Concrete Canoe Mix Design Testing

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Introduction

- ASU competes in the annual Concrete Canoe competition in which teams design, construct, present, and race a full-size canoe made out of lightweight concrete.
- A concrete mix is designed to meet minimum strength requirements, adhere to competition rules, have a density less than water, and have an appropriate workability.
- Light-weight concrete is increasing in usage as a sustainable building material because of its lower applied dead load, smaller steel reinforcement demand, and smaller foundation requirements.
- The mix will incorporate new materials to make the concrete mix more sustainable and stronger.

Objective

- This objective for this semester is solving the ongoing problem of designing a faster, lighter, and stronger canoe for annual competition.
- The team's goal was to design a concrete mix with a dry unit weight of 50 pcf, compressive strengths >2000 psi, tensile strengths >500 psi, and flexural strengths >1000 psi.
- Reduce the amount of materials used this year and to allow for more synergistic interaction between the various materials.
- Use sustainable products and reduce the amount of unique materials overall in the cementitious mix design.

Figure 1. Scenario 1 and 4 mortar cubes before and during compression testing.

Materials and Methods

- Cementitious material research and alumni insight was conducted to revamp the mix design process to reduce the materials needed.
- Class C Fly Ash was removed and replaced with Class F to accelerate the cement development when mixed with silica fume and metakaolin.
- The freshly mixed concrete, or mortar, is placed into molds and allowed to set overnight.
- The samples cure for 7 days in a custom curing chamber.
- The samples are compression tested for their 7-day, 14-day, and 28-day strength are tested for their dry unit weight (Figure 1).

Results and Analysis

Scenario 1	
Cementitious Materials	Proportion by Volume
OPC	70%
Class F Fly Ash	20%
Slag	0%
Silica Fume	5%
Metakaolin	0%
Fine Crushed Limestone	5%
Water to Powder Ratio by Volume	0.95
Superplasticizer	~14 mL

Scenario 2	
Cementitious Materials	Proportion by Volume
OPC	60%
Class F Fly Ash	20%
Slag	0%
Silica Fume	7.5%
Metakaolin	0%
Fine Crushed Limestone	12.5%
Water to Powder Ratio by Volume	0.95
Superplasticizer	~7.2 mL

Scenario 3	
Cementitious Materials	Proportion by Volume
OPC	60%
Class F Fly Ash	0%
Slag	20%
Silica Fume	0%
Metakaolin	7.5%
Fine Crushed Limestone	12.5%
Water to Powder Ratio by Volume	0.95
Superplasticizer	~5.5 mL

Scenario 4	
Cementitious Materials	Proportion by Volume
OPC	50%
Class F Fly Ash	30%
Slag	0%
Silica Fume	7.5%
Metakaolin	0%
Fine Crushed Limestone	12.5%
Water to Powder Ratio by Volume	0.95
Superplasticizer	~5.5 mL

Compressive Strength of Scenarios			
Scenario	Average 7 Day Strength	Average 14 Day Strength	Average 28 Day Strength
Scenario 1	5043 psi	5421 psi	5634 psi
Scenario 2	3640 psi	4868.5 psi	TBD
Scenario 4	3974 psi	TBD	TBD

Figure 2. Conference Canoe display from 2018-2019 at Cal Poly SLO.

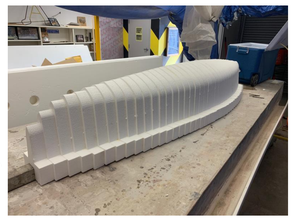

Figure 3. CNC Milled Styrofoam Mold for miniature canoe.

Based on compressive strength data:

- Scenario 1 has shown to be have the highest compressive strength.
- Higher ordinary Portland cement (OPC) ratio corresponds to higher breaking points
- Increases in reduced limestone and silica fume are not as synergistic as initially thought
- Aggregate testing may alter these values and optimized composition will be explored

Conclusions

Based on these results:

- The amount of OPC will remain at 70% of the volume.
- Decreases in metakaolin and silica fume will be explored.
- Superplasticizer must be reduced to adhere to national rules, leading to a potential increase in fine aggregates.
- Slag may not be as beneficial due to similar composition to the OPC.
- Less materials can prove to be more sustainable due to decrease waste.

Future Work

- Future testing will focus on introducing aggregate materials, one admixture, various fiber sizes, switching aggregate sources, testing aggregate gradations, and optimizing the aggregate to cementitious material ratio.
- Testing of scenario 3 will occur once slag material is obtained
- The technical report, enhanced focus areas, and video competition will be completed by the February deadline.
- The team will compete in the Pacific Southwest Conference (ASCE) in March 2021 at UCLA.

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