Concrete Canoe Design Competition

Recycled Materials in Design and Construction; Perception of "Most Sustainable" in the Built Environment

A Thesis Prospectus
In STS 4500
Presented to
The Faculty of the
School of Engineering and Applied Science
University of Virginia
In Partial Fulfillment of the Requirements for the Degree
Bachelor of Science in Civil Engineering

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November 3, 2023

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On my honor as a University student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments.

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Introduction

The American Society of Civil Engineers (ASCE) serves as the “world’s largest publisher of civil engineering content” and was founded as the nation’s first engineering society. Defining codified specification and standards, ASCE develops the codes that ensure public safety in the built environment, as well as provide technical and professional conferences for topics in civil engineering and continuing education for all ASCE members of varying professional and academic levels. ASCE hosts the annual national and regional Concrete Canoe Competition for all participating universities.

The competition is laid out within the set of rules written in the Request for Proposals (RFP), these rules vary each year and provide restrictions on the materials available for use, dimensions, quantity of materials, etc. The annual competition stimulates real-world civil engineering firm practices competing for a bid to design the mock product: a concrete canoe. At the regional competition, the teams are evaluated by a point system on the following four categories: Project Proposal, Final Project Display, oral technical presentation, and canoe races; with the first-place school moving on to the national competition. The Project Proposal should detail the technical details of the team’s process and the value the product brings to the consumer. The Product display will provide visual representations of the canoe’s design, materials chosen, fabrication process, and durability to withstand use in American waterways. The objective of the technical presentation is to allow judges to ask questions and raise concerns about any uncertainties in the team’s process, ideas, or final design.

While the history of the Concrete Canoe goes back to 1960s, when a few ASCE Student Chapters held intramural concrete canoe races, the first ASCE Concrete Canoe Competition was officially held in 1988. The competition was then known as the "America's Cup of Civil Engineering" as it combined "engineering excellence, hydrodynamic design, and racing technique". (ASCE, 2023) As the competition progressed over years, new competitions were created and added to the Symposium holding the Concrete Canoe Competition. These competitions include ASCE Sustainable Solutions Competition, AISC/ASCE Student Steel Bridge Competition, ASCE UESI Surveying Competition, ASCE Construction Institute Student Symposium Competition, and Concrete Frisbee. (ASCE Symposium, 2023)

With the recently passed Infrastructure Act and additional laws, there is a demand for new civil engineers, structures, and practices. There is much of the world that is still unbuilt, however, there would be no Earth to build on if engineers do not find more sustainable methods to produce steel and concrete. While there is an increase in the amount of recycled structural materials used, the design and construction industry are not as sustainable as the world needs. It is important that the new generation of civil engineers and material sciences find new practices to clean up the industry and that they go forward with these practices from now on.

While the Concrete Canoe Competition is a small subset of civil and construction, it still requires and should set the standard for sustainability in the industry. Reflecting on construction practices and materials for large-scale projects, there are much more sustainable options that could be enforced and widely used such as recycled concrete, steel, and timber. In this prospectus, I will discuss the perception of sustainability, the

opinions of construction and design professionals on the use of these materials, and the current standard and use for sustainability in the industry and within the concrete canoe competition.

ASCE Concrete Canoe Competition

As stated in the 2024 ASCE Concrete Canoe Competition Request for Proposal (RFP), the objectives of the competition includes the opportunity for civil-engineering students to gain hands-on practical and leadership experiences through concrete mix designs and project management, promoting awareness of concrete technology and versatility as a construction material, providing recognition of ASCE, national sponsors, benefits of an ASCE membership, and the innovative profession of civil engineering. Overall, the competition's purpose is to allow students to learn and build technical, social, and professional experience in a project that is critical to society's welfare. (ASCE Concrete Canoe, 2023). The RFP explicitly states the value of innovation design and sustainability over proposed production costs and stresses the impacts on these two topics in the budget, schedule, and safety. Therefore, the main purpose of the competition is to design and construct a prototype concrete canoe with an accompanying product display containing relevant information about the canoe's design, sustainability measures, material, fabrication process, and durability.

The Uva Concrete Canoe team participated in the 2023 Virginia Regional competition for the first time and earned 2nd place. For the upcoming 2024 competition, the team is focused on 3 main goals to gain first place and produce their best product.

1. Create an optimal mix to lighten the total weight of the canoe.

2. Design a hull shape that increases the turnability and maneuverability of the canoe during the races.

3. Introduce further sustainability efforts within the mix and construction methods.

The construction team plans on introducing sustainability in their mold by creating a reusable injection mold that can be used to mass-produce concrete canoes. The frame and all additional ridges of this mold would be made using wood, promoting its re-usable aspect. Compared to last year's mold technique, which was using Styrofoam and was entirety disposable, the construction team is already on track to achieving the third goal listed above. The hull design team is conducting research methods on a flat-bottom versus pointed-bottom canoe shape to achieve the admirable hull shape described in goal one.

With a common goal of sustainability and locally sourced materials, members of the mix team set out to research cement, secondary cementitious material (fly-ash, silica fume, pozzolan, blast slag), aggregates (pumice, shale, Poravor, and aerolite G2 and G3 particle sizes), admixtures (Superplasticizer and air entrainment) mesh types, and concrete fibers. Their observations and test results refined each subsequent mix design and guided them to create the best performing mix. The testing procedure consists of the moisture content of the mix as we combine all the materials, a slump test, and a compressive test for the 3, 7, and 28 day breaks. This year, the mix team is aiming to achieve a high strength, low weight, liquidly mix that would be easily inserted into the injection mold constructed for this year. The team's sustainable efforts include using hydrated lime or more clay-focuses cement to reduce the carbon footprint emitted

through the use of the primary cementitious material and incorporating Poraver expanded glass and natural aggregates into our testing procedures.

Perceptions of Sustainability

Concrete, steel, and timber are the main structural materials used around the world. With the increasing production of concrete and steel to support the need for structures, there should be more discussions on how we, as civil engineers, can reduce our carbon footprint and add to the built environment without harming it. More research is currently being done within the fields of sustainability to support the use of timber structures and re-using concrete and steel elements from structures that have collapsed or are ancient. This critical development demands more attention from industry and especially from the next generation of civil engineers and material scientists. The responsibilities of a civil engineer include designing buildings for not only the community but also for the environment. Changes must be enacted within our existing practices to reverse the generations of damage already done, and these new methods of sustainability must be quickly integrated into our classrooms, workforce, and everyday lives to ensure a future built environment. How can construction and design be more sustainable, and how is the perception of sustainability affecting the environment?

Multiple definitions of sustainability have been used to measure sustainable practice in construction and design. This paper will use the sustainability instrument described in “Measuring Sustainability Perceptions of Construction Materials”. The sustainability instruction has five main factors: quality, functionality, user appeal, resourcefulness, and Purchasability. The quality factors require the product to satisfy

the requirements of the project through a prolonged time. For the product to be functional, the product must be useful and appeal to the user. The resourcefulness factor embodies the sustainable characteristics and extensive use of the materials. Lastly, purchasability depicts the product's ability to bring in purchases and serve as an attraction. (Baladoz, n.d)

Structural steel fulfills many green codes, standards, and rating systems requirements such as LEED. Earlier versions of LEED awarded individual credit for the use of materials that documented a "high percentage of recycled content, a regional origin or a high bio-based content." (Cross, 2015) that ultimately decided what level of LEED certification the project would receive (Certified, Silver, Gold, or Platinum). While the required documentation for LEED certification is increasing, there has not been a decline in LEED-certified structures, meaning that many construction projects will continue to seek a green certification. Currently, there is an increasing number of sustainable building designs resulting in a projection in the number of codes, standards, and rating systems evaluating these designs and construction methods. ASHRAE 189.1 Standard for High-Performance Buildings and the International Green Construction Code (IgCC) have requirements for recycled content, point of origin, and Environmental Product Declarations (EPDs). EPCs were required to encourage product transparency and contain additional information on the environmental impacts of the product such as "global warming potential, acidification, eutrophication, primary energy use and the potential for smog generation." (AISC, 2023)

The recyclability and properties of building materials should not be compared with one another, “a ton of concrete is not the same as a ton of steel or a ton of wood” (AISC, 2023). To accurately compare two materials, the framing structure, location, orientation, size, function, and load capacity must be of similar fit. For example, one may say that wood is more sustainable than steel or concrete and choose it as the primary building material for a large-scale project, but due to the weak strength of timber and lumber, greater quantities are needed compared to steel or concrete. Thus, increasing the number of materials such as water, electricity, labor, etc. needed to create this “sustainable” building. This example shows the frequent wrongful thinking and selection of construction materials based on misleading information that results in increasing rather than decreasing the environmental mark of the building. Therefore, although each material has varying levels of sustainability, not one can be said to be better, the engineer’s goal should be to select the most applicable material that fits the design and then continue to optimize the use of materials environmentally. To gain the maximum benefit of a sustainable building, the engineer must choose the appropriate material for the project and gain proper and accurate information and properties on the material. Although online databases may contain well-organized technical data, perceived aspects of the varying materials are not included. This prospectus includes many studies that have been done to measure the perception of sustainability by professions and what influential factors are guiding design decisions and overall user preferability.

Conclusion

The sustainable efforts of the Uva Concrete Canoe team have set exceptional standards for the quality of sustainable materials needed in the construction and design industry. The constant testing and revision of the mix table done by the mix team are critical to determine if the most sustainable material is the most sustainable option considering all parameters of the project and the properties of the material. While the recycled use of structural steel is greatly emphasized in society, there should be an additional influence on the use of coarse recycled aggregate and electric arc furnace slag for structures that are fit for the mechanical and durability properties of the recycled material. I expect design professionals to begin to investigate the influential effects of perceived sustainable material and choose the material that is best for the project to achieve all five categories of the sustainability instrument (quality, functionality, user appeal, resourcefulness, and purchasability).

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