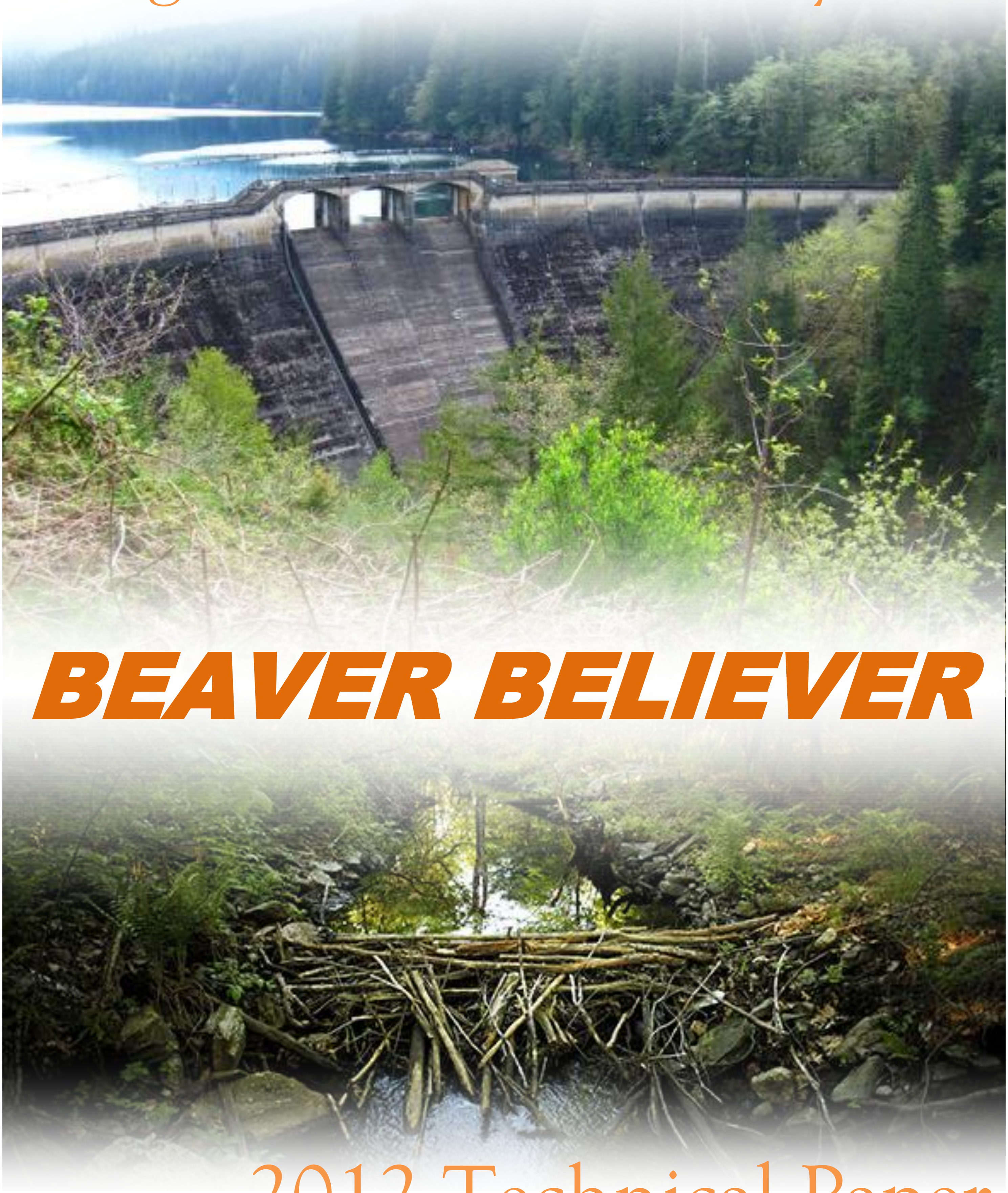
Oregon State University



BEAVER BELIEVER

2012 Technical Paper

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EXECUTIVE SUMMARY

Oregon first gained international renown for its prime supply of fur, especially from beavers. As such, the beaver was adopted as the state symbol, and may be found on the reverse side of any Oregon state flag. Now the beaver has become valued for its symbolism of intelligence, perseverance, and resourcefulness. Beavers work hard to create the ideal home, even going so far as to create dams to transform the environment they live in. Not only is the beaver used as the mascot for Oregon State University, "Beaver Believer" is also the nickname for a university supporter. This term has resonated with the Oregon State Concrete Canoe Team (OSCCT) and led to the creation of the 2012 canoe: ***BEAVER BELIEVER***.

Table 1: Concrete Properties	
Unit Weight (Plastic)	61.8 pcf
Tensile Strength	130 psi
Compression Strength	1240 psi
FibaTape Reinforcement	46.8% POA
Hardwire Reinforcement	40.0% POA

Oregon State University lies within a day's drive of deserts, mountains, forests, plains, wetlands, and coasts. As a result, Oregon State University is the only public university afforded the federal land, sea, space, and sun grants. These grants have funded 234 inventions from the College of Engineering since its creation in 1889. The School of Civil and Construction Engineering was formed in 1905, and has continued to be a strong competitor in the Pacific Northwest region of the National Concrete Canoe Competition. We placed as high as second in 1996 at the Pacific Northwest Regional Conference. In both 2006 and 2011, the OSCCT placed third in the Pacific Northwest. Last year the OSCCT gained overwhelming victories in all of the Pacific Northwest canoe races with the *Dam Fast* canoe.

This year the OSCCT renewed its focus for the 2012 Pacific Northwest Regional Concrete Canoe Competition in Seattle, Washington. The team made improvements in structural analysis and project management while building and maintaining an exemplary paddling team. The OSCCT of 2012 has also developed an innovative project management structure with two co-captains, which has improved performance and communications. We have incorporated an in-depth structural analysis. The addition of a recruiting chair has led to the addition of five new members, who comprise a third of the overall team. These members will offer their experience again next year providing a sustainable team structure.

Table 2: Specifications	
Estimated Weight	*475 lbs*
Length	20.0 ft
Depth	14.0 in
Width	31.5 in
Average Thickness	1.50 in
Main Color	Burnt Orange
Decal Color	Black

Canoe hull and mold design as well as mixture design were improved from *Dam Fast*. Tables 1 and 2 provide specific information regarding the concrete properties, including reinforcement percent open area (POA), and specifications surrounding ***BEAVER BELIEVER***. Innovative ideas surrounding this year's canoe included using wider cedar strips on the top of the sides of the mold to increase mold construction efficiency, and more mold release was applied to ease demolding. ***BEAVER BELIEVER*** continues to use lettering inlaid and filled with differently colored concrete. Sustainable materials have also continued to be used in the mixture design. These materials include fly ash, Elemix, and 3M Microspheres. The OSCCT has continued to focus on creating a foundation for next year's team. The 2012 ***BEAVER BELIEVER*** is the culmination of increasing excellence, and reflects our confidence in ourselves.

HULL DESIGN

The final hull design of ***BEAVER BELIEVER*** carried out the innovative construction strategy planned since 2011, and resulted in an almost identical hull design to *Dam Fast*. The mold from *Dam Fast* was deliberately constructed for reuse as an innovation to reduce construction time and improve sustainability. New cedar strips lined the existing cross sections to form the outside of the hull. OSCCT determined that since the rocker, chine, and shape were all derived from the required cross-sections for the 2011 ASCE National Concrete Canoe Competition, it was acceptable to reuse the existing hull design. All applicable dimensions to the cross sections are indicated in the design drawing on page 11 of the report.

The designed thickness for the canoe was one inch; however, the actual average thickness of ***BEAVER BELIEVER*** is one and a half inches due to concrete placement issues described in the construction section of this report. Figure 1 depicts the several stages of shaping the hull. Coordinates calculated from the mold design were used to model the canoe in AutoCAD Civil - 3D, as shown in Figure 2.

FIGURE 1: Hull Construction Stages

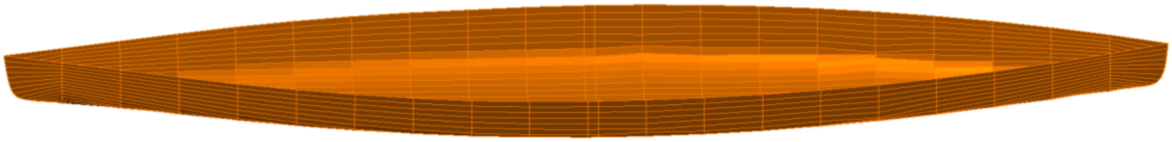


FIGURE 2: AutoCAD Model of Hull Design

STRUCTURAL ANALYSIS

Analysis was conducted with a Finite Element Model (FEM) using AutoCAD Civil 3D to generate the geometry and SAP2000v.14® for the analysis By modeling the canoe in AutoCAD Civil 3D the FEM provided an accurate estimate of surface area, as opposed to the simplified method used for *Dam Fast*. Volume was calculated using an average one and a half inch thickness. Increased detail in the FEM due to 3D modeling in AutoCAD also improved the accuracy of the loadings and stresses within the canoe.

FEM material section properties were estimated based upon the unique properties of the lightweight mixture design. The modulus of elasticity was first approximated through a simplified overestimate based on an from Carrasquillo et al. (1981) as 670 ksi, and then as 565 ksi for normal weight concrete using ACI 318 (2011). Modulus of elasticity used in the analysis was then determined from its relation to unit weight in aerated concrete as 519 ksi (Narayanan and Ramamurthy 2000). Poisson's ratio was approximated as 0.18 based upon general recommendation for concrete (Wight and MacGregor 2011).

Two loading cases were analyzed based upon the Pacific Northwest Concrete Canoe Competition races, one with two paddlers and one with four paddlers. Paddler effects were modeled as restraints assigned to the approximate areas of the positioned paddlers. Locations of the paddlers were based on photos of positioning from *Dam Fast*, due to the shared hull design. The buoyancy of the canoe was approximated from the photo documentation of water height relative to the sides of *Dam Fast*. For all loading cases of **BEAVER BELIEVER**, it was assumed that the water level remained approximately halfway up its sides. This surface area was then assigned vertical surface pressures in the FEM, to account for buoyancy effects. **BEAVER BELIEVER** will be fully supported in its mold during transport. Therefore, the support conditions for the transport system were not analyzed.

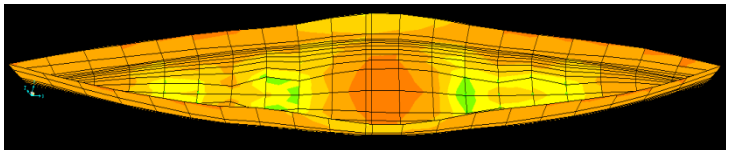


FIGURE 3: Maximum Stresses with 4 Paddlers

The magnitude of the surface pressure was iteratively assigned until the reactions yielded the calculated total weight. The total weight was the sum of the weight of the canoe and 180 pounds per paddler.

Once the surface pressure loading was determined, the compressive and tension stresses were analyzed, as seen in Figure 3. The range of stresses shown in Figure 3 is between 32 psi (compression) and 70 psi (tension) indicated in dark orange and green, respectively. Since the average 28-day splitting tensile strength for the concrete alone is 241 psi, the **BEAVER BELIEVER** nearly triples the necessary strength to support four paddlers. The 28-day compressive strength of the canoe is 1960 psi, which is also more than enough to support the maximum compressive stresses indicated from the model.

DEVELOPMENT AND TESTING

REINFORCEMENT

The reinforcement used in ***BEAVER BELIEVER***, consisted of ST2 Hardwire Composite Reinforcement and fiberglass mesh, FibaTape, as was used in *Dam Fast*. The entire amount of reinforcement was placed in between the two concrete lifts used to make the canoe, each lift being at least a half an inch thick. Hardwire uses high strength twisted steel which is woven into a fiberglass mesh, which makes it easy to work with in that it can be easily molded to fit a curved surface and can be applied in thin concrete. Hardwire has a tension strand strength of 346 pounds and has a percent open area (POA) of 63% (Hardwire LLC, 2009). FibaTape is typically used to prevent drywall cracking, and has a POA of 67%. The FibaTape was applied throughout the canoe, and the Hardwire was used in the chines and gunwales, so that if cracking does occur, the reinforcement helps to bridge the cracks, keeping them small, and major stresses along the chines and gunwales would be reduced. Three inches of overlap were provided for the FibaTape between the walls and bottom of the canoe, and the Hardwire extended two inches past the chines of the canoe. As seen in the FEM analysis, the major stresses are in the middle of the bottom of the canoe. In order to provide additional strength, a double layer of Fibatape was used at the center of the bottom of the canoe. The reinforcement used throughout the canoe insures safety for the paddlers, and is a cost effective method that decreases the amount of concrete needed to create the canoe, while enhancing tensile strength for any unexpected loadings.

MIXTURE DESIGN

Oregon State's primary goals for ***BEAVER BELIEVER***'s mixture design were to create a lightweight mixture with a plastic unit weight less than water's unit weight, a 14-day compressive strength over 1000 psi, a 14-day splitting tensile strength over 100 psi, and the replacement of at least 15% of portland cement by weight with fly ash.

TABLE 3: Material Mass and Volume

Cementitious	Mass	Volume
Class C Fly Ash	14.8%	5.74%
Type III Cement	50.2%	16.1%
Aggregates	**Mass**	**Volume**
Utelite Fine Expanded Shale	1.81%	1.15%
3M™ K15 Glass Bubbles	4.10%	26.0%
Elemixture®	1.02%	26.0%

Using *Dam Fast*'s mixture design as a baseline, lighter aggregates, especially lighter fine aggregates, were substituted by volume, while maintaining a high cementitious content in order to achieve a truly buoyant mixture. *Dam Fast*'s qualitative test results were a compressive strength of 1040 psi, a splitting tensile strength of 128 psi, a theoretical density of 62.4 pcf and a design density of 59.41 pcf. ***BEAVER BELIEVER***'s mixture design's lightweight aggregates include Utelite expanded shale fine aggregate, 3M™ K15 glass bubbles, and Elemix®, and their specific gravities were 1.59, 0.16 and 0.04, respectively. In order to achieve a light mixture, a lightweight expanded shale was used because it is 40% lighter than the foundry fine aggregate that was used in *Dam Fast*'s mixture design, and only 3M™ K15 glass bubbles were used instead of a combination with 3M™ K25 glass bubbles, which provided for a lighter portion of glass bubbles. Table 3 shows the percentages of each material by mass and volume. As seen in Table 3, the same proportion of Elemix®, a very lightweight spherical synthetic particle, was used and resulted in 26% of the volume and only 1.02% of the weight for ***BEAVER BELIEVER***'s concrete's wet density.

Utelite is made up of 100% shale, which was expanded at high temperatures in order to create a lightweight material. The shape is angular and has an absorption capacity of 18.1% as determined by ASTM C128. Because of its high absorption capacity as compared to *Dam Fast*'s foundry sand, the water to cementitious materials ratio was increased from 0.34 to 0.38.

3M™ K15 glass bubbles are created from soda-lime borosilicate glass, which also makes up laboratory beakers, and are a high strength and low density engineered additive. This aggregate is the second lightest in **BEAVER BELIEVER**'s mixture design, and accounts for 26% of its total volume.

As for the cementitious materials, it was imperative that fly ash replaced at least 15% of portland cement by mass, in order to promote the use of recycled materials in a building material whenever possible. The **BEAVER BELIEVER**'s mixture design met this goal by replacing 22.8% of portland cement with fly ash. This helped to create a more sustainable mixture design with the use of a post-recycled material, fly ash Class C, approved under ASTM C 618. Not only does fly ash support a sustainable design, it also provides an early age strength, and abrasion resistance for **BEAVER BELIEVER**.

Solid pigment was used instead of stain in order to decrease the project duration. Yellow and red pigments were proportioned to not exceed the 10% per hundred pounds of cementitous mass limit as stated in ASTM C 979, and to achieve a desired shade of orange for the main color of **BEAVER BELIEVER**. After testing a few combinations, 3% yellow pigment and 2% red pigment was chosen. Black pigment was tested from 5% to 10% per hundred pounds of cementitious mass in order to minimize the amount of pigment and maximize the richness of color without exceeding limits. 8% black was chosen and used to create the lettering and beaver decal on **BEAVER BELIEVER**.

ADMIXTURES

Three admixtures were used to create the desired putty-like consistency for the plastic state of **BEAVER BELIEVER**'s concrete, so as to easily apply the concrete to the female mold. Daravair 1000 was used as an air entrainment agent for the concrete to slightly increase workability and to aid in reduction of density, Advacast 555 was used as a superplasticizer to maintain workability without segregation and increase the high early strength, and Recover, a hydration stabilizer, was used to delay the set time of the canoe so that the separate lifts could cure evenly. All admixture dosages were within the range as recommended by suppliers and as used in *Dam Fast*, 5.98 fl oz/cwt, 8.97 fl oz/cwt, and 5.98 fl oz/cwt, respectively.

TESTING

The fresh unit weight of the mixture proved to be 61.8 pcf as determined with ASTM C 138, less than water's unit weight. Additionally, twelve 6 inch tall and 3 inch diameter cylinders cast from this mixture were batched to test compressive and splitting tensile strengths after 7 days and 14 days of curing in a fog chamber meeting ASTM C 511. Compressive testing was done according to ASTM C 39 and tensile testing was done according to ASTM C 496. The average 14-day compressive and tensile strengths of 1240 psi and 130 psi, respectively, are shown in Tables 4 and 5. These results meet Oregon State's goals.

TABLE 4: Splitting Tensile Test Results

7 Day	*14 Day*
115 psi	130 psi
65.2 psi	140 psi
163 psi	120 psi

TABLE 5: Compression Test Results

7 Day	*14 Day*
1150 psi	1225 psi
1120 psi	1070 psi
1100 psi	1440 psi

Specimens from the actual pour day were collected and tested for 28-day average compressive strength, and were found to be 1960 psi. Splitting tensile strength was 241 psi.

CONSTRUCTION

The specifications regarding the overall canoe dimensions did not change from the previous year. This allowed the *Dam Fast* mold to be almost entirely reused and partially reconstructed to form ***BEAVER BELIEVER***. Last year's form served the team well and only slight modifications to construction materials and mold release application were made to improve upon the construction process.

Construction began by determining the most cost effective methods and materials to use for the form. The most efficient way to build the ***BEAVER BELIEVER*** form was to reuse last year's single female mold and construction tables. First, the 22 foot long construction table was rebuilt from two 8 foot tables bolted together with a 6 foot floating section. A three-piece wooden strongback was reattached to the construction table to serve as a reference point once again.

After the strongback was set in place, the previously built cross sections were prepped to be refastened to the table. The cedar strips that were provided in the actual *Dam Fast* mold had to be removed from the cross sections due to their unusable condition. The cedar was the only material not reused from the *Dam Fast* mold.

After being prepped, the cross sections were each fastened to the table and braced in the top corners to create the mold skeleton. The cross sections were created last year based on the given hull design coordinates. These coordinates were imported into AutoCAD and plotted to make four cross sections per sheet of ¾ inch plywood. Each cross section was offset 4/10th of an inch larger to account for the thickness of the cedar wood strips, joint compound, and release agents. The use of a Computer Numerically-Controlled (CNC) router provided the highest level of accuracy for the cross sections. Cross sections were spaced at one-foot intervals including double cross sections at the table joints for the de-molding process.

FIGURE 4: Cedar Strips

Once the cross sections were secured and aligned, ¼ inch thick cedar bender boards with varying widths were secured to the cross sections as seen in Figure 4. These bender boards were used instead of cutting clear cedar lumber into hundreds of ¼ inch thick strips with varying widths as done previously. The bender boards came in much wider sections cutting down on mold construction time, cost and labor. The strips were routered with cove and bead router bits as done previously to create a locking system that ensured the most accurate curved surface. The strips were nailed to the interior of the cross sections and cut at the table joints. The interior surface was then sanded to reduce the presence of joints and coated with three layers of joint compound. The joint compound filled nail holes and smoothed the joints between strips.

Following the application of joint compound, ¼ inch thick insulating foam was cut to create the inlay lettering and beaver silhouette. The canoe name was glued 2 ½ inches below the top edge at the bow of the canoe and the school name was installed similarly along the stern. The beaver inlay was secured in the middle of the canoe on the bottom. After the lettering was installed, two thick coats of wax mold release were applied to the entire mold. This was done to improve upon the effectiveness of one light coat that was applied last year. The mold release produced a smooth surface that was hoped to have aided in the de-molding process. The mold release proved to be more of a bonding agent than a release agent making it so that a forklift and brute force were needed to demold the canoe.

To minimize casting time and maximize productivity, the team met the day prior to casting to review the entire process and divide members into four task related teams: concrete batch mixers, concrete placers, reinforcement layers, and material suppliers. The preparation and rehearsal prior to the pour day reduced the chaotic nature than can occur during casting. This organization of the team members would have allowed for the casting of **BEAVER BELIEVER** to take 50% less time than last year's *Dam Fast* if it had not been for a slightly higher than desired workability of the first batch of concrete. The team also batched out twice as much material than was needed in case something went wrong with one of the concrete batches. This emergency backup plan ultimately saved precious time for **BEAVER BELIEVER**.

At the beginning of pour day, the first lift of concrete applied to the mold had a slightly higher slump than intended, as seen in Figure 5. As a result, the concrete applied to sides of the canoe was not sticking and the intended ½ inch thick first lift was not uniform. Regardless of the setback, the reinforcement was rolled out in the canoe. A 1 ½ inch wide strip of wire reinforcement was placed along the top edge of the canoe and a 4 ½ inch wide strip was placed along the chines. In addition to the wire reinforcement, drywall mesh was installed everywhere along the canoe. After the first lift was in place, the second lift of concrete was applied to the canoe. Again, this mixture was slightly more fluid than intended. After completing the second lift, it was apparent that the concrete along the sides was not going to stay in place and the reinforcement was slipping downwards. It was decided that an emergency batch would be mixed with less water so that the sides of the canoe could be redone and the reinforcement could be replaced. Once the sides were repaired with the stiffer concrete batch, the canoe thickness was more consistent with the original intent.

FIGURE 5: Pour Day

After casting, the canoe was cured for 21 days with damp burlap and towels covering the form for adequate hydration. The mold was then removed in three sections with the help of a forklift. The connecting table screws were removed and force was applied to the center section of the form for removal. After using various bracing and expansion methods, the bow end was removed. The canoe was then released from the remaining stern end and set back in the expanded mold for storage.

For finishing, the exterior cast surface was sanded to ensure a smooth surface and a skim coat of concrete was applied to fill any remaining voids. Elemix® was excluded from the patch mix due to its poor finishing characteristics. The inlaid lettering and beaver silhouette were filled in with black non-structural concrete and a final liquid membrane forming compound was applied to seal the canoe.

In addition to constructing a quality canoe, safety was also a critical focus area for the team this year. Slight improvements to the material selection and reusing last year's mold increased safety due to the decrease in labor hours required for construction. All team members present during construction were required to wear personal protective equipment (PPE) for the hazards present, which included eye and ear protection, as well as dust masks, gloves and closed-toed footwear. For each material used, the project management team reviewed the material safety data sheets to protect the team members from any potential hazards. During pour day, a safety lead was designated to be in charge of making sure tasks were completed in a safe manner and with the proper PPE. Zero injuries were sustained the duration of the project due to a high level of diligence and safety.

PROJECT MANAGMENT

PROJECT MANAGEMENT STRUCTURE

An innovative co-captain organizational design was implemented this year. The two captains each focused on all aspects of the project and communicated progress daily. Several design and construction leads were also identified to focus on specific aspects of the ***BEAVER BELIEVER***. These aspects included paddling, mixture design, analysis, and graphics. However, the paddling team usually operated independently from the rest of the team, holding weekly gym and paddling practices.

PLANNING PROCESS

The first step in the planning process was to define the goals of the team and solidify the scope of the project. Ultimately, we wanted to at least maintain and, if possible, improve upon last year's successes with the mold construction, mixture design, and paddling techniques. We also wanted to improve on the quality of the technical paper and presentation. A risk management plan assessing safety concerns during concrete mixing and mold construction was also created after the goals were established.

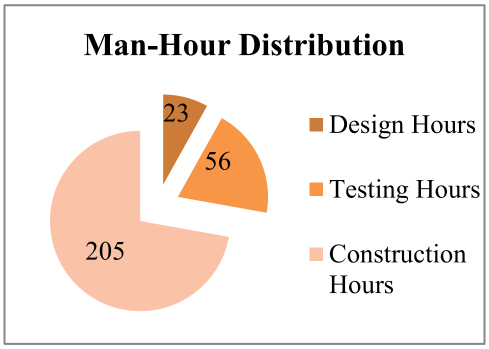


FIGURE 6: Man-Hours

The next step in the planning process was to develop a schedule based on our goals and determine the resources needed to complete each activity. Major milestones include the final mixture design selection, finishing mold construction, finishing the written report, and completing the oral presentation. These milestones were chosen based on their logical relationship to one another and completed as such. All of the milestones were met with little to no delay. The critical path consists of securing a workspace, reconstructing and aligning the work table, inlaying cedar strips, finishing the mold surface, installing inlays, pouring the canoe, curing the canoe in the mold, demolding the canoe, filling in inlays, sanding, patching, sealing, prepping the canoe for conference, and attending conference. The critical path was determined based on the activities needed for the completion of major milestones. The number of man-hours dedicated to the design, testing and construction of the canoe are indicated in Figure 8. In order to reach the set goals, time management was crucial.

Budgeting was the last step in the planning process. Financial resources were procured through grants and donations to meet our estimated project cost. The financial resources were allocated to purchasing concrete and construction materials to complete tasks according to the project schedule.

QUALITY CONTROL AND QUALITY ASSURANCE

There were quality control checks incorporated into the construction of the mold, mixture design, and during pour day to ensure satisfaction with competition rules. These checks were made in accordance with the quality assurance plan set in place by the co-captains.

SAFETY PRACTICES

Safety is always a priority to OSCCT. All team members participating in any part of the mixture design or construction processes were required to where personal protective equipment for the hazards present. Material safety data sheets were discussed and a safety lead was designated on pour day. Zero injuries were sustained throughout the duration of the project.

SUSTAINABILITY

Sustainable practices were used as often as possible during the course of this project and helped to reduce the cost of the project through the use of reused materials and maximizing on human-power. The hull mold was reused from *Dam Fast*'s year, but during its demolding process, the cedar strips in the mold were damaged and could not be reused and instead just the cross-sections and mold table were salvaged. The damaged cedar strips and nails were recycled using the large metal and wood recycling bins outside of the Green Building Materials Laboratory where ***BEAVER BELIEVER*** was constructed as shown in Figure 9.

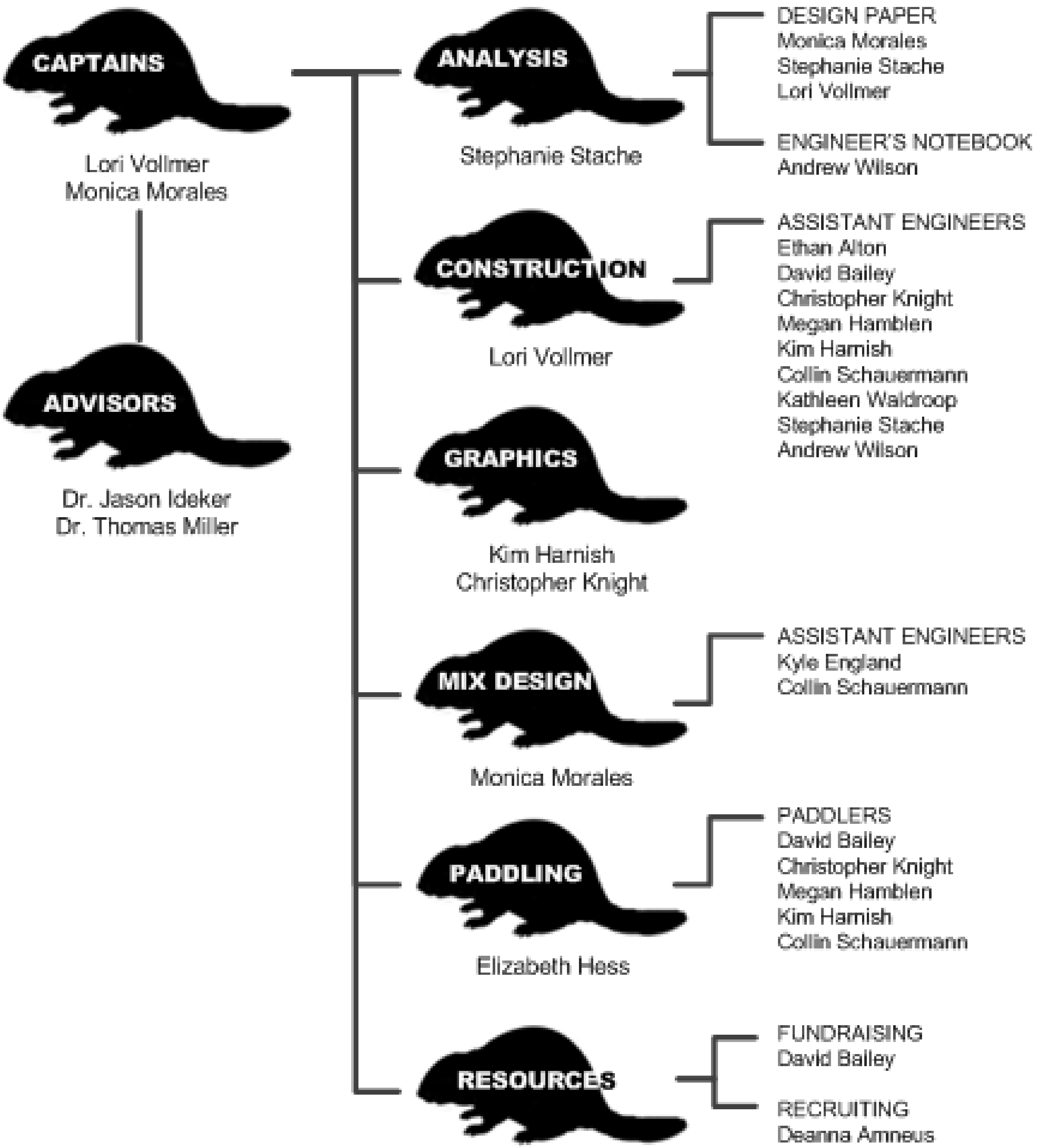
FIGURE 9: Recycling Damaged Cedar Strips

When new cedar strips were placed, some energy was conserved in hand sanding them instead of using electrical sanders. A theme of using human power trickled down throughout the project. When smaller materials needed to be transported from one civil engineering lab to another, most commonly between the Infrastructure Materials Laboratory and the Green Building Materials Laboratory, approximately a half-mile away from one another, often bicycles with bike racks were used rather than a truck. In order to get to the laboratories to work on the mixture or the mold itself, transportation in the form of biking and walking were used, saving even more in fossil fuel depletion. With Oregon State's great accessibility for pedestrians and bicyclists, resisting commuter transportation proved to not be a problem. As for the paddling team, plastic milk jugs were reused to create buoys for paddling practices.

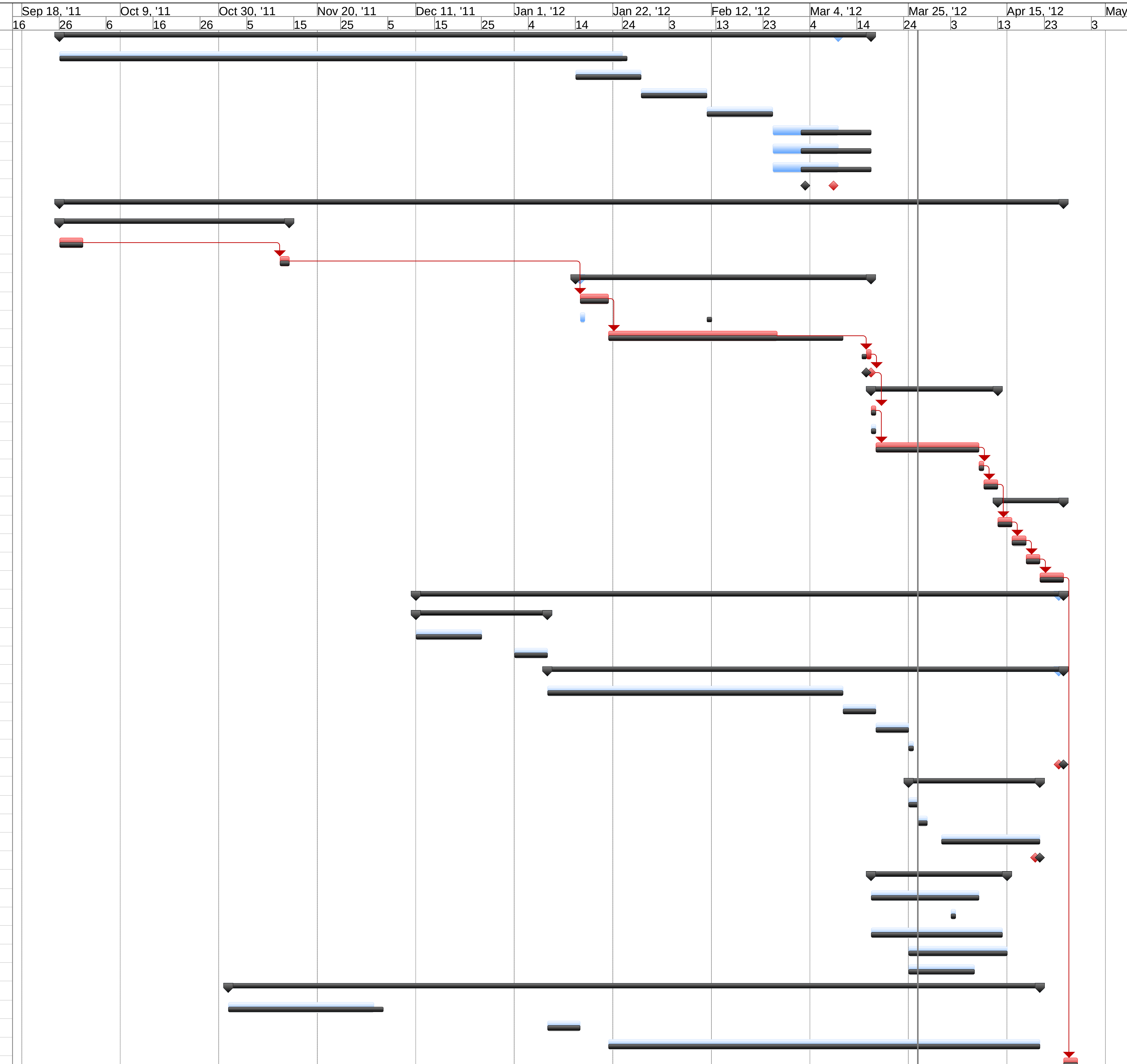
The mixture design itself is considered a sustainable design. A large percentage of portland cement was replaced with the coal by-product, fly ash, 22.8% by weight. Carbon dioxide equivalence and global warming potentials are reduced considerably through this replacement, in that portland cement uses a large amount of energy during its manufacturing process and produces approximately 5-7% of the world's CO_2 emissions, and that fly ash is a material that is land-fill prone. The fact that the mixture design was created to be very lightweight adds to its sustainable attributes. The fossil fuels used in order drive ***BEAVER BELIEVER*** from Corvallis, OR to Seattle, WA and Reno, NV for the 2012 Pacific Northwest Concrete Canoe Conference and National Conference, respectively, will be reduced for every pound ***BEAVER BELIEVER*** does not weigh. By using Elemix®, which makes up 1.02% of the weight and 26.0% of the volume of the plastic density, and 3M™ K15 glass bubbles, which makes up 4.10% of the weight and 26.0% of the volume, as the major contributors to the aggregates used in the mixture design, the unit weight of the concrete creating ***BEAVER BELIEVER*** was reduced significantly.

The Oregon State Student Sustainability Initiative was a funding source for ***BEAVER BELIEVER***. This organization financially supported our team for pursuing sustainable initiatives through creating a more sustainable concrete that is commonly used for infrastructure.

ORGANIZATION CHART



ID	Task Name	Planned Start	Planned Finish	Actual Start	Actual Finish
1	**Mix Design**	**Mon 9/26/11**	**Fri 3/9/12**	**Mon 9/26/11**	**Fri 3/16/12**
2	Procure & Inventory Materials	Mon 9/26/11	Mon 1/23/12	Mon 9/26/11	Tue 1/24/12
3	Mix & Crush Batch 1	Sat 1/14/12	Fri 1/27/12	Sat 1/14/12	Fri 1/27/12
4	Mix & Crush Batch 2	Sat 1/28/12	Fri 2/10/12	Sat 1/28/12	Fri 2/10/12
5	Mix & Crush Batch 3	Sat 2/11/12	Fri 2/24/12	Sat 2/11/12	Fri 2/24/12
6	Mix & Crush Batch 4	Sat 2/25/12	Fri 3/9/12	Fri 3/2/12	Fri 3/16/12
7	Mix & Crush Batch 5	Sat 2/25/12	Fri 3/9/12	Fri 3/2/12	Fri 3/16/12
8	Mix & Crush Batch 6	Sat 2/25/12	Fri 3/9/12	Fri 3/2/12	Fri 3/16/12
9	Final Mix Design Selection	Fri 3/9/12	Fri 3/9/12	Fri 3/2/12	Fri 3/2/12
10	**Construction**	**Mon 9/26/11**	**Thu 4/26/12**	**Mon 9/26/11**	**Thu 4/26/12**
11	**Table**	**Mon 9/26/11**	**Sun 11/13/11**	**Mon 9/26/11**	**Sun 11/13/11**
12	Secure Workspace	Mon 9/26/11	Fri 9/30/11	Mon 9/26/11	Fri 9/30/11
13	Reconstruct and Align Work Table	Sat 11/12/11	Sun 11/13/11	Sat 11/12/11	Sun 11/13/11
14	**Mold Surface**	**Sun 1/15/12**	**Fri 3/16/12**	**Sat 1/14/12**	**Fri 3/16/12**
15	Inlay Cedar Strips	Sun 1/15/12	Fri 1/20/12	Sun 1/15/12	Fri 1/20/12
16	Reconstruct Cutaway Section	Sun 1/15/12	Sun 1/15/12	Sat 2/11/12	Sat 2/11/12
17	Finish Mold Surface	Sat 1/21/12	Sat 2/25/12	Sat 1/21/12	Sat 3/10/12
18	Install Inlay Lettering & Beaver	Fri 3/16/12	Fri 3/16/12	Thu 3/15/12	Thu 3/15/12
19	Finish Mold Consruction	Fri 3/16/12	Fri 3/16/12	Thu 3/15/12	Thu 3/15/12
20	**Canoe Construction**	**Sat 3/17/12**	**Thu 4/12/12**	**Sat 3/17/12**	**Thu 4/12/12**
21	Pour Canoe	Sat 3/17/12	Sat 3/17/12	Sat 3/17/12	Sat 3/17/12
22	Pour Cutaway Section	Sat 3/17/12	Sat 3/17/12	Sat 3/17/12	Sat 3/17/12
23	Cure in Mold	Sun 3/18/12	Sun 4/8/12	Sun 3/18/12	Sun 4/8/12
24	De-Mold	Mon 4/9/12	Mon 4/9/12	Mon 4/9/12	Mon 4/9/12
25	Fill In Blocked Out Letters	Tue 4/10/12	Thu 4/12/12	Tue 4/10/12	Thu 4/12/12
26	**Canoe Finishing**	**Fri 4/13/12**	**Thu 4/26/12**	**Fri 4/13/12**	**Thu 4/26/12**
27	Sanding	Fri 4/13/12	Sun 4/15/12	Fri 4/13/12	Sun 4/15/12
28	Patching	Mon 4/16/12	Wed 4/18/12	Mon 4/16/12	Wed 4/18/12
29	Sealing	Thu 4/19/12	Sat 4/21/12	Thu 4/19/12	Sat 4/21/12
30	Prep Canoe for Conference	Sun 4/22/12	Thu 4/26/12	Sun 4/22/12	Thu 4/26/12
31	**Academics**	**Sun 12/11/11**	**Thu 4/26/12**	**Sun 12/11/11**	**Thu 4/26/12**
32	**Structural Analysis**	**Sun 12/11/11**	**Sat 1/7/12**	**Sun 12/11/11**	**Sat 1/7/12**
33	Create AutoCAD Drawing	Sun 12/11/11	Sat 12/24/11	Sun 12/11/11	Sat 12/24/11
34	SAP2000 Analysis	Sun 1/1/12	Sat 1/7/12	Sun 1/1/12	Sat 1/7/12
35	**Written Report**	**Sun 1/8/12**	**Thu 4/26/12**	**Sun 1/8/12**	**Thu 4/26/12**
36	Rough Draft	Sun 1/8/12	Sat 3/10/12	Sun 1/8/12	Sat 3/10/12
37	Editing	Sun 3/11/12	Sat 3/17/12	Sun 3/11/12	Sat 3/17/12
38	Revisions	Sun 3/18/12	Sat 3/24/12	Sun 3/18/12	Sat 3/24/12
39	Final Editing	Sun 3/25/12	Sun 3/25/12	Sun 3/25/12	Sun 3/25/12
40	Written Report Finished	Thu 4/26/12	Thu 4/26/12	Thu 4/26/12	Thu 4/26/12
41	**Oral Presentation**	**Sun 3/25/12**	**Sat 4/21/12**	**Sun 3/25/12**	**Sat 4/21/12**
42	Create Outline	Sun 3/25/12	Mon 3/26/12	Sun 3/25/12	Mon 3/26/12
43	Create PowerPoint Presentation	Tue 3/27/12	Wed 3/28/12	Tue 3/27/12	Wed 3/28/12
44	Practice Presentation	Sun 4/1/12	Sat 4/21/12	Sun 4/1/12	Sat 4/21/12
45	Oral Presentation Complete	Sat 4/21/12	Sat 4/21/12	Sat 4/21/12	Sat 4/21/12
46	**Conference Display**	**Sat 3/17/12**	**Sat 4/14/12**	**Sat 3/17/12**	**Sat 4/14/12**
47	Cutaway Section Curing & Labeling	Sat 3/17/12	Sun 4/8/12	Sat 3/17/12	Sun 4/8/12
48	Aggregate/Reinforcement Display	Tue 4/3/12	Tue 4/3/12	Tue 4/3/12	Tue 4/3/12
49	Cylinder Display	Sat 3/17/12	Fri 4/13/12	Sat 3/17/12	Fri 4/13/12
50	Engineers Notebook	Sun 3/25/12	Sat 4/14/12	Sun 3/25/12	Sat 4/14/12
51	Create Poster	Sun 3/25/12	Sat 4/7/12	Sun 3/25/12	Sat 4/7/12
52	**Paddling**	**Tue 11/1/11**	**Sat 4/21/12**	**Tue 11/1/11**	**Sat 4/21/12**
53	Tryouts	Tue 11/1/11	Thu 12/1/11	Tue 11/1/11	Sat 12/3/11
54	Team Selection	Sun 1/8/12	Sat 1/14/12	Sun 1/8/12	Sat 1/14/12
55	Practice & Conditioning	Sat 1/21/12	Sat 4/21/12	Sat 1/21/12	Sat 4/21/12
56	**Conference**	**Fri 4/27/12**	**Sun 4/29/12**	**Fri 4/27/12**	**Sun 4/29/12**



2012 Project Schedule *BEAVER BELIEVER*

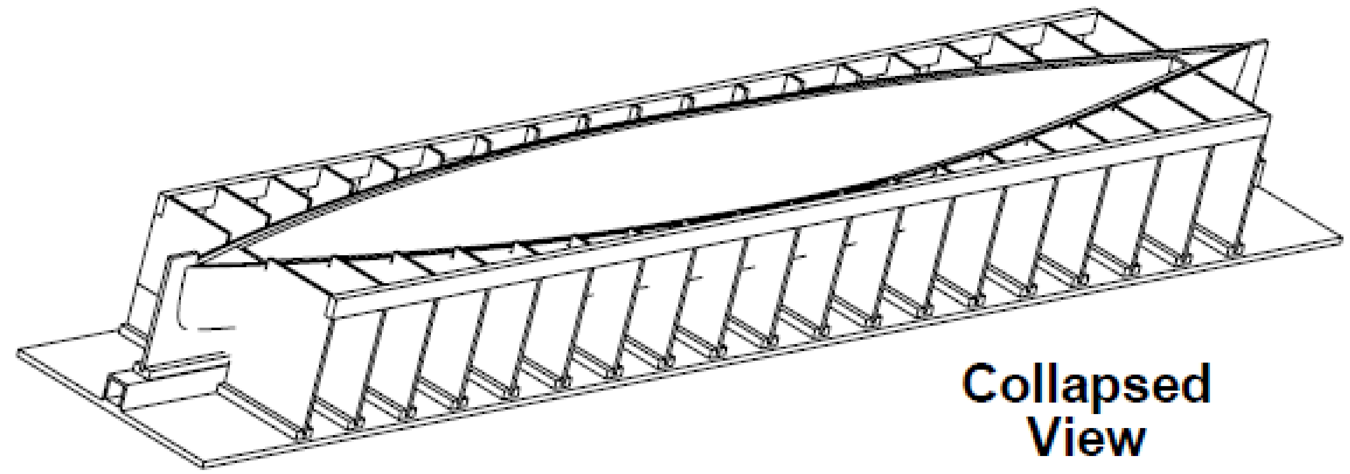
Planned Task | Actual Task | Actual Summary | Actual Milestone
Critical Path Task | Expected Summary | Planned Milestone

Bill of Materials

Sub-Section	Material Description	Quantity	Reference Number
Cross Sections	4'x8'x3/4" Plywood	6 sheets	1
Strongback	4'x8'x3/4" Plywood	1 sheet	2
	2"x4"x4' Lumber Bracing Blocks (not shown)	12	
	3" Screws	1 lb	
Supports	2"x4"x20" Lumber Cross Section Bases	42	3
	2"x4"x18" Lumber Top Corner Braces	2	4
	3" Screws	5lbs	
Cedar Strips	4"x10'x1/4" Cedar Bender Boards	40	5
	Brad Nails	2500	
Mold Sealing	MH Ready Patch	6 qts	6
	Partall Wax	1 qt	6
Table	4'x8'x1 1/8" Plywood Subfloor	3 Sheets	7
	2"x6"x8' Lumber Subframes (not shown)	12	
	4"x4"x24" Lumber Legs (not shown)	8	
	Adjustable Table Feet (not shown)	8	
	6" Lag Bolts	20	

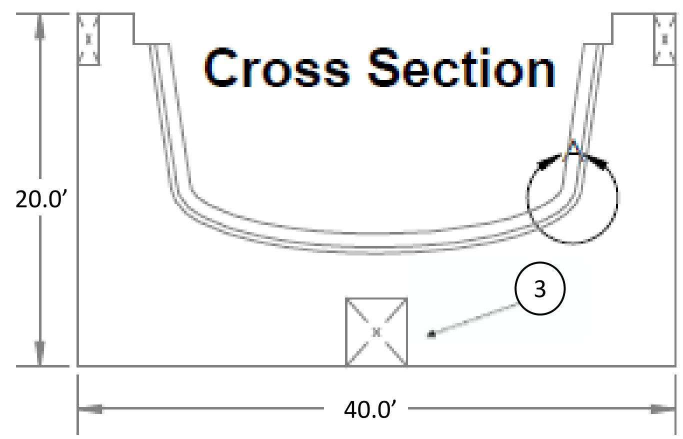
PROJECT: 2012 Concrete Canoe **BEAVER BELIEVER**	INSTITUTION: Oregon State University
DRAWN BY: JPP	DATE: 030/19/2012
CHECKED BY: LLV	PAGE: 11

OSU Oregon State UNIVERSITY

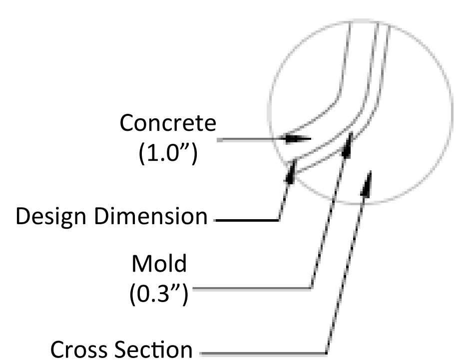


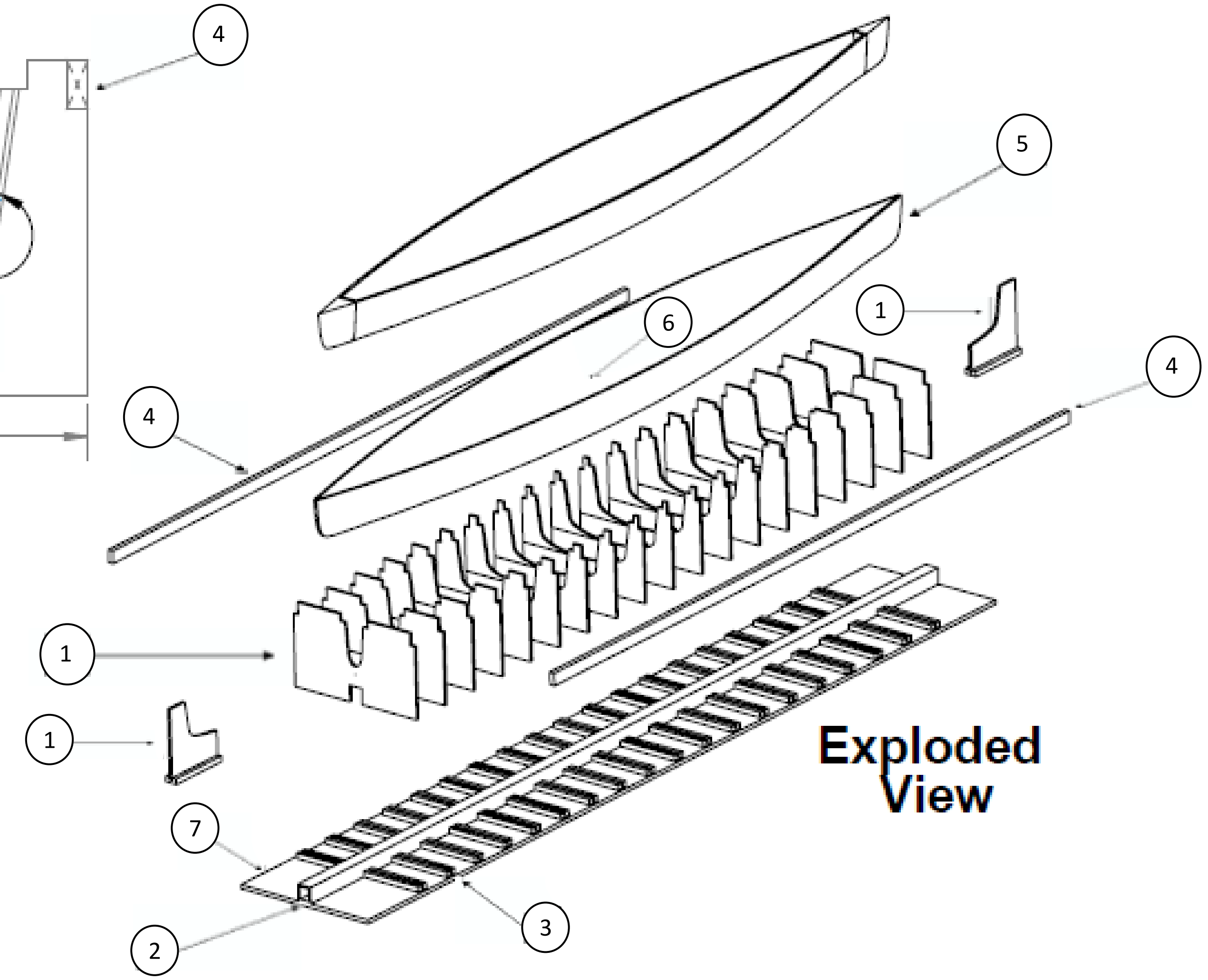
Collapsed View

Cross Section



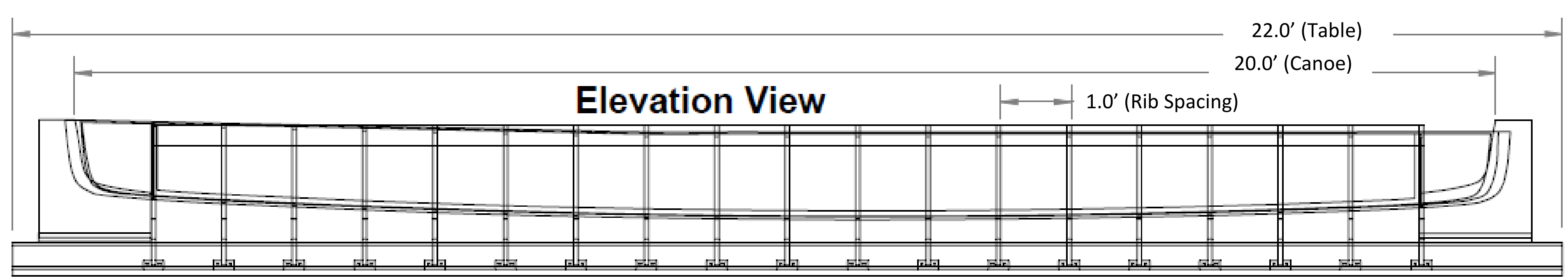
Detail View A



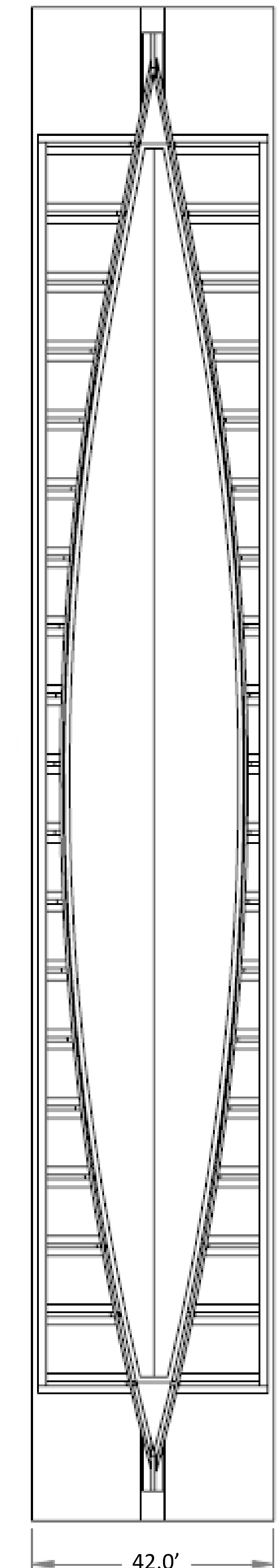


Exploded View

Elevation View



Plan View



APPENDIX A – REFERENCES

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APPENDIX B – MIXTURE PROPORTIONS

Mixture ID: Burnt Orange Structural Mix					Design Proportions (Non SSD)		Actual Batched Proportions		Yielded Proportions	
YD	Design Batch Size (ft3):			1						
Cementitious Materials				SG	Amount (lb/yd3)	Volume (ft3)	Amount (lb)	Volume (ft3)	Amount (lb/yd3)	Volume (ft3)
CM1	Portland Cement Type III			3.15	700.06	3.562	25.93	0.132	717.98	3.653
CM2	Class C Fly Ash			2.62	299.16	1.830	11.08	0.068	306.83	1.877
Total Cementitious Materials:					**999.22**	**5.39**	**37.01**	**0.20**	**1024.81**	**5.53**
Aggregates										
A1	Elemix®	Abs:	0.00	0.04	17.14	6.868	0.63	0.254	17.58	7.044
A2	3M K15	Abs:	0.00	0.16	68.75	6.886	2.55	0.255	70.51	7.062
A3	Utelite	Abs:	0.18	1.59	30.36	0.306	1.12	0.011	31.14	0.314
Total Aggregates:					**116.25**	**14.06**	**4.31**	**0.52**	**119.23**	**14.42**
Water										
W1	Water for CM Hydration (W1a+W1b)			1.00	391.74	6.278	14.51	0.233	401.78	6.439
	W1a. Water from Admixtures				14.68		0.54		15.06	
	W1b. Additional Water				377.06		13.97		386.72	
W2	Water for Aggregates, SSD			1.00	68.70		2.54		70.46	
Total Water (W1 + W2):					**460.44**	**6.28**	**17.05**	**0.23**	**472.23**	**6.44**
Solids Content of Dyes										
S1	Red Pigment			5.00	19.98	0.064	0.74	0.002	20.50	0.066
S2	Yellow Pigment			4.00	29.98	0.120	1.11	0.004	30.74	0.123
Total Solids of Dyes:					**49.96**	**0.18**	**1.85**	**0.01**	**51.24**	**0.19**
Admixtures				% 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	Recover	9.6	lb/gal	20.00	5.98	4.483	2.21	0.166	6.14	2.147
Ad2	Daravair1000	8.5	lb/gal	10.00	5.98	3.968	2.21	0.147	6.13	1.900
Ad3	Advacast555	8.9	lb/gal	35.00	8.97	6.232	3.32	0.231	9.20	4.476
Water from Admistures (W1a):						**14.68**		**0.54**		**8.52**
Cement-Cementitious Materials Ratio					0.701		0.701		0.701	
Water-Cementitious Materials Ratio					0.392		0.392		0.392	
Slump, Slump Flow, *in.*					0 in.		0.5 in.		0 in.	
M	Mass of Concrete, *lbs*				1625.88		60.22		1667.51	
V	Absolute Volume of Concrete, *ft3*				25.913		0.960		26.577	
T	Theoretical Density, *lb/ft3 = (M/V)*				62.74		62.74		62.74	
D	Design Density, *lb/ft3 = (M/27)*				60.22				61.76	
D	Measured Density, *lb/ft3*						61.76			
A	Air Content, *% = [(T - D) / T x 100%]*				4.02		1.57		1.57	
Y	Yield, *ft3 = (M/D)*				27		0.975		27	
Ry	Relative Yield = *(Y / Y D)*						0.975			

			Design Proportions (Non SSD)		Actual Batched Proportions		Yielded Proportions	
Mixture ID: Burnt Orange Patch Mix								
YD	Design Batch Size (ft3): 1							
Cementitious Materials		SG	Amount (lb/yd3)	Volume (ft3)	Amount (lb)	Volume (ft3)	Amount (lb/yd3)	Volume (ft3)
CM1	Portland Cement Type III	3.15	339.87	1.729	12.59	0.064	344.25	1.751
CM2	Class C Fly Ash	2.62	799.34	4.889	29.61	0.181	809.65	4.952
	Total Cementitious Materials:		**1139.21**	**6.62**	**42.19**	**0.25**	**1153.90**	**6.70**
Aggregates								
A2	3M K15 Abs: 0.00	0.16	96.78	9.694	3.58	0.359	98.03	9.818
A3	Utelite Abs: 0.18	1.59	33.45	0.337	1.24	0.012	33.88	0.341
	Total Aggregates:		**130.23**	**10.03**	**4.82**	**0.37**	**131.91**	**10.16**
Water								
W1	Water for CM Hydration (W1a+W1b)	1.00	432.90	6.937	16.03	0.257	438.48	7.027
	W1a. Water from Admixtures	1.00	13.39		0.50		13.56	
	W1b. Additional Water	1.00	419.51		15.54		424.92	
W2	Water for Aggregates, SSD	1.00	68.70		2.54		69.59	
	Total Water (W1 + W2):		**501.60**	**6.94**	**18.58**	**0.26**	**508.07**	**7.03**
Solids Content of Dyes								
S1	Red Pigment	5.00	22.78	0.073	0.84	0.003	23.08	0.074
S2	Yellow Pigment	4.00	34.18	0.137	1.27	0.005	34.62	0.139
	Total Solids of Dyes:		**56.96**	**0.21**	**2.11**	**0.01**	**57.69**	**0.21**
Admixtures		% 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	Recover 9.6 lb/gal	20.00	5.98	4.089	2.52	0.151	6.06	1.764
Ad2	Daravair1000 8.5 lb/gal	10.00	5.98	3.619	2.52	0.134	6.06	1.561
Ad3	Advacast555 8.9 lb/gal	35.00	8.97	5.684	3.78	0.211	9.09	3.677
Water from Admistures (W1a):				**13.39**		**0.50**		**7.00**
Cement-Cementitious Materials Ratio			0.298		0.298		0.298	
Water-Cementitious Materials Ratio			0.380		0.380		0.380	
Slump, Slump Flow, *in.*			0 in.		0 in.		0 in.	
M	Mass of Concrete, *lbs*		1828.00		67.70		1851.57	
V	Absolute Volume of Concrete, *ft3*		23.796		0.881		24.103	
T	Theoretical Density, *lb/ft3 = (M/V)*		76.82		76.82		76.82	
D	Design Density, *lb/ft3 = (M/27)*		67.70				68.58	
D	Measured Density, *lb/ft3*				68.58			
A	Air Content, *% = [(T - D) / T x 100%]*		11.86		10.73		10.73	
Y	Yield, *ft3 = (M/D)*		27		0.987		27	
Ry	Relative Yield = *(Y / Y D)*				0.987			

Mixture ID: Black Inlay Mix					**Design Proportions (Non SSD)**		**Actual Batched Proportions**		**Yielded Proportions**	
YD	Design Batch Size (ft3):			1						
Cementitious Materials				SG	Amount (lb/yd3)	Volume (ft3)	Amount (lb)	Volume (ft3)	Amount (lb/yd3)	Volume (ft3)
CM1	Portland Cement Type III			3.15	700.06	3.562	25.93	0.132	707.22	3.598
CM2	Class C Fly Ash			2.62	299.16	1.830	11.08	0.068	302.23	1.849
	Total Cementitious Materials:				**999.22**	**5.39**	**37.01**	**0.20**	**1009.44**	**5.45**
Aggregates										
A1	Elemix®	Abs:	0.00	0.04	17.14	6.868	0.63	0.254	17.32	6.938
A2	3M K15	Abs:	0.00	0.16	68.75	6.886	2.55	0.255	69.45	6.956
A3	Utelite	Abs:	0.18	1.59	30.36	0.306	1.12	0.011	30.67	0.309
	Total Aggregates:				**116.25**	**14.06**	**4.31**	**0.52**	**117.44**	**14.20**
Water										
W1	Water for CM Hydration (W1a+W1b)			1.00	388.81	6.231	14.40	0.231	392.78	6.295
	W1a. Water from Admixtures			1.00	11.75		0.44		11.87	
	W1b. Additional Water			1.00	377.06		13.97		380.92	
W2	Water for Aggregates, SSD			1.00	68.70		2.54		69.40	
	Total Water (W1 + W2):				**457.51**	**6.23**	**16.94**	**0.23**	**462.19**	**6.29**
Solids Content of Dyes										
S1	Black Pigment			4.60	79.94	0.278	2.96	0.010	80.76	0.281
	Total Solids of Dyes:				**79.94**	**0.28**	**2.96**	**0.01**	**80.76**	**0.28**
Admixtures				% 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	Recover	9.6	lb/gal	20.00	5.98	3.586	2.21	0.133	6.04	1.354
Ad2	Daravair1000	8.5	lb/gal	10.00	5.98	3.174	2.21	0.118	6.04	1.198
Ad3	Advacast555	8.9	lb/gal	35.00	8.97	4.986	3.32	0.185	9.06	2.821
Water from Admistures (W1a):						**11.75**		**0.44**		**5.37**
Cement-Cementitious Materials Ratio					0.701		0.701		0.701	
Water-Cementitious Materials Ratio					0.389		0.389		0.389	
Slump, Slump Flow, *in.*					0 in.		0.5 in.		0 in.	
M	Mass of Concrete, *lbs*				1652.92		61.22		1669.83	
V	Absolute Volume of Concrete, *ft3*				25.961		0.962		26.226	
T	Theoretical Density, *lb/ft3 = (M/V)*				63.67		63.67		63.67	
D	Design Density, *lb/ft3 = (M/27)*				61.22				61.85	
D	Measured Density, *lb/ft3*						61.85			
A	Air Content, *% = [(T - D) / T x 100%]*				3.85		2.87		2.87	
Y	Yield, *ft3 = (M/D)*				27		0.990		27	
Ry	Relative Yield = *(Y / Y D)*						0.990			

APPENDIX C – BILL OF MATERIALS

MATERIAL	QUANTITY	UNIT COST	TOTAL PRICE
Lafarge Cement, Type III	222.28 lbs	$ 0.24 / lb	$ 53.35
Fly Ash, Class C	65.72 lbs	$ 0.14 / lb	$ 9.20
Utelite, Lightweight aggregate	8.02 lbs	$ 2.64 / lb	$ 21.17
3M Class Microspheres K15	18.16 lbs	$ 10.85 / lb	$ 197.04
Elemix, Ultra-lightweight aggregate	4.52 lbs	$ 1.72 / lb	$ 7.77
Red Pigment	8.64 lbs	$ 2.02 / lb	$ 17.45
Yellow Pigment	8.64 lbs	$ 2.12 / lb	$ 18.32
Black Pigment	0.68 lbs	$ 2.10 / lb	$ 1.43
Daravair 1000, Admixture	259.85 g	$ 0.02 / g	$ 5.20
Advacast 555, Admixture	408.74 g	$ 0.02 / g	$ 8.17
Recover, Admixture	341.94 g	$ 0.06 / g	$ 20.52
Wooden Mold, Complete	1 Lump Sum	$ 1,178.85	$ 1,178.85
Wire Mesh, Reinforcement	20 sq. ft.	$ 1.78 / sq. ft.	$ 35.60
Drywall Mesh, Reinforcement	90 sq. ft.	$ 0.11 / sq. ft.	$ 9.90
Insulating Foam, Lettering	275 sq. ft.	$ 0.02 / sq. ft.	$ 5.50
Total Production Cost			**$ 1,589.47**

APPENDIX D – REPAIR PROCEDURES REPORT

Repair Procedure Report

School Name: Oregon State University

Canoe Name: Beaver Believer

Team Captain(s): Lori Vollmer and Monica Morales

Date of Request: 5/3/2012

Description of Cause:
There are two repair issues that we would like to address in the report and they are as follows;

1) Significant damage to the canoe was sustained during the races. The canoe was swamped and rolled over by waves created by a passing yacht on Lake Washington. In an attempt to turn the boat over, the deck hands on the police boat broke off a three foot section along the middle portion of the canoe wall on its right side. Severe cracking around the broken section was sustained as well. We do not feel that we should be penalized for this repair as the damage was done out of our control.
2) During transportation, one transverse crack was created that affects the structural integrity of tl canoe and makes it unsafe for our paddlers to race in due to the amount of water it lets in durin the races. A piece of the bow also broke off during transportation, however it doesn't affect the structural integrity of the canoe. We are prepared to take the 25-point deduction for these repai if permission is granted.

Description of Repair:
The repair procedures for the two cases are as follows;

1) The Oregon State University Canoe Team would repair the damage sustained during the races the PNW conference and during transportation using the same means and methods used to construct the canoe. To repair the large hole and damaged area around the hole, the remaining broken pieces would be removed. Then, a structural mix would be batched, mixed, placed in two lifts and finished to fill in the broken sections. The same type of reinforcement used durin the original casting would be placed in between the lifts of concrete and extend along the insid wall of the canoe, past the damaged area, to provide adequate development length. The extending pieces of reinforcement would also be covered with the structural concrete mix.
2) To repair the crack sustained during transportation, the damaged area would be sanded down slightly in order to add reinforcement. A layer of patch mix would be placed along the crack or both the inside and outside, covering the reinforcement. Once cured, the patch mix would be sanded smooth and finished with two coats of concrete sealer. We would also like to repair the bow of the canoe with the patch mix for aesthetic reasons.

Materials used in Repair:
Materials needed for repairing each case are as follows;

1) The large hole sustained during the races will be patched with the same structural mix used to cast the canoe presented in the design report. Both original types of reinforcement would be used including the wire mesh and the Fibatape.
2) The patch mix presented in the design report will be used to patch the crack and bow damage. The reinforcement used in the original casting will also be used to provide tensile strength to the damaged areas. These reinforcements include wire mesh and Fibatape.

Description of Supporting Documentation:
Provide a list of Supporting Documentation attached to this report

The accident report submitted after the police boat damaged the canoe is attached as supporting documentation. Photos of all damaged areas described are also included with captions.

Oregon State University attests that all information provided in this document is true.

ASCE Faculty Advisor: Signature: Thomas H. Miller Date: 5/2/12
Dr. Thomas Miller

Canoe Faculty Advisor: Signature: Jason H Ideker Date: 5/2/2012
Dr. Jason Ideker

Canoe Co-Captain: Signature: Lori L. Vollmer Date: 5/2/12
Lori Vollmer

Canoe Co-Captain: Signature: Monica Morales Date: 5/2/12
Monica Morales

CNCCC Disposition			
Date:	5/4/12		
Request to Repair Canoe:		☒ Granted	☐ Declined
Reason for Disposition: You are allowed to repair the police boat damage to the canoe per the method listed under repair #1 above using your structural concrete mix because this damage was not due to any fault of the team. You are only allowed to repair the crack in the canoe with tape because the damage is due to the team's transportation methods or structural design, there will be a deduction for the use of the tape. The bow of the canoe may not be repaired for aesthetics.			

This report, CNCCC disposition, and supporting documentation shall be included in Appendix D of the Design Paper. Failure to do so will result in a 25-point deduction from the Design Paper final score.

Filing this report does not guarantee the school will be granted permission to conduct repairs to their canoe. The ability to do so is a function of the reason for the request and the supporting documentation. Under no circumstances should a school consider a verbal disposition permission to repair their canoe.

If the school is permitted to conduct repairs, that school will receive a 25-point penalty for doing so. The maximum final product points will be reduced to 75 out of 100 points. This penalty may be waived at the discretion of the CNCCC on a case by case basis.

List of Supporting Documentation

PNW Conference Accident Report

Figure 1: Police boat damage covered in tape

Figure 2: Damage to the right of taped area also caused by police boat accident

Figure 3: Outside view of exposed police boat damage

Figure 4: Inside view of exposed police boat damage

Figure 5: Inside view of crack

Figure 6: Outside view of crack

Figure 7: Bow Damage

DAMAGE/ACCIDENT REPORT

School Name: Oregon State University

Name of Canoe: Beaver Believer

Date of Accident: 4/27/12

Location of Accident: Magnuson Park Beachfront

Type of Accident:

( ) Collision with other canoe ( ) Paddler fell out of canoe

( ) Collision with inanimate object (X) Other: Police Boat Accident

Briefly Describe Circumstances of Accident:

Police boat broke off piece of canoe in attempt to ~~[illegible]~~ roll the canoe back over. The canoe rolled over after being swamped by a wake.

Describe in Detail the Extent of Damage:

Three foot section of middle, right wall. Cracking and ripped out piece removed

Team Captain's Signature: Tori L. Vollmer

Team Captain's Signature: Monica Morales

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Damage is due to accident outside the control of the paddlers? (Circle one) YES NO

Comments:

Boat was swamped due to a wave out of their control. While being rescued the police boat damaged their boat. We allowed them to repair only the damage from the police boat and re-run

Deduct 25 points from Final Product ____ Do Not Deduct 25 Points from Final Product X

the race and compare their time to the other teams for the Co-ed Grand Final.

Head Judge: [illegible]


Figure 1: Police boat damage covered in tape


Figure 2: Damage to the right of taped area also caused by police boat accident


Figure 3: Outside view of exposed police boat damage

Figure 4: Inside view of exposed police boat damage

Figure 5: Inside view of crack

This crack opens up and leaks severely when put in tension or in the water. The top of the canoe is in compression in this photo, which makes it appear minor.

Figure 6: Outside view of crack
Again, this crack lets in an immense amount of water when in tension.

Figure 7: Bow Damage