Mesektet

Michigan Technological University

2012-2013 Design Paper

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Executive Summary

Michigan Technological University, (Michigan Tech) established in 1885, sits on the edge of Portage Lake in Houghton, Michigan. Many miles and ages away, the Nile flowed and brought life, transportation, and civilization to Ancient Egypt, just as the Portage Lake flowed through the Houghton area and brought life to the mining region. Each consequently nurtured the beginnings of great engineers. Ancient Egyptians earned the title as the pinnacle of ancient society and stood as an inspiration for future civil engineers. This inspired the team to choose an Ancient Egyptian theme for this year's concrete canoe competition.

In Ancient Egyptian mythology, the god Ra claimed the sun and presided over the world. Each day he would sail across the morning sky, balancing the sun on his head in his morning boat, and each evening he would plunge into the realm of the Underworld in his evening boat, Mesektet. The journey through the Underworld was a harrowing one where the fate of the sun rising on the next day was on the line. By avoiding deadly danger, a successful Ra would be renewed into greatness for another day.

Since 1978, Michigan Tech's Concrete Canoe Team has participated in the North Central Conference and has earned a place in the national competition 13 times. Most recently, the team was honored to take third place overall in last year's competition with *Genoa*, matching a previous team best set in 2005 with *The MacInnes*. Striving to continue its success, the team optimized a hull design that reduced drag while retaining displacement and stability. The rocker of 2008's *Gambler* was brought together with the racing canoe hull and gunwale caps featured in 2012's *Genoa* and hybridized together with the geometry of a slalom ski to form an inventive hull design. In addition to these improvements, a mix was created that achieved high tensile strength and low unit weight. Safety was also a key concern which Michigan Tech tackled by developing a new air filtration system. The team did not forget about sustainability, continuing the recycled water system and implementing an environmentally responsible method of air brush staining.

Like the sun's renewal at the end of Mesektet's journey, the team learned from the past and innovated for the future to proudly excel into this year's competition with its 2012-2013 canoe, *Mesektet*.

Table 1: 2013 Concrete properties.

2013 Concrete Properties			
	Unit Weight	Compressive Strength	Tensile Strength
Structural	56.0 Wet 53.5 Dry	1915 psi	314 psi
Finishing	60.2 Wet 48.6 Dry	1050 psi	210 psi
Inlay/Outlay	68.5 Wet 64.8 Dry	1050 psi	210 psi

Table 2: 2013 Canoe properties.

2013 Canoe Properties	
Weight	220 pounds
Length	20 feet
Width	32.8 inches
Depth	14.6 inches
Nominal Thickness	1/2 inch
Main Color	White
Inlay/Outlay Color	Black

Table 3: 2013 Reinforcement properties.

2013 Reinforcement Properties	
Continuous Reinforcement	Kevlar Fabric 4009-1
Fiber Reinforcement	Nycon Kuralon RF4000 and RECS15 Polyvinyl Alcohol Fibers, Forta PE-2, GRT Polymesh

Project Management

The Michigan Tech Concrete Canoe team prides itself on strong leadership, teamwork, and communication. To lead all team projects, junior and senior co-captains were elected to staggered two-year terms. A safety chairperson was selected to oversee construction tasks throughout the year. This year, rather than having one compliance committee ensure all rules are met, individuals working within different aspects of the project were assigned to compliance positions. Leadership positions were held by experienced members of the team, who worked with younger members in order to assure that knowledge would be passed down. Due to high recruitment, an education committee was formed and held concrete and concrete canoe informational sessions for the benefit of the 14 new members. The organization chart can be seen on page 2.

The team placed an emphasis on safety throughout the year. In October, the team participated in a general safety course led by Michigan Tech's Civil and Environmental Engineering Department Safety Coordinator. This familiarized all team members with safety equipment, material safety data sheets, fire extinguishers, exit routes, and proper emergency contact information. The team's safety chair also explained proper power tool equipment use and care. The use of personal protective equipment (PPE) was stressed when performing any work within the team's facilities.

Last year, the team experienced a significant delay in material procurement, setting the team back over a month on canoe construction. In order to avoid this, the team was cautious and ordered materials well in advance. No major setbacks occurred, and the team was able to cast on time.

In order to construct Mesektet, the team had to procure resources. The team received about $7,000 in donations and fundraised nearly $700. Figure 1 shows how resources were used.

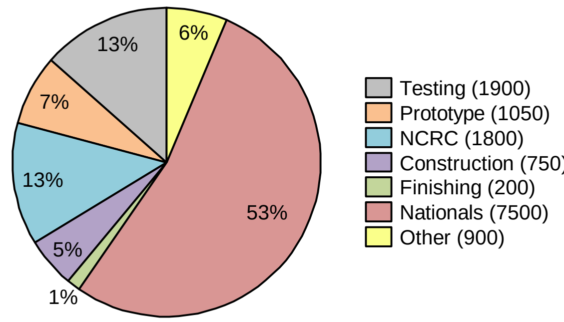


Figure 1: Competition took up a large majority of this year's costs.

Milestones were determined using the previous year's project schedule and are indicated with a black dot on the project schedule on page 9. These were met through hard work and the guidance of committee heads.

The critical path was based on any activity that, if not completed by its scheduled date, would postpone completion of the entire project. These activities can be seen on the project schedule in red.

Figure 2 illustrates how team members allocated their time spent working throughout the year. In order to create *Mesektet*, the team spent nearly 900 man-hours on hull design, 400 man-hours on structural analysis, 385 man-hours casting, and devoted nearly 800 man-hours on aesthetic work.

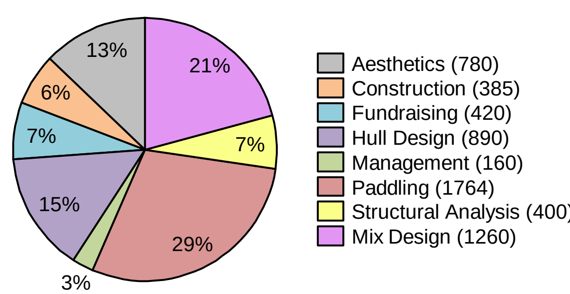
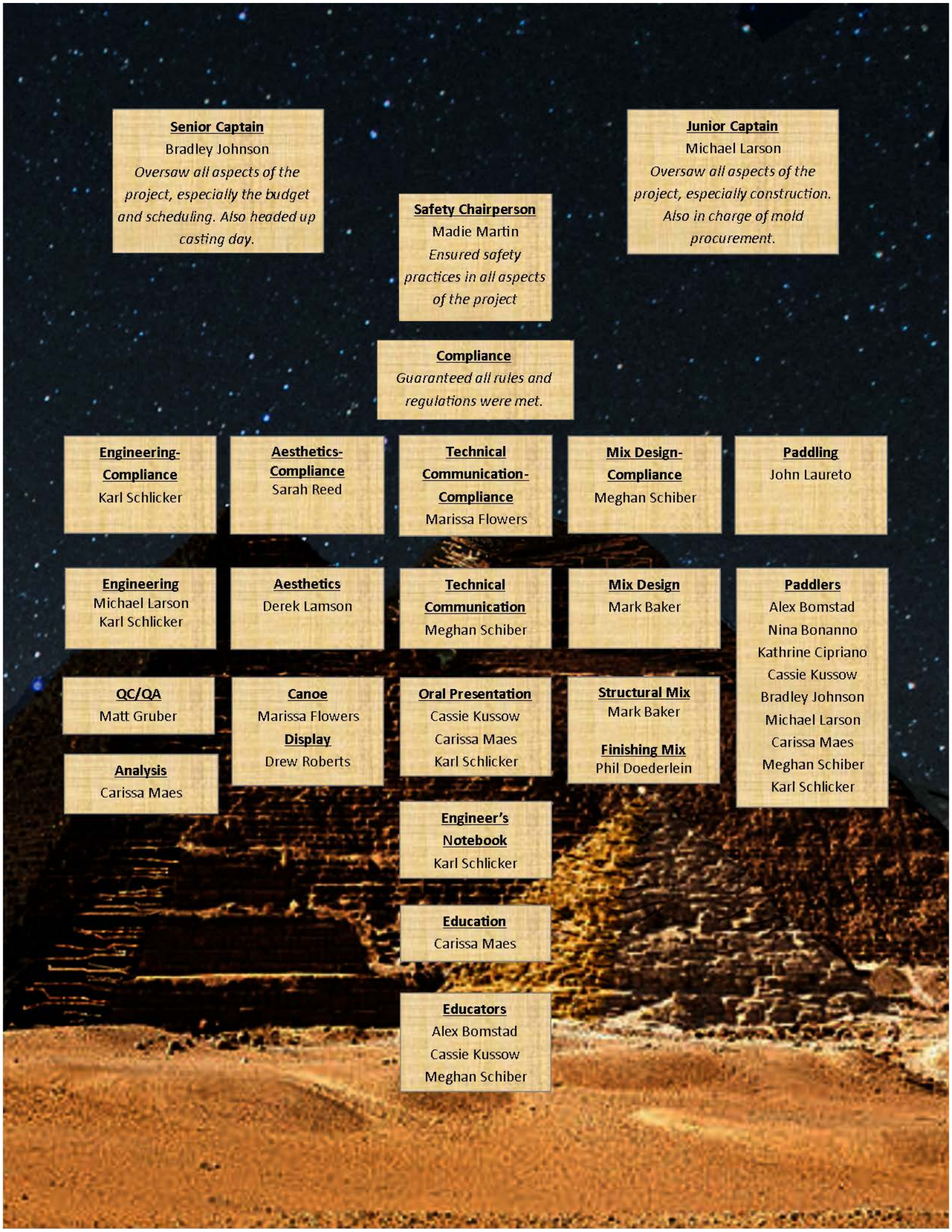


Figure 2: The majority of man-hours were spent on paddling and mix design this year.

Organization Chart



Hull Design and Structural Analysis

Historically, hull design has been a way for Michigan Tech to show its ingenuity at competition. The team's 2008 canoe, *Gambler*, had hard chines and a severe rocker, while the 2012 canoe, *Genoa*, had a uniquely modified racing hull. This year, the team combined elements from both of these designs to bring a truly innovative hull to the 2013 competition. *Mesektet* was derived from the core principles of *Gambler*'s quantitative results, *Genoa*'s racing hull, and the geometry of slalom skis (as seen in Figure 3 below).

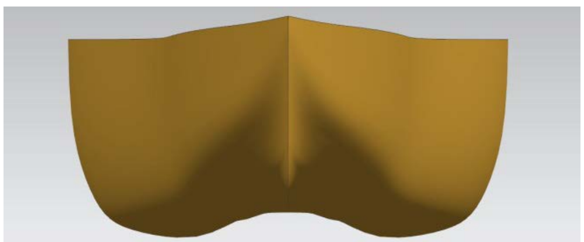


Figure 3: Derived from a slalom ski, the concave geometry improves key performance characteristics.

Based on last year's performance in paddling, a faster canoe was deemed necessary to be competitive. Goals were set for this year to decrease drag while maintaining adequate stability and displacement. Keeping ample freeboard was also a concern, as last year the team experienced problems in this area.

To maintain displacement and stability, the team used *Genoa* as a baseline. The size, shape, and location of the bulge had been optimized for this purpose last year. The rocker and concavity were then implemented to resemble a slalom ski, which together decreased drag, created lift, and allowed for sharper turning.

Using *Gambler*, with a block coefficient of 0.328 in the women's sprint, as a baseline for drag reduction, a range of rocker heights was tested. It was determined that 5 to 6 inches of rocker produced the optimal minimization in drag while maintaining straight-line tracking. Adding rocker resulted in a block coefficient of 0.340 in *Mesektet* during the women's sprint; this represents a 20% decline from the 0.429 value of *Genoa*. Block coefficients were determined from PROLINES software, which was used throughout the hull design process.

The team experimented with different hull lengths and found that 20 feet optimized the balance between maximum velocity and frictional resistances. The added rocker counteracts the decrease in maneuverability associated with a longer hull. Adding a skeg to the stern of the canoe minimized the frictional drag created by transverse waves and assisted in straight-line tracking.

The combination of all these elements resulted in a dramatic reduction in wave drag as compared to *Genoa*. As seen in Figure 4, wave drag remains zero until a velocity of 3.2 knots and decreases after 5.7 knots, the velocity at which *Mesektet* rises on its bow wave and begins to plane.

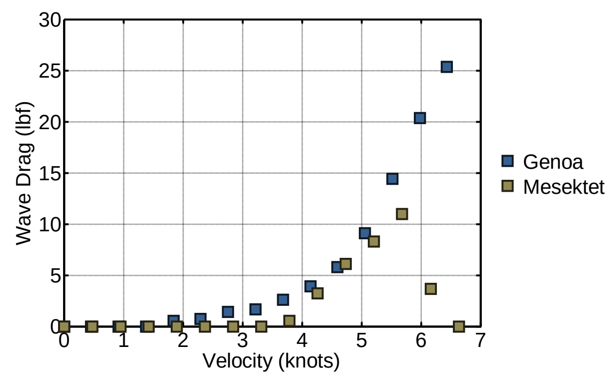


Figure 4: *Mesketet*'s wave drag was dramatically decreased from *Genoa*'s through the use of a semi-planing hull.

To practice with the radical hull design, a prototype was constructed of low-cost Luann wood. After several test runs, the team found that the prototype met all of the aforementioned performance requirements of this hull design.

In order to determine the survivability of *Mesektet*, hand calculations were performed to compare the flexural capacity of canoe to the principal stresses, both when in areas of compression and tension, in seven load cases. MATLAB and Excel were used to perform iterative calculations to supplement hand calculations. The normal stresses from flexural bending and shear stresses from torsional bending during buoy turns were combined to find the principal stresses in each load cases.

In order to perform these calculations, a few assumptions needed to be made. A flexural analysis was completed using straight-line dynamic loading conditions. Male and female paddlers' weights, 200 pounds and 170 pounds respectively, were increased by 20% to account for dynamic loading during paddling. The canoe was modeled as 140 pounds with a nominal thickness of 3/8 inch. *Mesektet* was modeled as a U-channel beam with varying dimensions at every one-foot increment. The buoyant force was presumed to be uniformly distributed beneath the canoe. For this analysis, loads were only applied in the vertical direction, and the system of the canoe and the water is assumed to be in equilibrium and thus, stationary.

Each paddler was represented by two linear distributive loads that reflected their preferred paddling position; all five race scenarios were considered. Seated paddlers were found to transfer 83% of their weight through the rear contact load, whereas kneeling paddlers transferred only 37% of their weight through the same area during straight line paddling. The load cases of vehicular transportation and resting on display stands were also simulated.

Additionally, the shear stresses from the torsional loading of paddlers and water forces during a buoy turn were added to the paddling load scenarios. For this portion of the analysis, the canoe was modeled as a uniform U-channel beam with a continuous height of 14.6 inches and width of 32.8 inches. This allowed all torques to be calculated about the same centroid along the length of the canoe. The force of the water acting on the canoe was estimated by calculating the average angular acceleration of the canoe during turning.

It was determined that a maximum principal stress in an area of tension is 156 psi located in the gunwale, nine feet from the stern of the canoe during the men's endurance race, as seen in Figure 5. The maximum principal stress in a zone of compression was found to be 199 psi was located one foot from the stern along the gunwale in the men's sprint race.

Since both the maximum tensile and compressive stresses were located along the gunwale of the canoe, it was determined that a gunwale cap should be incorporated into the design of *Mesektet*.

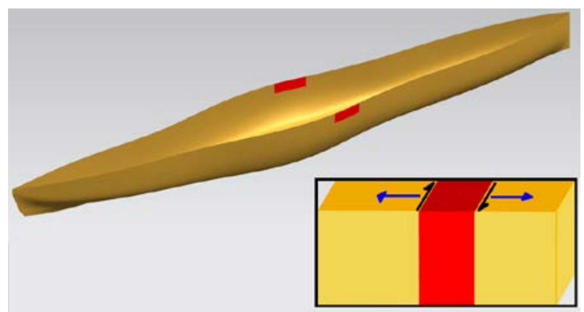


Figure 5: The location of the maximum tensile stress was located nine feet from the stern of the canoe in the men's endurance race.

After the canoe was cast, a more accurate analysis was performed using *Mesektet*'s nominal thickness of 1/2 inch. This calculation yielded maximum stresses at the same locations; however the values of the calculated maximum tensile and compressive stresses were reduced to 118 psi and 136 psi, respectively.

The tensile and compressive strengths of the concrete are 314 psi and 1915 psi, respectively, and thus strong enough to survive the stresses developed through this analysis. However, the team's past experience indicates that reinforcement is still required. With these concerns in mind, the team considered additional testing to determine an appropriate reinforcement scheme.

Development and Testing

The mix design team aimed to design a structural mix with high tensile strength while maintaining a low unit weight. Aesthetics were also a priority, as an all-white mix was needed to complement *Mesektet*'s design. Last year's structural mix, Ballast, was used as a baseline as it met initial criteria of strength, weight, and color. Musa was chosen as the name of the final mix design, which means "on the water" in Arabic. Data comparing this year's mix to previous mixes is shown in Table 4 below.

Due to material constraints, the team began by testing aggregate-to-binder ratio (a/b ratio) using materials from previous years. Ballast had an a/b ratio of 3.5, but after testing it was determined that an a/b ratio of 4.5 better suited the low unit weight goal while still providing adequate strength.

This year, white Portland cement, ground granulated blast furnace slag (GGBFS), VCAS 8, VCAS 160 were all re-examined from last year's mix design. VCAS 8 was omitted due to strength constraints. In order to compensate for a lower a/b ratio, more Portland cement was used to increase early strength.

New sizes of Poraver glass microspheres were obtained this year for testing. Poraver 2.0-4.0 mm spheres proved to be too large for the reinforcement, and the reduction in weight was inadequate to justify the loss in strength. Poraver 0.1-0.3 mm spheres were used in the finishing mix to produce a smoother finish. Other aggregates tested and used were Poraver 1.0-2.0 mm, 0.5-1.0 mm, and 0.25-0.5 mm microspheres, as well as 3M™ K-1, a glass bubble aggregate. Extendospheres SG, a ceramic microsphere, was dismissed due to its dark color.

In past years, a blend of coarse and fine polyvinyl alcohol (PVA) fibers was used as secondary reinforcement. This year, two additional fibers, Forta PE-2, a polyethylene fiber, and GRT Polymesh, a polypropylene fiber, were used in conjunction with the PVA fibers to produce better tensile strength results. This compensated for the loss in strength caused by a higher a/b ratio. Dramix OL13/.20, a steel fiber, was tested, but the increase in tensile strength was not sufficient to compensate for the additional weight. Additionally, the fibers were very difficult to trowel and team members found that they tore through the PPE being used.

In order to be more sustainable, the team tested Pycal-94, an environmentally-friendly water reducer. However, the sustainable benefits did not offset the results of using BASF Glenium® 3030 NS, a high-range water reducer. The team omitted the set retarder that was used in last year's mix, as it was deemed unnecessary for casting day. Xypex Xycrilic admixture was used for ease of troweling and to improve bonding between the concrete and reinforcement.

The final structural mix combined the best qualities of the previously tested batches. Both the finishing and inlay/outlay mixes were adapted incorporating the same binders, but omitting the fibers and utilizing a blend of smaller aggregates. The final water-to-cementitious materials ratio was 0.4. This was higher than last year's mix because more water was required to maintain good workability. The final strength obtained was still adequate based

Table 4: Engineering properties 2010-2013.

Year	Mix Name	Unit Weight (pcf)	14-Day Compressive Strength (psi)	14-Day Tensile Strength (psi)
2010-2011	Kodiak	60.2	1026	389
2011-2012	Ballast	55.4	2112	323
2012-2013	Musa	53.5	1915	314

on analysis results. Final mix components can be seen in Appendix B.

Tensile and compression testing was performed at 7 and 14 days in accordance with ASTM standards. For each batch, six 3 by 6 inch cylinders were cast; four were tested in split tensile, two in uniaxial compression.

The final structural mix is 75% by weight and 71% by volume sustainable materials. Musa's finishing mix is 73% by weight and 62% by volume sustainable materials. The team made an effort to use sustainable materials whenever possible while still meeting the goals set at the beginning of testing.

Although extensive research was done to find a new primary reinforcement material, none found were adequate in both strength and price. Therefore, the team decided on Kevlar® 4009-1, the same material used last year. This material has a percent open area sufficient for the competition at 48%. According to the material technical data sheet, the material has a minimum tensile strength of 530 ksi.

Using the rule of mixtures equation, the team determined the concrete composite tensile strength in three-eighths inch thick concrete to be 976 psi with two layers of reinforcement. These numbers analytically prove that the stress specified by the analysis is attainable by the reinforced concrete. However, the team wanted to ensure the reinforced concrete could live up to its ideal values. A tensile test was conducted, and the composite sample with two layers of Kevlar® reinforcement was determined to have a yield strength of 1180 psi.

A cantilever beam test was created to test the flexural strength of the reinforced concrete as it would be in a gunwale without gunwale caps, as shown in Figure 6. Testing was performed as such: three-eighths inch thick reinforced concrete plates were cut into 2 inch by 12 inch specimens for testing. Weights were applied to the specimens until the first visible crack formed, giving the flexural strength of the composite. Samples with two layers of Kevlar® reinforcement yielded a strength of 1012 psi. In addition, this test showed that the concrete was successfully bonding to the reinforcement.

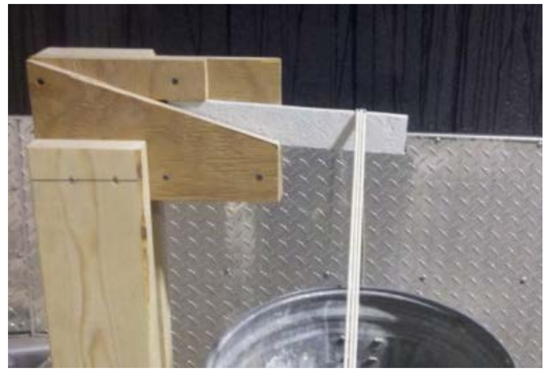


Figure 6: The team designed its own cantilever beam test stand.

Based off of testing completed last year, it was determined that punching shear would not be an issue for *Mesektet*. Two square foot plates were cast, one with one layer of reinforcement and the second with two layers. After curing for 14 days, the plates were individually placed on top of a foam-covered frame. A given force was then applied to each plate to simulate the load distribution of a paddler. The plate with one layer of reinforcement cracked but the plate with two layers of reinforcement was able to withstand the stress without the formation of any visible micro-cracks. This indicated the canoe would need two layers of reinforcement under the paddlers. These tests were conducted with the same Kevlar® reinforcement and concrete which is similar in material properties as Musa, and are thus relative to *Mesektet.*

The low unit weight and adequate tensile strength properties of Musa combined with good primary and secondary reinforcement materials means that *Mesektet* is expected to survive the rigors of competition.

Construction

The construction goals for this year were to trowel *Mesektet* to 5/8 inch and sand it to a nominal thickness of 3/8 inch. A female mold was necessary for this casting process and to capture the complex geometry of the hull.

The team ordered a CNC-milled, female mold made from 10% pre-consumer recycled high-density polystyrene foam. The mold was received in two sections, cut in half along the keel. Two layers of epoxy were applied to each section for the purposes of providing a stiff surface for concrete placement as well as a barrier to prevent water loss through the foam.

After the epoxy set, the sections were put together and fastened by aligning the edges and attaching the mold to a rigid frame. This can be seen in the design drawing located on page 10. Ten minutes prior to casting, Huron Technologies Release Coating 7572 was applied to the mold; manufacturer specifications state that the release agent is designed for use between concrete and epoxy surfaces for an aesthetically-appealing result.

On casting day, the team was divided into specific assignments: trowelers to construct the canoe, each assigned a quality control (QC) partner to ensure proper thickness; reinforcement team members to guarantee proper placement of the reinforcement; and mix crew workers to make sure the concrete was consistent throughout the day. Figure 7 shows the relationship between trowelers and QC members. Due to the team's facilities having separate areas for the mix and troweling groups, the team captain served as a runner between the two to encourage communication and consistency throughout the day.

Team members assigned to QC used premeasured depth gauges to determine the thickness of the canoe throughout its construction. The team has had problems with QC in the past, and a new style of depth gauge was created this year. The new gauges were color coded, rather than labeled with a piece of tape. Figure 8 shows the depth gauges used for this year: color-coded plastic with metal pins 1/8 inch to 5/8 inch long. The team hoped that the smaller width of gauge would be able to penetrate the small open space of the Kevlar reinforcement, but difficulties were still experienced on casting day.

Figure 7: A troweler and QC member working together to ensure proper thickness.

This year, to save time with the finishing process, the team planned to trowel two layers of finishing mix on casting day in addition to the three layers of structural mix. Reinforcement would be placed between the layers of structural mix as usual. However, the team experienced major problems with sloughing while troweling the first layer of structural mix (the second layer of concrete overall) and removed all mix that had been placed. The team began to cast the canoe a second time after the mold release had been reapplied and allowed to dry.

Figure 8: Depth gauges were color-coded for each layer of placed concrete.

Mesektet was cast with three layers of structural concrete and two layers of Kevlar reinforcement. After last year's success of casting a gunwale cap with a female mold, the team decided to use the same process this year.

Extruded polystyrene foam was used as a placement guide for the gunwale caps on casting day. One layer of epoxy and one layer of release aid were applied to the polystyrene form. This prevented the concrete from sticking while still allowing the foam to shape to the curves of the gunwale. During casting day, these forms were clamped to the exterior of the mold, as seen in Figure 9.

Figure 9: Clamps were used to hold the gunwale caps in place while curing.

Concrete was placed by hand in the gunwale caps after the main body of the canoe was completed. The continuous layer of reinforcement in the wall was folded into the gunwale cap form. A second layer of concrete was placed, and the end of the reinforcement layer was again folded on top of the concrete. Finally, a third layer of concrete was placed flush with the top of the mold.

According to analysis and previous years' experience, the team was able to determine that additional side-wall reinforcement would be unnecessary. One continuous layer of reinforcement throughout the entire canoe would account for any unforeseen stresses, while a second layer along the bottom was required to resist punching shear.

The final thickness of the canoe was measured to be 1/2 inch, which was over the goal of 3/8 inch. In order to prevent this from happening again, a new QC system is being developed that should eliminate the error caused by the current method of depth gauges.

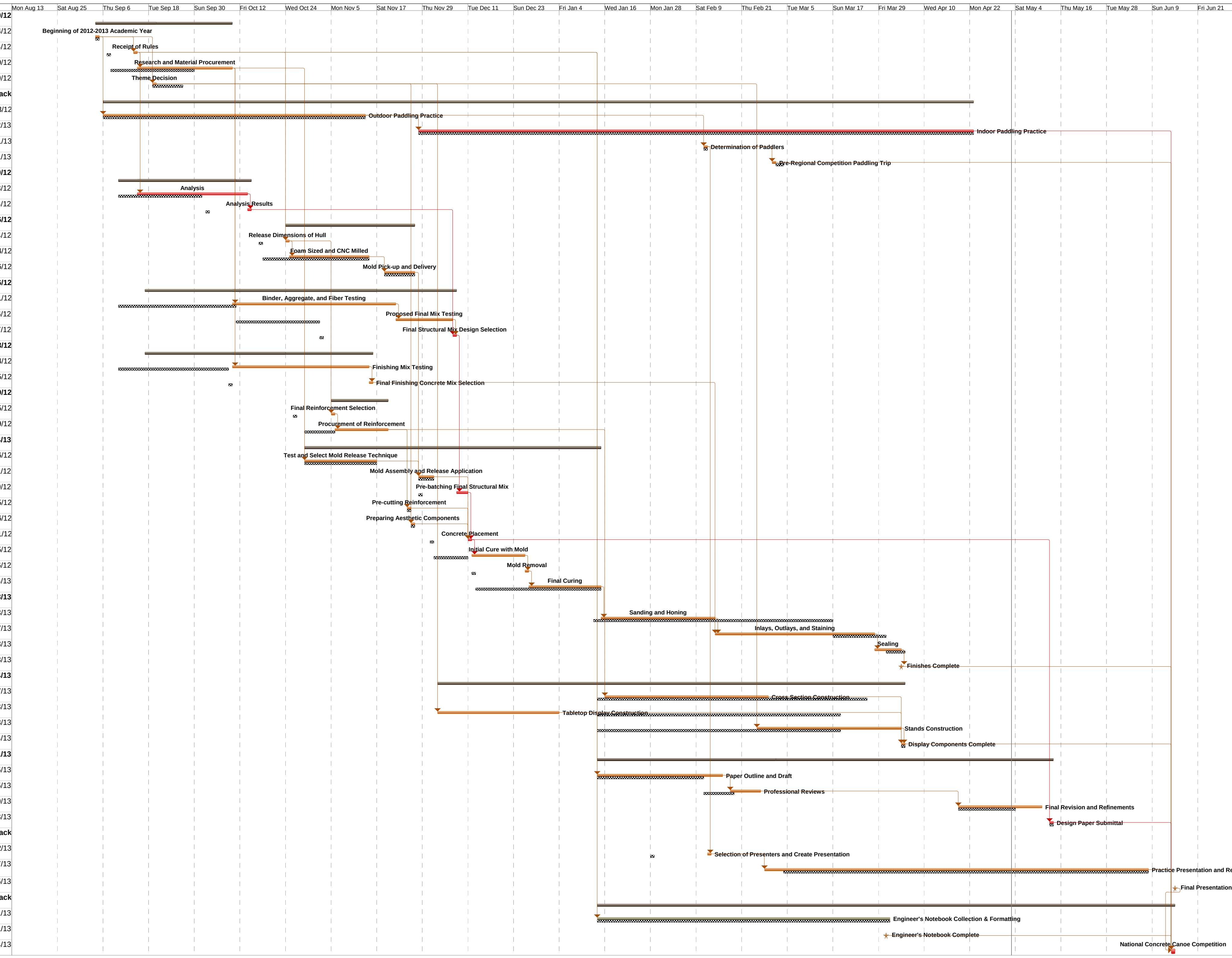
Sanding began after one week of ambient curing while the canoe was still in the mold. A combination of sanding and finishing continued for five more weeks. The mold was removed with ease after two weeks of curing, which then allowed the canoe to be flipped as needed to continue the finishing and staining process.
This year, an improved air filtration system was used while team members were sanding the boat. Less dust was in the air as a result, improving the safety of the process.

The team also was able to utilize the air compressor in the facilities for use with airbrush staining. This not only saved money, but eliminating the usage of aerosol cans makes the process much more sustainable. After staining is completed, two layers of ChemMasters Crystal Clear-A were applied and allowed to set for one week prior to the regional competition.

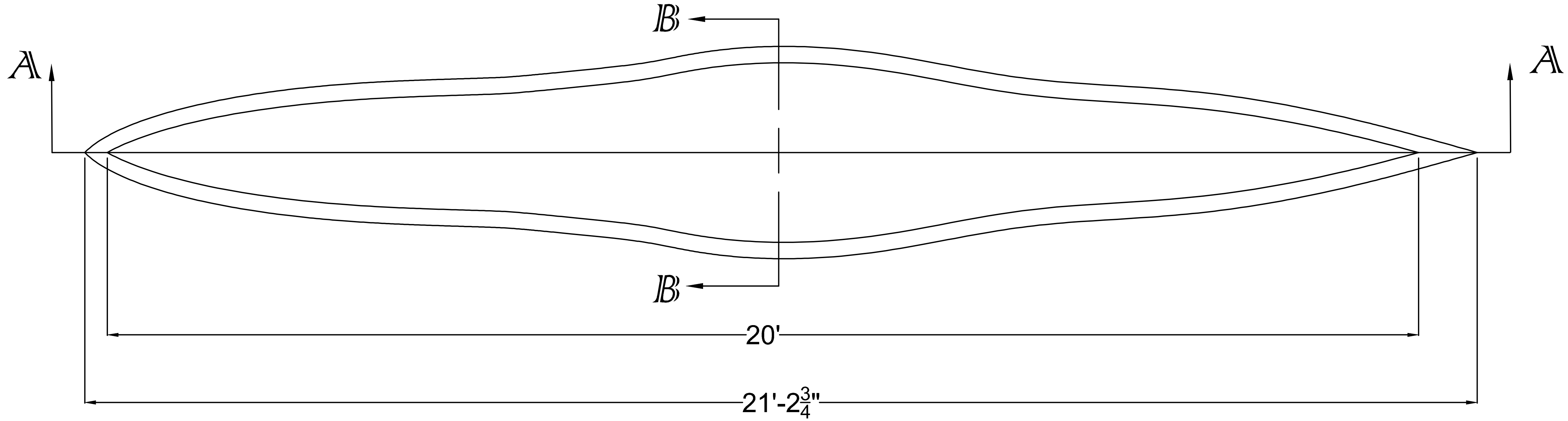
Concrete that was removed from the canoe was cast into decorative bricks to eliminate waste. The water recycling process that the team implemented last year is still in use. It was tested per ASTM standards to determine whether it was usable for concrete mixing, but failed. Research is being done to improve the process to produce higher quality water.

Mesektet's hull design is by far the most innovative design that Michigan Tech has ever produced. The team is excited to show off all that it has learned this year and hopes that *Mesektet* is worthy to catch the eye of Ra.

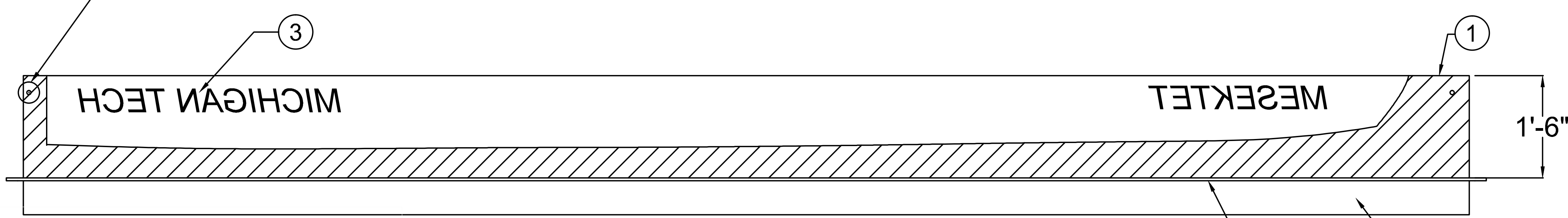
ID	Task Name	Baseline Start	Baseline Finish	Start	Finish
1	**Notice to Proceed**	**Tue 9/4/12**	**Sat 9/29/12**	**Tue 9/4/12**	**Wed 9/19/12**
2	Beginning of 2012-2013 Academic Year	Tue 9/4/12	Tue 9/4/12	Tue 9/4/12	Tue 9/4/12
3	Receipt of Rules	Fri 9/7/12	Fri 9/7/12	Fri 9/14/12	Fri 9/14/12
4	Research and Material Procurement	Sat 9/8/12	Sat 9/29/12	Sat 9/15/12	Tue 10/9/12
5	Theme Decision	Wed 9/19/12	Wed 9/26/12	Wed 9/19/12	Wed 9/19/12
6	**Physical Conditioning**	**Thu 9/6/12**	**Sun 3/3/13**	**Thu 9/6/12**	**On Track**
7	Outdoor Paddling Practice	Thu 9/6/12	Tue 11/13/12	Thu 9/6/12	Tue 11/13/12
8	Indoor Paddling Practice	Wed 11/28/12	Mon 4/22/13	Wed 11/28/12	Mon 4/22/13
9	Determination of Paddlers	Mon 2/11/13	Mon 2/11/13	Mon 2/11/13	Mon 2/11/13
10	Pre-Regional Competition Paddling Trip	Sat 3/2/13	Sun 3/3/13	Fri 3/1/13	Fri 3/1/13
11	**Analysis**	**Mon 9/10/12**	**Wed 10/3/12**	**Mon 9/10/12**	**Wed 10/10/12**
12	Analysis	Mon 9/10/12	Mon 10/1/12	Sat 9/15/12	Sat 10/13/12
13	Analysis Results	Wed 10/3/12	Wed 10/3/12	Sun 10/14/12	Sun 10/14/12
14	**Mold Fabrication**	**Wed 10/17/12**	**Mon 11/26/12**	**Wed 10/24/12**	**Mon 11/26/12**
15	Release Dimensions of Hull	Wed 10/17/12	Wed 10/17/12	Wed 10/24/12	Wed 10/24/12
16	Foam Sized and CNC Milled	Thu 10/18/12	Wed 11/14/12	Thu 10/25/12	Wed 11/14/12
17	Mold Pick-up and Delivery	Mon 11/19/12	Mon 11/26/12	Mon 11/19/12	Mon 11/26/12
18	**Structural Concrete Mix Design**	**Mon 9/10/12**	**Fri 11/2/12**	**Mon 9/17/12**	**Fri 11/16/12**
19	Binder, Aggregate, and Fiber Testing	Mon 9/10/12	Wed 10/10/12	Wed 10/10/12	Wed 11/21/12
20	Proposed Final Mix Testing	Thu 10/11/12	Thu 11/1/12	Thu 11/22/12	Thu 12/6/12
21	Final Structural Mix Design Selection	Fri 11/2/12	Fri 11/2/12	Fri 12/7/12	Fri 12/7/12
22	**Finishing Concrete Mix Design**	**Mon 9/10/12**	**Tue 10/9/12**	**Mon 9/17/12**	**Tue 10/23/12**
23	Finishing Mix Testing	Mon 9/10/12	Mon 10/8/12	Wed 10/10/12	Wed 11/14/12
24	Final Finishing Concrete Mix Selection	Tue 10/9/12	Tue 10/9/12	Thu 11/15/12	Thu 11/15/12
25	**Reinforcement**	**Fri 10/26/12**	**Mon 11/5/12**	**Mon 11/5/12**	**Mon 11/19/12**
26	Final Reinforcement Selection	Fri 10/26/12	Fri 10/26/12	Mon 11/5/12	Mon 11/5/12
27	Procurement of Reinforcement	Mon 10/29/12	Mon 11/5/12	Tue 11/6/12	Mon 11/19/12
28	**Construction and Casting**	**Mon 10/29/12**	**Sat 12/1/12**	**Mon 10/29/12**	**Mon 1/14/13**
29	Test and Select Mold Release Technique	Mon 10/29/12	Fri 11/16/12	Mon 10/29/12	Fri 11/16/12
30	Mold Assembly and Release Application	Wed 11/28/12	Sat 12/1/12	Wed 11/28/12	Sat 12/1/12
31	Pre-batching Final Structural Mix	Wed 11/28/12	Wed 11/28/12	Sat 12/8/12	Mon 12/10/12
32	Pre-cutting Reinforcement	Sun 11/25/12	Sun 11/25/12	Sun 11/25/12	Sun 11/25/12
33	Preparing Aesthetic Components	Mon 11/26/12	Mon 11/26/12	Mon 11/26/12	Mon 11/26/12
34	Concrete Placement	Sat 12/1/12	Sat 12/1/12	Tue 12/11/12	Tue 12/11/12
35	Initial Cure with Mold	Sun 12/2/12	Mon 12/10/12	Wed 12/12/12	Tue 12/25/12
36	Mold Removal	Wed 12/12/12	Wed 12/12/12	Wed 12/26/12	Wed 12/26/12
37	Final Curing	Thu 12/13/12	Mon 1/14/13	Thu 12/27/12	Mon 1/14/13
38	**Finishes and Aesthetics**	**Sun 1/13/13**	**Thu 4/4/13**	**Sun 1/13/13**	**Wed 4/3/13**
39	Sanding and Honing	Sun 1/13/13	Sat 3/16/13	Tue 1/15/13	Wed 2/13/13
40	Inlays, Outlays, and Staining	Sun 3/17/13	Sat 3/30/13	Thu 2/14/13	Wed 3/27/13
41	Sealing	Sun 3/31/13	Thu 4/4/13	Thu 3/28/13	Wed 4/3/13
42	Finishes Complete	Thu 4/4/13	Thu 4/4/13	Wed 4/3/13	Wed 4/3/13
43	**Product Display**	**Mon 1/14/13**	**Mon 3/25/13**	**Mon 12/3/12**	**Thu 4/4/13**
44	Cross Section Construction	Mon 1/14/13	Mon 3/25/13	Wed 1/16/13	Wed 2/27/13
45	Tabletop Display Construction	Mon 1/14/13	Mon 3/18/13	Mon 12/3/12	Thu 1/3/13
46	Stands Construction	Mon 1/14/13	Mon 3/18/13	Mon 2/25/13	Wed 4/3/13
47	Display Components Complete	Thu 4/4/13	Thu 4/4/13	Thu 4/4/13	Thu 4/4/13
48	**Design Paper**	**Mon 1/14/13**	**Fri 3/1/13**	**Mon 1/14/13**	**Fri 3/1/13**
49	Paper Outline and Draft	Mon 1/14/13	Sun 2/10/13	Mon 1/14/13	Fri 2/15/13
50	Professional Reviews	Mon 2/11/13	Mon 2/18/13	Mon 2/18/13	Mon 2/25/13
51	Final Revision and Refinements	Fri 4/19/13	Fri 5/3/13	Fri 4/19/13	Fri 5/10/13
52	Design Paper Submittal	Mon 5/13/13	Mon 5/13/13	Mon 5/13/13	Mon 5/13/13
53	**Presentation**	**Mon 1/28/13**	**Thu 4/4/13**	**Mon 2/4/13**	**On Track**
54	Selection of Presenters and Create Presentation	Mon 1/28/13	Mon 1/28/13	Tue 2/12/13	Tue 2/12/13
55	Practice Presentation and Review Possible Questions	Mon 3/4/13	Fri 6/7/13	Wed 2/27/13	Fri 6/7/13
56	Final Presentation	Sat 6/15/13	Sat 6/15/13	Sat 6/15/13	Sat 6/15/13
57	**Competition**	**Mon 1/14/13**	**Sat 4/6/13**	**Mon 1/14/13**	**On Track**
58	Engineer's Notebook Collection & Formatting	Mon 1/14/13	Sun 3/31/13	Mon 1/14/13	Sun 3/31/13
59	Engineer's Notebook Complete	Sun 3/31/13	Sun 3/31/13	Sun 3/31/13	Sun 3/31/13
60	National Concrete Canoe Competition	Fri 6/14/13	Fri 6/14/13	Fri 6/14/13	Fri 6/14/13



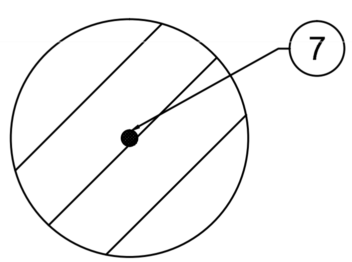
Task · Critical · Baseline · Milestone · Summary · Inactive Task · Inactive Milestone · Inactive Summary · Manual Task · Duration-only · Manual Summary Rollup · Manual Summary · Start-only · Finish-only



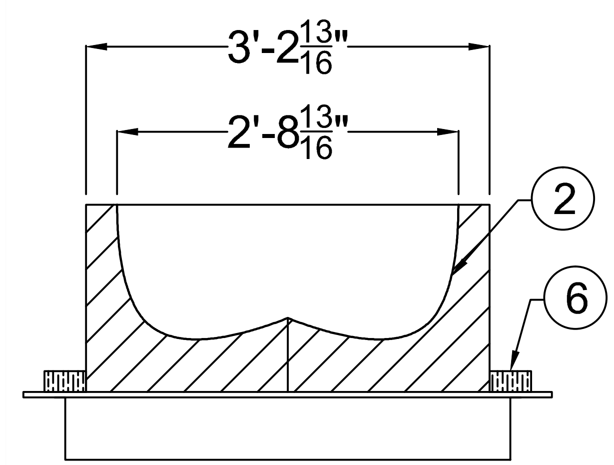
DETAIL 'C'



SECTION A-A



DETAIL 'C'
SCALE 4:1



SECTION B-B
SCALE 2:1

BILL OF MATERIALS		
NO.	DESCRIPTION	QTY.
1	POLYSTYRENE FOAM MOLD	2 PIECES
2	EPOXY	1 GALLON
3	FOAM INLAYS	83 SQ IN
4	1/2" OSB	24 SQ FT
5	2"X6" LUMBER	56 LN FT
6	2"X4" LUMBER	4 LN FT
7	3/8" X 8" BOLT ASSEMBLY	2 EA.

MichiganTech

MICHIGAN TECHNOLOGICAL UNIVERSITY
CONCRETE CANOE
1400 TOWNSEND DRIVE
HOUGHTON, MI 49931

DRAWING NAME: CANOE MOLD DESIGN	DATE: 2/21/2013
BOAT NAME: MESEKTET	SCALE: 1:30
DRAWN BY: PHILIP DOEDERLEIN	
CHECKED BY: BRADLEY JOHNSON	SHEET: 10

Appendix A – References

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Appendix B – Mixture Proportions

				Design Proportions (Non SSD)		Actual Batched Proportions		Yielded Proportions	
Mixture: Musa - Structural									
Y_D	Design Batch Size (ft³):	0.087							
Cementitious Materials			SG	Amount (lb/yd³)	Volume (ft³)	Amount (lb)	Volume (ft³)	Amount (lb/yd³)	Volume (ft³)
CM1	Federal White Type I Portland Cement		3.15	351.33	1.787	1.14	0.006	344.41	1.751
CM2	Lafarge NewCem® GGBFS		2.99	148.22	0.794	0.48	0.003	145.29	0.778
CM4	VCAS™ 160		2.60	225.55	1.390	0.73	0.004	221.10	1.362
	Total Cementitious Materials:			**725.10**	**3.970**	**2.35**	**0.013**	**710.80**	**3.892**
Fibers									
F1	PVA Fine		1.30	8.52	0.105	0.03	0.000	8.35	0.103
F2	PVA Coarse		1.30	3.41	0.042	0.01	0.000	3.34	0.041
F6	Forta PE-2		0.91	2.56	0.045	0.01	0.000	2.51	0.044
F7	GRT Polymesh		0.91	2.56	0.045	0.01	0.000	2.51	0.044
	Total Fibers:			**17.04**	**0.237**	**0.06**	**0.001**	**16.70**	**0.232**
Aggregates									
A1	Poraver 1.0-2.0 mm	Abs: 20.0	0.39	130.49	5.360	0.42	0.017	127.92	5.254
A2	Poraver 0.5-1.0 mm	Abs: 25.0	0.47	157.26	5.360	0.51	0.017	154.16	5.254
A3	Poraver 0.25-0.5 mm	Abs: 30.0	0.59	65.81	1.787	0.21	0.006	64.51	1.751
A4	3M™ K-1	Abs: 22.0	0.13	43.50	5.360	0.14	0.017	42.64	5.254
	Total Aggregates:			**397.06**	**17.865**	**1.28**	**0.058**	**389.23**	**17.513**
Water									
W1	Water for CM Hydration (W1a+W1b)			290.04	4.646	0.94	0.015	284.32	4.554
	W1a. Water from Admixtures		1.00	50.67		0.23		48.69	
	W1b. Additional Water			239.37		0.71		235.63	
W2	Water for Aggregates, SSD		1.00	94.73		0.31		92.86	
	Total Water (W1 + W2):			**384.76**	**4.65**	**1.24**	**0.015**	**377.18**	**4.554**
Solids Content of Latex Admixtures and Dyes									
S1	Xypex Xycrilic - Admix		1.05	18.44	0.281	0.06	0.001	18.08	0.276
	Total Solids of Admixtures:			**18.44**	**0.281**	**0.06**	**0.001**	**18.08**	**0.276**
Admixtures (including Pigments in Liquid Form)			% Solids	Dosage (fl oz/ cwt)	Water in Admixture (lb/yd³)	Amount (fl oz)	Water in Admixture (lb)	Dosage (fl oz/ cwt)	Water in Admixture (lb/yd³)
Ad1	Xypex Xycrilic - Admix	8.76 lb/gal	28.02	132.64	47.379	3.11	0.213	130.0	45.53
Ad2	BASF Glenium® 3030NS	9.18 lb/gal	20.27	7.93	3.288	0.19	0.013	7.8	3.16
	Water from Admixtures (W1a):				**50.667**		**0.226**		**48.69**
Cement-Cementitious Materials Ratio				0.485		0.485		0.485	
Water-Cementitious Materials Ratio				0.400		0.400		0.400	
Slump, Slump Flow, in.				1.00±0.50		0.50		0.50	
M	Mass of Concrete, *lbs*			1542.41		4.99		1512.00	
V	Absolute Volume of Concrete, *ft³*			27.000		0.087		26.467	
T	Theoretical Density, *lb/ft³*	= (M/V)		57.13		57.13		57.13	
D	Design Density, *lb/ft³*	= (M/27)		57.13					
D	Measured Density, *lb/ft³*					56.0		56.0	
A	Air Content, %	= [(T-D)/T x 100%]		0.00		1.97		1.97	
Y	Yield, ft³	= (M/D)		27.00		0.089		27.00	
R_y	Relative Yield	= (Y/YD)				1.020			

	Mixture: Musa - Finishing			Design Proportions (Non SSD)		Actual Batched Proportions		Yielded Proportions	
Y_D	Design Batch Size (ft³):	0.092							
Cementitious Materials			SG	Amount (lb/yd³)	Volume (ft³)	Amount (lb)	Volume (ft³)	Amount (lb/yd³)	Volume (ft³)
CM1	Federal White Type I Portland Cement		3.15	457.56	2.327	1.56	0.008	387.79	1.972
CM2	Lafarge NewCem® GGBFS		2.99	193.03	1.034	0.66	0.004	163.60	0.876
CM3	VCAS™ 160		2.60	293.74	1.810	1.00	0.006	248.95	1.534
	Total Cementitious Materials:			**944.34**	**5.171**	**3.22**	**0.018**	**800.33**	**4.382**
Aggregates									
A1	Poraver 0.25 - 0.5 mm	Abs: 30.0	0.59	114.27	3.102	0.39	0.011	96.84	2.629
A2	3M™ K-1	Abs: 22.0	0.13	62.94	7.756	0.21	0.026	53.35	6.573
A3	Poraver 0.1 - 0.3 mm	Abs: 35.0	0.90	261.46	4.654	0.89	0.016	221.59	3.944
	Total Aggregates:			**438.68**	**15.512**	**1.50**	**0.053**	**371.78**	**13.147**
Water									
W1	Water for CM Hydration (W1a+W1b)		1.00	377.73	6.051	1.29	0.021	320.13	5.128
	W1a. Water from Admixtures			47.99		0.16		40.67	
	W1b. Additional Water			329.74		1.13		279.46	
W2	Water for Aggregates, SSD		1.00	139.64		0.48		118.35	
	Total Water (W1 + W2):			**517.38**	**6.051**	**1.77**	**0.021**	**438.48**	**5.128**
Solids Content of Latex Admixtures and Dyes									
S1	Xypex Xycrilic - Admix		1.05	17.47	0.267	0.06	0.001	14.81	0.226
	Total Solids of Admixtures:			**17.47**	**0.267**	**0.06**	**0.001**	**14.81**	**0.226**
Admixtures (including Pigments in Liquid Form)			% Solids	Dosage (fl oz/ cwt)	Water in Admixture (lb/yd³)	Amount (fl oz)	Water in Admixture (lb)	Dosage (fl oz/ cwt)	Water in Admixture (lb/yd³)
Ad1	Xypex Xycrilic - Admix	8.76 lb/gal	28.02	96.47	44.876	3.11	0.153	81.76	38.033
Ad2	BASF Glenium® 3030 NS	9.18 lb/gal	20.27	5.77	3.114	0.19	0.011	4.89	2.639
	Water from Admixtures (W1a):				**47.990**		**0.164**		**40.672**
	Cement-Cementitious Materials Ratio			0.485		0.485		0.485	
	Water-Cementitious Materials Ratio			0.400		0.400		0.400	
	Slump, Slump Flow, in.			1.00±0.50		1.50		1.50	
M	Mass of Concrete, *lbs*			1917.86		6.55		1625.40	
V	Absolute Volume of Concrete, *ft³*			27.000		0.092		22.883	
T	Theoretical Density, *lb/ft³*	= (M/V)		71.03		71.03		71.03	
D	Design Density, *lb/ft³*	= (M/27)		71.03					
D	Measured Density, *lb/ft³*					60.2		60.2	
A	Air Content, %	= [(T-D)/T x 100%]		0.00		15.25		15.25	
Y	Yield, ft³	= (M/D)		27.00		0.109		27.00	
R_y	Relative Yield	= (Y/YD)				1.180			

	Mixture: Musa - Inlay / Outlay			Design Proportions (Non SSD)		Actual Batched Proportions		Yielded Proportions	
Y_D	Design Batch Size (ft^3):	0.093							
Cementitious Materials			SG	Amount (lb/yd^3)	Volume (ft^3)	Amount (lb)	Volume (ft^3)	Amount (lb/yd^3)	Volume (ft^3)
CM1	Federal White Type I Portland Cement		3.15	454.41	2.311	1.56	0.008	436.47	2.220
CM2	Lafarge NewCem® GGBFS		2.99	191.70	1.027	0.66	0.004	184.13	0.986
CM3	VCAS™ 160		2.60	291.72	1.797	1.00	0.006	280.20	1.726
	Total Cementitious Materials:			**937.84**	**5.135**	**3.22**	**0.018**	**900.81**	**4.932**
Aggregates									
A1	Poraver 0.25 - 0.5 mm	Abs: 30.0	0.59	113.48	3.081	0.39	0.011	109.00	2.959
A2	3M™ K-1	Abs: 22.0	0.13	62.51	7.703	0.21	0.026	60.04	7.399
A3	Poraver 0.1 - 0.3 mm	Abs: 35.0	0.90	259.66	4.622	0.89	0.016	249.41	4.439
	Total Aggregates:			**435.66**	**15.405**	**1.50**	**0.053**	**418.46**	**14.797**
Water									
W1	Water for CM Hydration (W1a+W1b)		1.00	375.14	6.009	1.29	0.021	360.32	5.772
	W1a. Water from Admixtures			61.40		0.21		58.97	
	W1b. Additional Water			313.74		1.08		301.35	
W2	Water for Aggregates, SSD		1.00	138.68		0.48		133.20	
	Total Water (W1 + W2):			**513.82**	**6.009**	**1.77**	**0.021**	**493.53**	**5.772**
Solids Content of Latex Admixtures and Dyes									
S1	Xypex Xycrilic - Admix		1.05	17.35	0.265	0.06	0.001	16.66	0.254
S2	Quikrete Cement Color - Charcoal		1.8	20.86	0.186	0.07	0.001	20.04	0.178
	Total Solids of Admixtures:			**38.21**	**0.450**	**0.13**	**0.002**	**36.70**	**0.433**
Admixtures (including Pigments in Liquid Form)			% Solids	Dosage (fl oz/ cwt)	Water in Admixture (lb/yd^3)	Amount (fl oz)	Water in Admixture (lb)	Dosage (fl oz/ cwt)	Water in Admixture (lb/yd^3)
Ad1	Xypex Xycrilic - Admix	8.76 lb/gal	28.02	96.47	44.567	3.11	0.153	92.66	42.807
Ad2	BASF Glenium® 3030 NS	9.18 lb/gal	20.27	5.77	3.093	0.19	0.011	5.54	2.971
Ad3	Quikrete Cement Color - Charcoal	15.01 lb/gal	60.30	31.46	13.736	1.01	0.047	30.21	13.194
	Water from Admixtures (W1a):				**61.396**		**0.211**		**58.972**
	Cement-Cementitious Materials Ratio			0.485		0.485		0.485	
	Water-Cementitious Materials Ratio			0.400		0.400		0.400	
	Slump, Slump Flow, in.			1.00±0.50		0.50		0.50	
M	Mass of Concrete, *lbs*			1925.53		6.62		1849.50	
V	Absolute Volume of Concrete, *ft^3*			27.000		0.093		25.934	
T	Theoretical Density, *lb/ft^3*	= (M/V)		71.32		71.32		71.32	
D	Design Density, *lb/ft^3*	= (M/27)		71.32					
D	Measured Density, *lb/ft^3*					68.5		68.5	
A	Air Content, %	= [(T-D)/T x 100%]		0.00		3.95		3.95	
Y	Yield, ft^3	= (M/D)		27.00		0.097		27.00	
R_y	Relative Yield	= (Y/YD)				1.041			

Appendix C – Bill of Materials

Material	Units	Quantity	Unit Price	Total
Federal White Type I White Portland Cement	lb	80.82	$0.27	$21.82
Lafarge NewCem® GGBFS	lb	34.08	$0.05	$1.70
VCAS™ 160	lb	51.77	$0.35	$18.12
Poraver® 1.0-2.0mm	lb	20.58	$0.85	$17.49
Poraver® 0.5-1.0mm	lb	24.99	$0.85	$21.24
Poraver® 0.25-0.5mm	lb	16.53	$0.85	$14.05
Poraver® 0.1-0.3mm	lb	14.24	$0.85	$12.10
3M™ K-1	lb	10.22	$11.03	$112.73
Nycon Kuralon™ RECS15 (8mm) PVA	lb	1.47	$6.60	$9.70
Nycon Kuralon™ RF4000 (30mm) PVA	lb	0.49	$6.90	$3.38
FORTA® PE-2®	lb	0.49	$5.60	$2.74
GRT Polymesh™	lb	0.49	$5.75	$2.82
Xypex Xycrylic-Admix	gal	1.58	$5.10	$8.05
BASF Glenium® 3030 NS	gal	0.10	$15.00	$1.45
Textile Products Kevlar® 4009-1	sq ft.	88.00	$7.69	$676.72
Butterfield Color Elements™ Transparent Concrete Stain - Yellow	oz	4.00	$1.85	$7.39
Butterfield Color Elements™ Transparent Concrete Stain - Red	oz	4.00	$1.85	$7.39
Butterfield Color Elements™ Transparent Concrete Stain - Blue	oz	4.00	$1.85	$7.39
Butterfield Color Elements™ Transparent Concrete Stain - Black	oz	4.00	$1.85	$7.39
Butterfield Color Elements™ Transparent Concrete Stain - Purple	oz	4.00	$1.85	$7.39
Butterfield Color Elements™ Transparent Concrete Stain - Verdigris	oz	4.00	$1.85	$7.39
Butterfield Color Elements™ Transparent Concrete Stain - Tannin	oz	4.00	$1.85	$7.39
Butterfield Color Elements™ Transparent Concrete Stain - Caribbean	oz	4.00	$1.85	$7.39
Butterfield Color Elements™ Transparent Concrete Stain - Cordovan Leather	oz	4.00	$1.85	$7.39
Butterfield Color Elements™ Transparent Concrete Stain - Gray	oz	4.00	$1.85	$7.39
Quikrete Liquid Cement Color - Charcoal	oz	2.00	$0.70	$1.40
Huron Technologies Release Coating 7572	gal	1.00	$22.50	$22.50
ChemMasters Crystal Clear - A	gal	1.00	$22.00	$22.00
10% Post-Consumer Recycled Foam Mold	LS	1	$1,702.02	$1,702.02
Canoe Finishing	LS	1	$112.00	$112.00
Design Stencil	LS	1	$50.00	$50.00
			Total Production Cost	**$2,913.55**