NORTHERN ARIZONA UNIVERSITY

NAU ASCE
Concrete Canoe Team 2015-16

American Society of Civil Engineers
National Concrete Canoe Competition
Proposal, DRAFT #4
CENE 476: Capstone Prep

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List of Abbreviations

Organizations/Universities/Departments	
ASCE	American Society of Civil Engineers
CECMEE	Civil Engineering, Construction Management, Environmental Engineering
CSULB	California State University, Long Beach
NAU	Northern Arizona University
General Terms	
NCCC	National Concrete Canoe Competition
PSWC	Pacific Southwest Conference
RFI	Requests for Information
Staffing	
SENG	Senior Engineer
ENG	Engineer
LAB	Lab Technician
INT	Intern
AA	Administrative Assistant
Units	
ft	feet
lbs	pounds
pcf	pounds per cubic foot
psi	pounds per square inch

1.0 Project Understanding

1.1 Project Purpose

The American Society of Civil Engineers (ASCE) annually hosts a National Concrete Canoe Competition (NCCC) in which engineering students have the opportunity to design, construct and race a concrete canoe. The NCCC is judged based on four equally weighted components: the design report, oral presentation, final product, and canoe races. The design paper and oral presentation provide students the opportunity to improve technical writing and public speaking skills. In addition, the final product addresses the canoe's aesthetic appeal, durability, and overall construction quality. A successful final product requires coordination amongst all team members to assure that the hull design, concrete mix, reinforcement placement, and canoe mold are compatible with one another. Because the canoe will be raced, it is vital that the hull design is shaped in accordance with the desired speed and maneuverability. This provides constraints that the hull designer must comply with, similar to constraints provided by a client. This constraint is one of many provided in the rules and regulations, a document that students must read carefully and thoroughly to meet the client's needs.

For ASCE, the purpose of the project is to allow students to gain "hands-on, practical experience and leadership skills by working with concrete mix designs and project management" (ASCE, 2016). Students involved with this project will perform hands-on tests such as concrete compressive strengths as well as reinforcement and steel cable tensile strengths. The project manager will gain experience with coordination, scheduling, and budgeting. In addition, this competition promotes concrete's versatility, durability, and contemporary technologies to students, educators, and practicing engineers. The competition also represents the organization's commitment to university-level engineering education and the value and benefits of being an ASCE member. (ASCE 2016)

1.2 Project Background

1.2.1 Project Site

The construction of the canoe will predominantly occur in the Civil Engineering, Construction Management, and Environmental Engineering (CECMEE) Field Station, also known as Trotta's Farm as seen below in Figure 1-1. The field station will be used to perform concrete mixing, canoe mold construction, concrete pouring, and concrete canoe curing; the field station was used in 2014-15 for the same purposes. This one year-old facility is in good condition, however cleaning and reorganizing of equipment and materials must be done. A previous issue occurred due to misuse of a table saw, resulting in an expensive repair and a delay in the team's schedule. To prevent this problem, students will gain full understanding of equipment before use.

Northern Arizona University's (NAU) Engineering Building, Building 69, will be used for analysis and further testing; room 113 will be used to hold team meetings and to perform analysis, room 116 will be used to cure concrete cylinders at room temperature, and room 117 will be used to test concrete cylinders under the concrete compression machine. NAU's Engineering Building is shown in Figure 1-1 below.

The paddling portion of the concrete canoe competition consists of five races which includes the following: men's endurance, women's endurance, men's sprint, women's sprint and co-ed sprint. Racing is worth 25% of the overall competition score, therefore the team will hold paddling practice to prepare. Practices will be held weekly at Upper Lake Mary, Flagstaff, Arizona; as shown in Figure 1-2 below.

The ASCE Pacific Southwest Conference (PSWC) will be held at California State University, Long Beach (CSULB) from March 31-April 2, 2016. The campus is approximately seven hours away from NAU and the NAU ASCE student chapter will transport 40 to 50 civil engineering students to the conference.

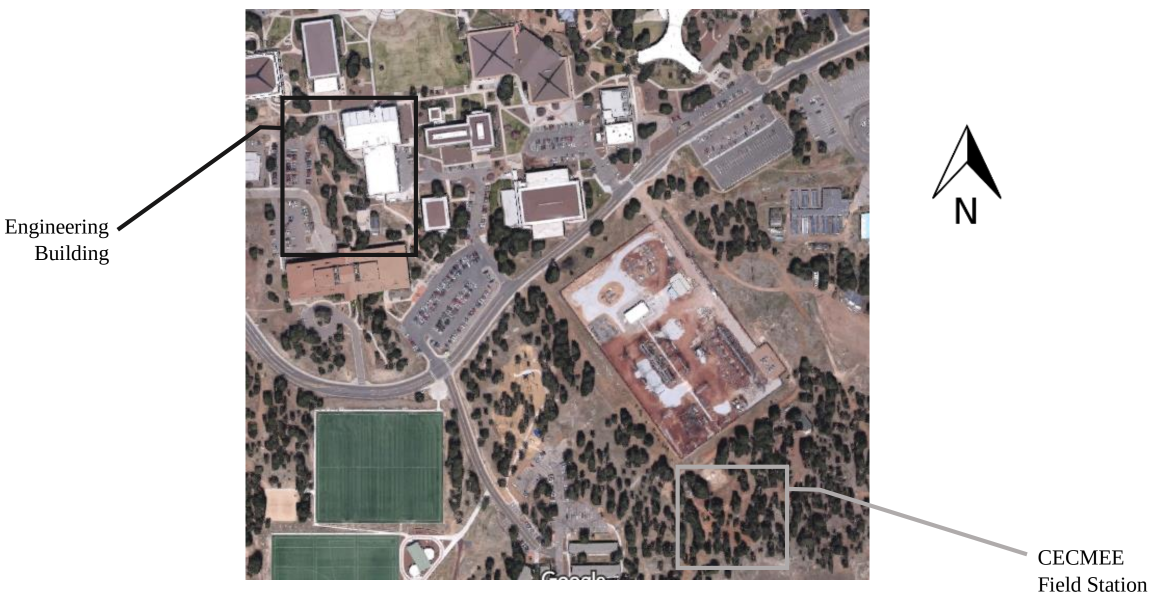

Figure 1-1: NAU CECMEE Field Station and Engineering Building (Bldg. 69), (Google Maps, 2015)

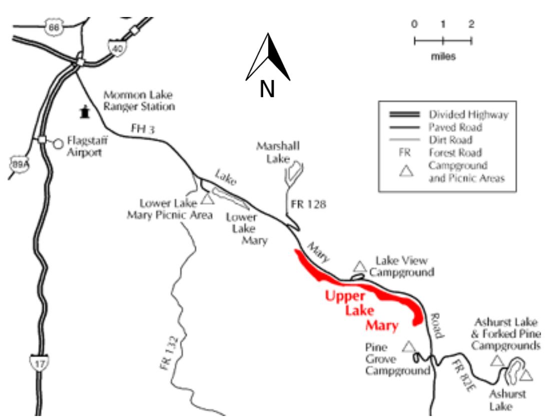

Figure 1-2 Location of Upper Lake Mary, Flagstaff, AZ
(Arizona, 2000)

1.2.2 Existing Conditions

Last year, the NAU ASCE Concrete Canoe team made significant progress at the PSWC, moving up from 13^{th} place in 2014, to 3^{rd} place in 2015. The drastic improvement resulted from a complete and detailed analysis towards the project, as the team did not make assumptions or decisions based on NAU's previous data and research. First, the team decided to use a male mold rather than a female mold; female molds have been used by NAU from 2011-14. This decision was made to accommodate the use of a post-tensioning system. In addition, the team utilized Ekkomaxx, a lightweight fly-ash based cement, in place of standard Portland cement for their concrete. This material along with admixtures provided by CeraTech and S32 Glass Bubbles, allowed the team to achieve a 28-day compressive strength of 2150 pounds per square inch (psi) and a 65.5 pounds per cubic foot (pcf) plastic unit weight (NAU, 2015); see Appendix A-1 for the mix design associated with this strength. In addition, the team decided to sacrifice some stability to optimize speed, by lengthening the canoe and by making it narrower. Due to the alterations for the canoe dimensions, the 2015 concrete canoe has a length of 21 feet (ft.), a value close to the maximum 22 ft. allowed by the ASCE Rules and Regulations (NAU, 2015), and a maximum beam width of 27 in. The lack of stability was addressed with the expectation of better paddling by holding canoe practices more frequently in comparison to previous years. In addition, structural calculations proved that the canoe experienced a compressive stress of 340 (psi) and a tensile stress of 119 psi. The nominal flexural capacity was calculated to be 29.6 pound (lb.)-in (inch)/in and therefore provided the team with a factor of safety of 7.5 (Appendix A-2). With these improvements, the 2014-15 NAU Concrete Canoe team provided a strong foundation for the teams to follow. The team this year will focus on refining the concrete mix, testing more reinforcement materials and sizes, and making appropriate adjustments in hull design using last year's paddling experience.

1.3 Technical Considerations

The concrete canoe project requires understanding of hull design and analysis, concrete mix design, reinforcement use, and construction methods. The hull design requires modeling and analysis using Prolines, Microsoft Excel, and AutoCAD to optimize the canoe's width, length, and shape. These characteristics determine the canoe's ability to accelerate and maneuver. In addition, the canoe requires a high strength and lightweight concrete mix design to carry loads from the two and four person races, transportation of the canoe, and the reaction forces from the display stand to the canoe. Finally, to make these aspects come together the construction methods will be the key to creating a structurally stable watercraft.

Concrete mix designs will be tested to determine maximum compressive strengths using various types and proportions of fly ash, admixtures, aggregates and fibers. Concrete inherently has high compressive strength, however it lacks tensile strength. To provide tensile strength, the team will incorporate reinforcement and pre-stressed or post-tensioning methods. To create a successful reinforcement system, the team must consider the constructability of the system and its compatibility with the concrete mix. Mold construction must be completed in accordance with the needs of the hull design, concrete mix, and reinforcement system. The tasks listed above must be carried out in order to complete a quality final product and improve performance in the canoe races. In addition, the process must be well documented in a technical design report and an oral presentation for the ASCE PSWC.

1.4 Potential Challenges

Potential challenges that the team plans to overcome are limited resources, time, and weather. To overcome all three challenges, the team will follow a schedule to stay on track and complete tasks in a timely manner. This year, the team aims to refine the concrete mix and test more reinforcement types; however to achieve this goal, the team must fundraise money from businesses around Northern Arizona to purchase the material. Fundraising must be completed promptly to gain the funds which in turn are used to purchase concrete mix materials. In order to perform many tests, the team must begin testing as soon as possible due to concrete's required curing time. The final canoe will take 28 days to cure, therefore, the team must plan accordingly.

Due to Flagstaff's cold winters, the team must utilize paddling practices while the weather remains warm. Paddling uses certain techniques to keep the canoe straight at high speeds and while making hairpin turns around buoys. Therefore, paddling practice must start immediately and workouts must be planned ahead to utilize the time at Lake Mary.

1.5 Stakeholders

Stakeholders for the NAU ASCE Concrete Canoe consist of the following: ASCE, NAU, several civil engineering professors, sponsors, and the NAU ASCE Student Chapter. The ASCE board expects to judge a professional quality technical paper, oral presentation and final product; in addition, ASCE also expects sportsmanship during the concrete canoe races. Because the concrete canoe team is competing under the NAU name, the team is required to represent the university in an appropriate manner.

The NAU civil engineering professors Mark Lamer P.E., and Robin Tuchscherer, Ph.D., P.E., and technical advisor, Thomas Nelson, P.E., provide the team with time and advice, and therefore expect the advice to be understood and considered when making decisions. The professors and technical advisor are valuable assets and their time should be used wisely. Sponsors provide product or financial assistance and therefore expect that the donation will be utilized responsibly. By responsibly, the donation should be used towards specified items needed to design and construction the concrete canoe. The sponsors name is also associated with the team and is even more of a reason to act professionally at all times.

Lastly, the concrete canoe team represents the NAU ASCE Student Chapter at the competition and plays a large role in the university's overall placement at the PSWC conference. In addition, the concrete canoe team has a mentee program in which underclassmen have the opportunity to shadow members of the canoe team leads. The ASCE student mentees are stakeholders because the work done by the concrete canoe team this year will provide further references for mentees in the following years and will hopefully keep creating a more successful team.

2.0 Scope of Services

The ASCE Concrete Canoe team is required to fulfill services for two entities: the ASCE Pacific Southwest Conference and the NAU civil engineering capstone course, CENE 486. The ASCE

PSWC deliverables will include a design report, oral presentation, final product, and paddling competition, while the NAU CENE 486 capstone requires a design report, final presentation, and website. To construct a quality project, the following services will be completed: project management, ASCE PSWC deliverables, CENE 486 capstone deliverables, material research, structural analysis and design, and construction.

2.1 Project Preparation

Before working in the laboratories, the team first must complete safety and chemical training, and concrete compression machine training. This is done in order to assure safety throughout the duration of the project when using power tools and various chemicals; Gerjen Slim oversees this training. In addition, training with Dr. Robin Tuchscherer on the concrete cylinder compression machine is important to assure proper use of the machine to obtain correct data and to be safe.

2.2 Mentoring Program

The NAU ASCE Concrete Canoe team has a mentoring program in which freshman to junior-level students have the opportunity to attend team meetings and gain foundational knowledge of the concrete canoe project. The team will reach out to interested underclassmen and select strong candidates. These underclassmen students, called mentees, are each partnered up with a canoe team member to obtain a detailed understanding tasks that must be done by each role of the canoe team.

2.3 CENE 486: Capstone

2.3.1 Design Report

All components – research, testing, analysis, design and construction – will be presented to the client in a final design report. Prior to the final submittal, the team will prepare a 50% and 90% design for the client to review and provide feedback.

2.3.2 Presentation

Multiple presentations will be made to the client, grading instructors, and classmates regarding the proposal and status of the project. This will allow students to practice public speaking, answer questions, and clearly present information. The final design, construction, and results of the PSWC will be presented at the undergraduate symposium on Friday, April 29th, 2016 to instructors, professionals, classmates, and other interested students and faculty.

2.3.3 Website

A website will be created to provide online access to information about the Concrete Canoe Capstone project. The webpage will include a project description, team information, conference information, capstone deliverables, a list of sponsors and the client, Mark Lamer, P.E.

2.4 Conference Deliverables

Throughout the concrete canoe project, there are deliverables required for both the ASCE NCCC and CENE-486 class. The required deliverables are presented in the following paragraphs.

2.4.1 ASCE NCCC Oral Presentation

The concrete canoe team will present an overview of the project at the ASCE PSWC 2016. The presentation has a time limit of five minutes, and at a minimum two team members must present and speak throughout the presentation. To prepare, the team will create and practice the presentation.

2.4.2 Engineer's Notebook

The engineer's notebook is a technical document containing detailed information on the design and construction processes of the team's concrete canoe. The engineer's notebook is to be on display at the conference, along with the design paper. Prior to conference, the engineer's notebook is to be sent in as an electronic copy for judging. The engineer's notebook must contain the following:

- School name and canoe name
- Table of contents
- Signed compliance certificate
- Names and ASCE National Member ID Numbers of registered participants
- Table summarizing the following canoe and concrete dimension and parameters:
    - Maximum length, maximum width, maximum depth, average thickness, and overall weight
    - Concrete densities (wet and dry), concrete compressive strength, concrete tensile strength, concrete composite flexural strength, and concrete air content
- Construction photographs of the following:
    - Eight of the mold construction showing fabrication, assembly, and coatings
    - Eight of the canoe construction showing concrete placement, reinforcement placement, and floatation placement
    - Four of the finishing techniques including sanding, patching, and application of sealers/graphics
- Hull thickness, reinforcement thickness, and percent open area calculations
- Material technical data sheets

2.4.3 Design Paper

The design paper covers the design and construction of the concrete canoe. It will be on display as a deliverable for the PSWC 2016 conference and will be submitted as an electronic copy prior to the conference for judging. The design paper is to include the following topics:

- Report cover and table of contents
- Executive summary
- Project management and organization chart
- Hull design and structural analysis
- Development and testing

- Construction
- Schedule
- Appendices of materials and calculations

2.4.4 Product Display

The display for the final product at the conference must meet the parameters set by the ASCE NCCC. The table top display shall fit within the maximum dimensions of 96''x30''x48'' and shall be placed on a conference table measuring no more than 96''x30''x29''. The table top display and table shall provide enough room to display all of the necessary documents and items. Along with the table top display, the items necessary for the display include:

- Samples of the concrete aggregates, concrete cylinders, and reinforcement
- The design paper and engineer's notebook
- A bill of materials and production cost estimate
- Canoe cutaway section
- Seats and/or mats used by the paddlers for the races

2.5 ASCE PSWC Conference

The ASCE PSWC will be held at California State University, Long Beach, in March-April 2016, where the concrete canoe will be evaluated. The canoe will be scored under four categories, each worth 25 percent of the team's overall score. The categories include:

- Oral Presentation
- Design Paper
- Final Product
- Races (to race, the canoe must pass a swamp test, testing its floating capabilities). There are five races which include:
    - Men's Endurance
    - Men's Sprint
    - Women's Endurance
    - Women's Sprint
    - Coed Sprint

2.6 Project Design

2.6.1 Hull Analysis

The hull analysis consists of designing the shape of the concrete canoe's body, otherwise known as the hull. This will be achieved through the use of last year's hull design and from there modifying various aspects such as thickness, beam width, and overall weight of the hull. With the use of the software Prolines, the original design will be altered accordingly and the modified canoe hull will be analyzed for, but not limited to buoyancy, waterline, hull speed, and drag resistance.

Hand-calculations for these aspects will be conducted using Excel, to verify values obtained through Prolines.

2.6.2 Structural Analysis

The structural analysis consists of evaluating the longitudinal and transverse stresses that the canoe will be influenced by and the maximum moment that the canoe will be able to resist.

2.6.2.1 Estimating Stresses

These will be hand-calculated with the assistance of the software, Excel, and will involve analyzing a simplified cross-section and a more "refined" cross-section (i.e., a flat-bottom U-shaped and a parabolic shaped cross-section respectively). The maximum stresses will be calculated through Equation 1 below:

Equation 1: $$\sigma = \frac{Mc}{I}$$

With the use of the 3D method Finite Element Analysis, the calculated stresses will be verified to reassure accuracy.

2.6.2.2 Shear Diagram

The shear diagram will be determined from designing the canoe as a simply-supported beam and applying various load cases. The maximum moment and shear will be verified through the use of the software RISA-2D.

2.6.2.3 Moment Diagram

The moment diagram will be determined from designing the canoe as a simply-supported beam and applying various load cases. The maximum moment and shear will be verified through the use of the software RISA-2D.

2.6.2.4 Flexural Capacity

With the concrete standards of the ACI 318-14, the flexural capacity will be calculated with the software Excel from the two cross-sections stated previously in Section 2.6.2.1.

2.6.3 Concrete Mix

2.6.3.1 Research of materials

Research of different types of materials must be completed prior to testing various concrete mixes. Materials that require research are lightweight aggregates, admixtures, pigments, and cementitious materials. Research will involve analyzing data sheets and ensuring the aggregates, admixtures, pigments, and types of cement will work well together. Due to limited resources, companies providing materials will be asked to sponsor their product to the team.

2.6.3.2 Testing Flexural Strength of Concrete

Numerous concrete mixes will be made until the team finds a mix that fulfills the necessary requirements of the client. Compressive strength or flexural tests will be performed on each mix. Sample cylinders are created with each mix and will be compressed vertically until failure. Each mix will be tested at 7, 14, and 28 days after the mix was made.

2.6.3.3 Testing Tensile Strength of Concrete

Once the team selects a few mixes that will work for the concrete canoe, the selected mixes will be tested tensile strength. The tensile strength of the concrete will be tested with sample cylinders placed horizontally on a thin triangular piece of wood and then loaded until failure. The selected mixes will also be cured with different reinforcement meshes and tested for the tensile strength of the combined reinforcement and concrete.

2.6.3.4 Testing Shrinkage of Concrete

The shrinkage of the concrete will be tested on the final mix design. Shrinkage will be tested by measuring the original wet measurement of the specimen subtracted by the dry measurement, divided by the dry length. This test will be a 28 day test to determine how much the concrete will shrink while curing.

2.6.3.5 Finalize Concrete Mix Table

A concrete mix table will be created for the final mix design. The concrete mix table will be provided by the American Society of Civil Engineers (ASCE) committee and will be completed using the information found in Material Technical Data Sheets (MTDS) of the materials used. The mix design tables will consist of a structural mix, finishing mix, and patch repair mix.

2.6.4 Reinforcement

An integral portion of the concrete canoe structural design is reinforcement. Reinforcement materials will be researched in order to purchase samples for further examination and testing. The samples will be examined for their strength, thickness, percent open area (POA), and overall suitability for the canoe. The samples will also be tested for their tensile strength, bonding properties with the concrete, and compression strength. The reinforcement material(s) and testing methods used for the canoe will conform to the set ASCE NCCC rules and regulations.

To aid with the canoe’s tensile strength, post-tensioning and pre-tensioning methods will be researched for implementation in the canoe. Also, the materials necessary to build the systems will be researched. The chosen tensioning method for the canoe will be designed for the canoe and implemented within it, and the materials used will conform to all ASCE NCCC rules and regulations.

2.7 Construction

There are three steps when performing the construction of the canoe. These include pre-construction where the formwork, or mold, is fabricated. Then there is the construction itself where the concrete is poured and the physical shape of the canoe is developed. Finally, there is the post construction where the formed concrete is being cured and finished. Along with those tasks of construction there are also tasks of transportation and storage that are addressed. These tasks include ensuring that the transport rig, curing structure, and coffin are constructed and maintained properly.

2.7.1 Mold

Since the dimensions from last year's mold fall within the rules presented by the ASCE National Concrete Canoe Competition, it has been determined that this year's team will reuse the foam mold and reapply stronger and more durable shrink wrap.

2.7.2 Coffin

The coffin is a wooded box that has plywood spaced approximately every foot and is cut into the shape of the concrete canoe. The cuts are shaped into a negative or female fashion for secure storage of the canoe. The coffin that is available requires modifications and additions so that the canoe has a better fit without being damaged. To accommodate this, cuts will be made and carpet will be added for padding and smoother storage.

2.7.3 Pour Day

The concrete and reinforcement will be added to the hull mold layer by layer. For example, there would be a layer of concrete then reinforcement then concrete then reinforcement, etc. Tensioning will also be incorporated this day and will be encased by concrete. The type of tensioning has not been determined, but will be incorporated in the schedule for pour day.

2.7.4 Curing

After the pour is complete, the concrete form would then be monitored on a daily basis to ensure it is kept moist at all times to avoid loss of internal moisture and cracking. This curing will begin by being placed in a newly constructed "incubator" box. Being contained in the box ensures that the canoe obtains an optimal cure, without being disturbed by outside forces.

2.7.5 Finishing

Once the 28-day strength of the concrete has been reached, the canoe will be sanded down with various grits of diamond pads until all rough surfaces are smoothed out. Once the canoe has been sanded and patched, a sealant will be applied.

2.7.6 Transport Rig

The transport rig is a structure that is simply created to transport the concrete canoe to its destinations. Currently, a steel rig is available for use, but is not sufficient for this year's canoe. The Construction Manager is coordinating with Cody Elliot who is the creator of the rig so that the team can create and construct a new or modified rig.

2.8 Exclusions

The NAU 2015-16 Concrete Canoe team will not be required to reconstruct a mold and coffin; instead the team will renovate both items, as stated in Section 2.7.1 and Section 2.7.2. Because of this decision, the team will save money and construction time so that these resources may be used to complete other tasks. In addition, this will allow the team to conserve storage space at the CECMEE Field Station.

2.9 Broader Impacts

The Concrete Canoe Capstone project not only impacts the students involved, but also future civil engineering students at NAU. The concrete and reinforcement testing data, structural analysis, structural design, and construction methods from 2014 to the present are currently compiled on Google Docs. This will provide future teams a strong foundation so that they may explore additional designs and expand the database. With this, NAU teams can continue to improve the canoe year by year. In addition, performing well at the PSWC can also improve NAU's reputation amongst the ASCE community. Placing well at the competition can leave a positive impression of NAU's civil engineering department, which may ultimately attract more engineering students to NAU.

3.0 Scheduling

3.1 Gantt Chart

The Gantt Chart is split into seven overarching tasks including the following: 1.0 Project Management, 2.0 CENE 486 Capstone, 3.0 Paddling, 4.0 Analysis and Design, 5.0 Testing, 6.0 Construction and 7.0 ASCE PSWC. Project Management includes tasks that relate to project preparation and team finances. The CENE 486 Capstone section accounts for deliverables, however dates are currently approximate and will be known on January 19th, 2016. Paddling consists of practices as well as a date to select teams and positions. Analysis and Design involves structural calculations as well as concrete, reinforcement, and construction research. Testing incorporates concrete mix and reinforcement, and composite testing. Construction includes tasks for the concrete pour, structures to hold and transport the canoe and concrete finishing. Lastly, the ASCE PSWC includes deliverables for the conference, as well as dates of the conference. The official start date of the project was on September 4th, 2015, the day in which CENE 486 capstone projects and groups were assigned. The ASCE competition's key external due date is the PSWC, held from March 31 to April 2, 2016 at California State University, Long Beach. However, the capstone completion date will be on the last day of the spring 2016 semester, May 13, 2016.

3.2 Critical Path

The team collectively created a schedule of tasks and corresponding due dates using the Gantt chart provided in Appendix D. Using these resources, the team identified the critical path as follows: fundraise and contact possible sponsors to obtain materials, mix and test various concrete cylinders and reinforcement samples, perform composite testing using both concrete and reinforcement, verify strength using hull and structural analysis, pour the concrete canoe, and sand and finish the canoe. The project schedule heavily relies on the concrete design due to its required curing time. Other tasks, such as structural analysis, have larger float times.

3.3 Meetings

Team meetings will occur twice a week on every Tuesday and Thursday from 11:00am-12:00pm. These meetings will allow face-to-face time for team coordination and capstone or PSWC updates. In addition, project leads will share any new findings obtained to keep the team informed about all project components. Technical advising meetings will occur on Wednesdays from 7:00-8:00pm as necessary to ask the technical advisor, Thomas Nelson, about various parts of the project.

3.3 Project Funding

As a team, a budget was created by determining all the necessary materials and equipment for the concrete canoe project. The initial cost was approximately $10,000, however, with adjustments from the team's technical advisor and department purchases, the cost has reduced to approximately $5,000. The budget includes items such as canoe display materials, cost of conference, wood for the concrete curing structure, concrete finishing supplies, and other similar construction items.

To raise $5,000, the team has sent sponsorship letters to various engineering firms around the Flagstaff area, seeking potential sponsors. In addition, a Go Fund Me account was created to fundraise money from friends, family and alumni.

4.0 Staffing Costs and Engineering Services

4.1 Staffing Plan

4.1.2 Senior Engineer (SENG):

The senior engineer is responsible for covering the project management tasks (e.g., keeping co-workers on schedule and updated on project progression), reviewing any regulations that pertain to conference, as well as creating and editing design papers and presentations. This role must be organized, constantly aware of material estimates, personable, and have general experience in concrete design.

4.1.3 Engineer (ENG):

The engineer is responsible for the structural analysis, the engineering notebook, the concrete mix prep (i.e., consists of iterating possible mix designs in an Excel spreadsheet), and the display stand for the canoe. This role must have a fair understanding and experience in hull analysis, post-tension concrete design, and bi-axial bending.

4.1.4 Lab Technician (LAB):

The lab technician is responsible for mixing the concrete mixes, testing the cured concrete cylinders, testing the reinforcement, constructing and finishing of the canoe. This role must have high regard for safety, experience in operating various machinery, and computing various concrete parameters (e.g., unit weight of concrete and compressive strength).

4.1.5 Intern (INT):

The intern is responsible for shadowing the senior engineer, engineer, and lab technician for experience in the different areas of specialization. This role must have a high motivation and keen idea of the general concepts relating to concrete as well as experience with various software such as AutoCAD 2013, Microsoft Word and Excel.

4.1.6 Administrative Assistant (AA):

The administrative assistant is responsible for coordinating any meetings and activities relating to the job itself. This role must be efficient with Microsoft Word and Excel, well organized, and a personable individual.

4.2 Cost Estimate for Engineering Services

4.2.1 Person-Hour Breakdown

The overall project has been separated into 23 general tasks and in ***Table.1***, the hours for the SENG, ENG, LAB, INT, and AA are stated.

Table.1: Hourly Breakdown of the Senior Engineer, Engineer, Lab Technician, Intern, and Administrative Assistant Roles

Task	SENG (hrs)	ENG (hrs)	LAB (hrs)	INT (hrs)	AA (hrs)
1.0 Team Meetings	-	-	-	80	150
2.0 Client Meetings	-	-	-	-	23
3.0 Tech Advisor Meetings	-	-	-	27	75
4.0 Project Management Tasks	50	-	-	-	-
5.0 Concrete Mixing Prep	-	10	-	-	-
6.0 Concrete Mixing/Testing	-	-	110	20	-
7.0 Field Station Setup/Organization	-	-	-	-	25
8.0 Paddling	-	-	-	-	125
9.0 Reinforcement Analysis/Testing	10	-	3	-	-
10.0 Structural Analysis	-	100	-	50	-
11.0 Rule Review	15	-	-	-	-
12.0 Canoe Pour Day	-	-	46	19	-
13.0 Canoe Sanding/Staining/Sealing/Monitoring	-	-	50	-	-
14.0 Display	-	23	15	16	-
15.0 Engineer's Notebook	-	50	-	-	-
16.0 Conference Design Report	75	-	-	-	-
17.0 Website	-	-	-	-	60
18.0 Presentation	28.5	-	-	-	-
19.0 Fundraising	40	-	-	-	-

20.0 Research	-	45	-	-	-
21.0 CENE 486 Design Report (50%)	-	-	-	-	-
22.0 CENE 486 Design Report (Final)	-	-	-	-	-
23.0 CENE 486 Presentation	13.5	-	-	-	-
∑hrs:	232	228	224	212	458

The total hours for the senior engineer, engineer, lab technician, intern, and administrative assistant are 232 hrs, 228 hrs, 224 hrs, 212 hrs, 458 hrs respectively.

4.2.2 Billing Rate

The base pay rates for the SENG, ENG, LAB, INT, and AA are $65, $40, $20, $10, $16 respectively. These rates are the amount each position will be paid per hour. The actual pay is the amount the company will be paying in total, which includes retirement funds, healthcare, and other company benefits. The billing rate includes benefits, all overhead costs, and the amount of profit the company will gain from the client which is illustrated in ***Table.2***.

Table.2: Billing Rate

	Base Pay Rate	Benefits	Actual Pay	Overhead (OH)
SENG	$65.00 /hr	10%	$72 /hr	19.2%
ENG	$40.00 /hr	25%	$50 /hr	16.4%
LAB	$20.00 /hr	35%	$27 /hr	16.1%
INT	$10.00 /hr	0%	$10 /hr	15.3%
AA	$16.00 /hr	40%	$23 /hr	33.0%

	Actual Pay + OH	Profit	Billing Rate
SENG	$85.24 /hr	10%	$95 /hr
ENG	$58.21 /hr	10%	$64 /hr
LAB	$31.35 /hr	10%	$35 /hr
INT	$11.53 /hr	10%	$13 /hr
AA	$29.79 /hr	10%	$33 /hr

The billing rate for the SENG, ENG, LAB, INT, and AA is $95, $64, $35, $13, $33 respectively, as can be seen from ***Table.2***.

4.2.3 Total Project Cost

The total project cost consists of the personnel, travel, subcontract, and overhead costs for the concrete canoe. The personnel expenses cover the SENG, ENG, LAB, INT, and AA costs. The travel expenses consist of the registration for conference, the lodging and food, and the roundtrip travel cost. The expenditures are taken into account as well consisting of materials and equipment costs. The total project costs of the personnel, travel, and expenditures is $76,340 as can be seen in ***Table.3***.

Table.3: Total Project Cost

1.0 Personnel				
Classification:	**Hours**	**Billing Rate**	**Multiplier**	**Cost**
SENG	267	$95.00 /hr	1.5	$25,036
ENG	228	$64.00 /hr	1.6	$14,598
LAB	224	$35.00 /hr	1.8	$7,726
INT	212	$13.00 /hr	1.3	$2,688
AA	458	$33.00 /hr	2.1	$15,006
				$65,054
2.0 Travel				
Conference Registration:		$150.00 /person		$1,500
Lodging/Food:		$250.00 /person		$2,500
Mileage (miles roundtrip):		$0.56 /mi		$535
				$4,535
3.0 Expenditures				
Materials:		$5,250.00		$6,750
Equipment:		$1,500.00		
		Total Project Cost:		$76,340

5.0 References

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Appendix A-1: Mixture Proportions (NAU, 2015)

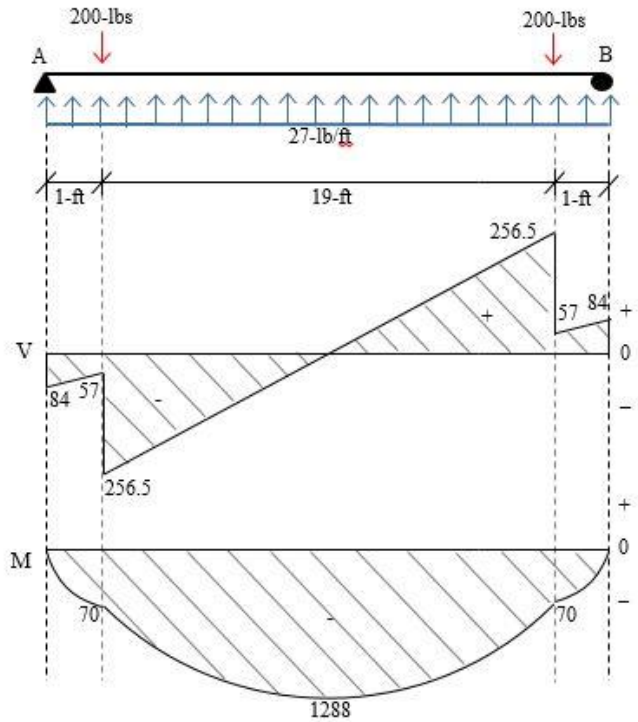
Mixture ID: Structural Mix			Design Proportions (Non SSD)		Actual Batched Proportions		Yielded Proportions	
Y_D	Design Batch Size (ft^3): 1							
Cementitious Materials		SG	Amount (lb/yd^3)	Volume (ft^3)	Amount (lb)	Volume (ft^3)	Amount (lb/yd^3)	Volume (ft^3)
CM1	EkkoMAXX™ (Flyash)	2.78	1040.83	6.00	38.55	0.222	1056.71	6.092
	Total Cementitious Materials:		**1040.83**	**6.00**	**38.55**	**0.22**	**1056.71**	**6.09**
Fibers								
F1	MasterFiber M 100 (0.75")	0.91	0.50	0.009	0.02	0.0003	0.51	0.009
	Total Fibers:		**0.50**	**0.01**	**0.02**	**0.0003**	**0.51**	**0.01**
Aggregates								
A1	Poraver® (0.5-1.0 mm) Abs: 20.0%	0.44	267.17	9.731	9.90	0.360	271.25	9.879
A2	3M S32 Glass Bubbles Abs: 1.0%	0.32	118.59	5.939	4.39	0.220	120.40	6.030
	Total Aggregates:		**385.76**	**15.67**	**14.29**	**0.58**	**391.65**	**15.91**
Water								
W1	Water for CM Hydration (W1a + W1b)	1.00	260.21	4.17	9.64	0.15	264.18	4.23
	W1a. Water from Admixtures		1.98		0.07		2.01	
	W1b. Additional Water		258.23		9.57		262.17	
W2	Water for Aggregates (SSD)	1.00	54.62		2.02		55.45	
	Total Water *(W1 + W2)*:		**314.83**	**4.17**	**11.66**	**0.15**	**319.63**	**4.23**
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)
Ad3	MasterAir AE 90 *8.51 lb/gal*	6.00	3.00	1.98	1.16	0.072	3.05	2.01
	Water from Admixtures *(W1a)*:			**1.98**		**0.07**		**2.01**
Cement-Cementitious Materials Ratio			0.00		0.00		0.00	
Water-Cementitious Materials Ratio			0.25		0.25		0.25	
Slump, Slump Flow, *in.*			7 ± 1		8.00		8.00	
M	Mass of Concrete. *lbs*		1741.93		64.52		1768.50	
V	Absolute Volume of Concrete, *ft^3*		25.84		0.96		26.24	
T	Theorectical Density, *lb/ft^3 = (M / V)*		67.41		67.39		67.39	
D	Design Density, *lb/ft^3 = (M / 27)*		64.52					
D	Measured Density, *lb/ft^3*				65.5		65.5	
A	Air Content, *% = [(T - D) / T x 100%]*		4.3%		2.8%		2.8%	
Y	Yield, *ft^3 = (M / D)*		**27.0**		0.985		**27.0**	
Ry	Relative Yield *= (Y / Y_D)*				0.985			

Mixture ID: Patching Mix		Design Proportions (Non SSD)	Actual Batched Proportions	Yielded Proportions
Y_D	Design Batch Size (ft^3): 1			

Cementitious Materials			SG	Amount (lb/yd^3)	Volume (ft^3)	Amount (lb)	Volume (ft^3)	Amount (lb/yd^3)	Volume (ft^3)
CM1	EkkoMAXX™ (Flyash)		2.78	1040.83	6.00	38.55	0.222	1046.19	6.031
	Total Cementitious Materials:			**1040.83**	**6.00**	**38.55**	**0.22**	**1046.19**	**6.03**
Aggregates									
A1	3M S32 Glass Bubbles	Abs: 1.0%	0.32	312.90	15.670	11.59	0.580	314.51	15.751
	Total Aggregates:			**312.90**	**15.67**	**11.59**	**0.58**	**314.51**	**15.75**
Water									
W1	Water for CM Hydration (W1a + W1b)		1.00	260.21	4.17	9.64	0.15	261.55	4.19
	W1a. Water from Admixtures			0.00		0.00		0.00	
	W1b. Additional Water			260.21		9.64		261.55	
W2	Water for Aggregates (SSD)		1.00	3.13		0.12		3.15	
	Total Water *(W1 + W2)*:			**263.34**	**4.17**	**9.75**	**0.15**	**264.69**	**4.19**
Cement-Cementitious Materials Ratio				0.00		0.00		0.00	
Water-Cementitious Materials Ratio				0.25		0.25		0.25	
Slump, Slump Flow, *in*.				7 ± 1		6.00		6.00	
M	Mass of Concrete. *lbs*			1617.07		59.89		1625.40	
V	Absolute Volume of Concrete, ft^3			25.84		0.96		25.97	
T	Theorectical Density, lb/ft^3 = *(M / V)*			62.58		62.58		62.58	
D	Design Density, lb/ft^3 = *(M / 27)*			59.89					
D	Measured Density, lb/ft^3					60.2		60.2	
A	Air Content, % = *[(T - D) / T x 100%]*			4.30		3.80		3.80	
Y	Yield, ft^3 = *(M / D)*			**27.0**		0.995		**27.0**	
Ry	Relative Yield = (Y / Y_D)					0.995			

Appendix A-2: Structural Calculations (NAU, 2015)

Longitudinal Internal Stress



Assume:

- Self-weight of the canoe (SW_{canoe}) = 170-lbs
- Self-weight of the paddlers ($SW_{paddlers}$) = 200-lbs each
- Canoe length = 21-ft

Determine Buoyant Force, F_B:

$$F_B = SW_{canoe} + SW_{paddlers} = 170\ lbs + 200\ lbs = 570\ lbs$$

∴ Water will push upwards at 570-lbs per 21-ft or **27-lb/ft**

Find Reactions:

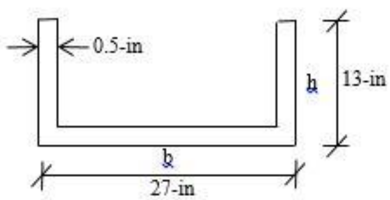
$$\curvearrowleft + \Sigma M_A = 0 = (200\ lbs)(1\ ft) + (200\ lbs)(20\ ft) - 27\frac{lb}{ft}(21\ ft)(10.5\ ft) + R_B(21\ ft)$$

$R_A = R_B =$ **83.5-lbs (↓)**

Drawing Shear & Moment Diagrams:

M_{max} = 1288-lbft or **15456-lbin**

Simplified Cross-Section:



$$\bar{y} = \frac{\Sigma A_i y_i}{\Sigma A_i} = \frac{(27\ in)(0.5\ in)(0.25\ in) + 2(12.5\ in)(0.5\ in)(6.75\ in)}{(27\ in)(0.5\ in) + 2(12.5\ in)(0.5\ in)} = \mathbf{3.375 - in}$$

$$I = \Sigma(I_i + A_i d_i^2) = \left[\frac{(0.5\ in)^3(27\ in)}{12} + (0.5\ in)(27\ in)(3.375\ in - 0.25\ in)^2\right] + 2\left[\frac{(27\ in)^3(0.5\ in)}{12} + (0.5\ in)(12.5\ in)(3.375\ in - 6.75\ in)^2\right] = \mathbf{437.3 - in^4}$$

- $\bar{y}$ = Centroid of cross-section
- A_i = Area of individual rectangular segment
- y_i = centroid of individual segment
- I_i = Moment of inertia = $\frac{bh^3}{12}$
- $d_i = y_i - \bar{y}$

Flexural Formula:

$$\sigma = \frac{My}{I}$$

- σ = Normal stress
- M = Moment
- y = Distance from centroid to stress face
- I = Moment of Inertia

$$\sigma_{compression} = \frac{(15456\ lbin)(13\ in - 3.75\ in)}{437.3\ in^4} = \boxed{\mathbf{340 - psi}}$$

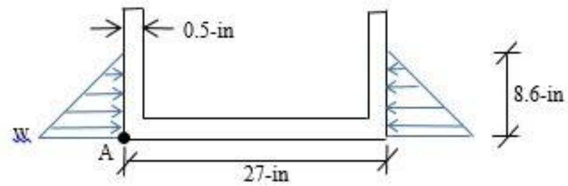
$$\sigma_{tension} = \frac{(15456\ lbin)(3.75\ in)}{437.3\ in^4} = \boxed{\mathbf{119 - psi}}$$

Appendix A-2: Structural Calculations, continued (NAU, 2015)

Transverse Internal Stress

Assume:

- Density of water = 62.4-pcf
- Waterline = 8.6-in (From Prolines waterline analysis)



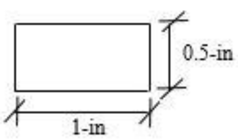
Find Force of Water, w:

$$w = 62.4\frac{lb}{ft^3}\left(\frac{1\ in}{12\ ft}\right)^3(8.6\ in)(1\ in) = \mathbf{0.311 - \frac{lb}{in}}$$

$$\curvearrowleft + \Sigma M_A = 0 = \left(0.311\frac{lb}{in}\right)(8.6\ in)(0.5)\left(\frac{1}{3}\right)(8.6\ in)$$

$$\boldsymbol{M = 3.83 - \frac{lbin}{in}}$$

One-inch Section-Cut at A:



$$I = \frac{bh^3}{12} = \frac{(1\ in)(0.5\ in)^3}{12} = \mathbf{0.0104 - in^4}$$

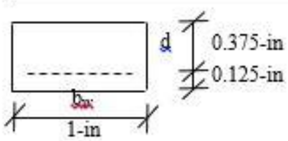
Flexural Formula:

Conventional to use 0.1(h for compression face

$$\sigma_{compression} = \frac{(3.83\frac{lbin}{in})(0.20\ in)}{0.0104} = \boxed{\mathbf{73.5 - psi}}$$

$$\sigma_{tension} = \frac{(3.83\frac{lbin}{in})(0.25\ in)}{0.0104\ in^4} = \boxed{\mathbf{92 - psi}}$$

Single Layer of Reinforcement:



Assume:

- Compressional Strength of Concrete, f'c = 2150-psi (from concrete mix)
- Tension force, T = 135-lb/in (from mesh reinforcement testing)
- Neutral axis depth factor, $\beta_1 = 0.85$
- Strength reduction factor, $\phi = 0.65$

Depth to Compression Zone, c:

$$c = \frac{T}{0.85f'c\beta_1 b_w} = \frac{\left(135\frac{lb}{in}\right)(1\ in)}{0.85(2150\ psi)(0.85)(1\ in)} = \mathbf{0.0869 - in}$$

Nominal Flexural Capacity, ϕM_n:

$$\emptyset M_n = \emptyset\left[T(d - \frac{\beta_1 c}{2}\right] = 0.65\left[135\ lbs(0.375\ in - \frac{0.85(0.0869\ in)}{2}\right] = \mathbf{29.6 - \frac{lbin}{in}}$$

$\emptyset M_n \gg M$ **Factor of Safety ≈ 7.5**

Appendix B: Client Meeting Cover Letter

NAU Concrete Canoe Team
Northern Arizona University
Flagstaff, AZ 86001

October 2, 2015

Mark Lamer, P.E.
P.O. Box 15600
Flagstaff, Arizona, 86011

Dear Mr. Mark Lamer,

The Northern Arizona University Concrete Canoe Team appreciated your time on September 18, 2015 to discuss the scope of work for this project. The team consists of Brent Lipar, Chelsie Kekaula, Colton McConnell, Emily Melkesian, and Evan Kaichi. We are excited to achieve a quality product while staying within a set budget, finish by the provided deadlines, and working as one team.

The team has decided to use last year's data as a resource due to a successful design and excellent concrete mix. The team wants to analyze the data and dramatically improve the concrete mix, concrete reinforcing, and the accuracy of the structural calculations. Attached is our Project Understanding Memo, which outlines the details and requirements for the upcoming project. This memo is to assure the team fully understands the scope of work for this project.

If you would like additional information, or if you have any questions concerning our understanding of the scope of work, please feel free to contact us via email at ck398@nau.edu. Thank you.

Sincerely,

NAU Concrete Canoe Team

Appendix C: TA Agreement

CENE 476 / 486 Technical Advising Requirements

An essential element in the education of engineering students is their culminating senior design experience, also known as capstone. In Civil and Environmental Engineering, students work in teams of three or four with a client, usually external to the department, to develop a real-world engineered design. Each student team will work with their client and technical advisor first to develop a proposal for the project due at the end of CENE476, then to complete the full design and develop a design report and associated documents (e.g. plans, specifications, etc.), due near the end of CENE486C. This document provides a framework for the responsibilities of the student team to the technical adviser, and explanation of the technical adviser's responsibilities.

The student team agrees to:

- Interact with their technical adviser in a professional manner at all times.
- Prepare for meetings with their tech adviser so that the adviser's time is used efficiently and effectively.
- Provide meeting agendas at least three business days in advance for any meetings between the team and tech adviser.
- Keep detailed meeting minutes (date, time spent, items discussed, etc.) from meetings with their technical adviser.
- Follow all recommendations made by the tech adviser with respect to technical aspects of their design. Where a team does not adhere to their adviser's advice, they must justify and document reasons why they chose not to follow the adviser's input.
- Not request reviews of submittals for grammar, punctuation, spelling, etc.

The technical adviser agrees to:

- Interact with their student team in a professional manner at all times.
- Be available to the student team for at least one hour each week.
- Prepare for meetings with their team in advance (e.g. review documents for technical soundness, review upcoming meeting agenda, etc.)
- Provide input to the team with respect to the technical approaches used on their project. This is the PRIMARY role of the tech adviser – one of expert who can help students avoid critical mistakes (incorrect assumptions, analyses methods, etc.) that have the potential to derail the design solution.
- Provide honest yet constructive feedback to their student team on performance, professionalism, etc.
- Provide assessments of various team activities including: team preparedness for TA meetings, 50% design deliverable, and 100% design deliverable.

Signatures:

Technical Advisor: [signature] Date: 9/30/15

Print Name: Thomas Nelson

Student: [illegible] Date: 10/2/15

Print Name: CHELSIE KEKAULA

Student: [illegible] Date: 10/2/15

Print Name: Colton McConnell

Student: [illegible] Date: 10/2

Print Name: Brent Lper

Student: [illegible] Date: 10/2

Print Name: Emily Meikesian

STUDENT: [illegible] DATE: 10/2

PRINT NAME: Evan Kaichi