Cement} = Mass of the Cement

Vol_{Cement} = Volume of the Cement

SG_{Cement} = Specific Gravity of the Cement

Equation 4. Total Water with Set w/c Ratio

$$\boldsymbol{Water} = \frac{\boldsymbol{w}}{\boldsymbol{c}}(\boldsymbol{c})$$

Where…

w/c = Water to Cement Ratio

c = Mass of Cement

Equation 5. Total Mass of Concrete

$$\boldsymbol{M} = \boldsymbol{Amount_{Cement}} + \boldsymbol{Amount_{Fibers}} + \boldsymbol{Amount_{Aggregate}} + \boldsymbol{Amount_{Solids}}$$

Equation 6. Absolute Volume of Concrete

$$V = Vol_{Cement} + Vol_{Aggregate} + Vol_{Water} + Vol_{Fibers} + Vol_{Solids}$$

Equation 7. Theoretical Density

$$\rho_{theo} = \frac{M}{V}$$

Where…

ρ_{theo} = Theoretical Density

M = Total Mass of Concrete

V = Total Volume of Concrete

Equation 8. Air Content

$$AC = \frac{\rho_{theo} - \rho_{anticipated}}{\rho_{theo}}(100)$$

Where…

AC = Air Content

ρ_{theo} = Theoretical Density

$\rho_{anticipated}$ = Anticipated Density

APPENDIX B

Aggregates	***Abs (%)***	***% Volume***	***Volume (cm^3)***	***Free Water (g)***
Arcosa LW, *agg_1*	*-10.78%*	*50%*	*743.5*	*-34.9*
Poraver, *agg_2*	*-10.00%*	*25%*	*371.7*	*-59.3*
Recycled Concrete Aggregate, *agg_3*	*-17.25%*	*25%*	*371.7*	*-90.6*

Component	***Specific Gravity***	***Volume (cm^3)***
Cement, *c*	3.15	318.3
Fly Ash, *cm_1*	2.4	49.1
Silica Fume, *cm_2*	*2.4*	*24.6*

Component	***Value***
Desired w/c	0.4
% Aggregate Volume	60%
% Air	*8.00%*
Actual w/c	*0.392*
Mix Design SG	*1.285*

APPENDIX C

Design Factor	Page number, or reason not applicable
Public health safety, and welfare	NA
Global	NA
Cultural	Section 1.2
Social	Sections 1.1, 1.2, 1.3, 1.4
Environmental	Sections 1.5, 4.1
Economic	Section 3.3
Ethical & Professional	Sections 6.2.1,
Reference for Standards	ASCE

A1 - PUBLIC HEALTH SAFETY, AND WELFARE

The concrete canoe does not have any direct effects that would sway any public health or welfare. The canoe simply does not have any health benefits, nor does it help others in a medical sense. It was not designed to nor expected to do such things.

A2 - GLOBAL

The concrete canoe was used at the Indiana Kentucky Symposium and therefore was used at a regional level. This canoe will therefore not be used on a scale that would involve the entire world.

A3 - CULTURAL

At the University of Southern Indiana, concrete canoes are openly displayed within the Business and Engineering Center, a very common location for tours and many students to attend classes. By creating this canoe, we were able to generate discussion on not only civil engineering, but on ASCE, the canoe itself, and helped to generate interest for potential future students. By creating the canoe, we helped to foster that interest within the engineering department as well as in the University itself.

A4 - Social

The concrete canoe was a great way to meet new people. Members within the USI chapter of ASCE were able to meet and create new friendships that might not have kindled otherwise. The symposium was also a method of meeting new civil engineers from other schools in the Midwest region.

A5 - Environmental

The idea of "Second Generation" was used alongside the ASCE requirements to recycle different materials throughout the canoe making process. This was not just performed for the aggregate however, as the mold, other ingredients, and sealant were all either reused or recycled from previous years, leading to less waste than that of the average concrete canoe.

A6 - Economic

A lot of the economic factors stem from the recycling theme mentioned above. By refraining from purchasing new materials, money was saved for the canoe that could be spent in future years. Though there was no hard budget, saving money on the canoe by reusing many of the necessary items presented a theme that was acted on for the ASCE competition.

A7 - Ethical & Professional

Throughout the canoe building process, there were many rules that had to be followed in order to ensure that the canoe was built to the correct standards. This ensure us that there were no competitive advantages for the canoe when compared to those also present at the competition. During the building process, one of the more difficult challenges faced was applying concrete along the gunwales, where gravitational forces work to pull down on the concrete as it is applied. An unethical solution would be to neglect the rules and add a concrete paste before applying the concrete and therefore having a very application process. Rather than this, we adhered to the rules set forth by ASCE to create an even playing field amongst the other schools.

A8 - Reference for Standards

The standards that were followed for the entirety of the project were the ASCE concrete canoe rules.