MPC-560
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Project Title:
Rapid Set Cement for Precast Prestressed Bridge Girder Applications

University:
Utah State University

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Research Needs:
Utah Department of Transportation (UDOT) is a self-proclaimed leader in accelerated bridge construction (ABC). Accelerated bridge construction relies heavily on precast concrete elements in order to minimize bridge construction time, and, therefore, limit its impact on the public. Recent environmental life cycle cost analyses highlight an immediate need to improve sustainability within the precast concrete industry. An industry-wide environmental product declaration (EPD) reported a carbon footprint of over 300 kg CO2 and primary energy consumption of more than 2.6 GJ per metric ton of structural precast concrete. Furthermore, over 99% of material resources consumed were non-renewable. In response to this, the precast concrete industry seeks sustainable alternatives to portland cement for use in precast concrete.

This study will investigate calcium sulfoaluminate (CSA) cement as a sustainable alternative to portland cement in precast concrete. Compared with portland cement, CSA cement offers a 60% reduction in consumption of natural resources, 50% lower associated carbon emissions, and 35% lower embodied energy. CSA cement offers the additional benefits of very rapid hydration and improved durability over portland cement. CSA cement exhibits setting times between ten minutes and one hour, which will allow precast CSA concrete elements to be cast and demolded in a fraction of the time that their portland cement concrete counterparts require. Since CSA-based materials exhibit improved dimensional stability and resistance to chloride ingress, as well as immunity to alkali-silica reaction and sulfate attack, the durability of the resulting precast elements will be exceptional.

Research Objectives:

1. Demonstrate the feasibility and sustainability of manufacturing precast CSA concrete bridge girders;
2. Measure and predict losses in precast CSA concrete girders; and
3. Compare the structural performance of precast CSA and portland cement concrete girders.

The main objectives of the proposed work are to:

1. Demonstrate the feasibility and sustainability of manufacturing precast CSA concrete bridge girders. This will be accomplished by fabricating CSA concrete members at a precast concrete fabricator and compare it to a control member fabricated using portland cement concrete.
2. Measure and predict losses in precast CSA concrete girders. This will be accomplished at the member level using the previously mentioned CSA and control concrete members.
3. Compare the structural performance of precast CSA and portland cement concrete girders. Both members will be tested to failure, with a focus on flexural and shear strength.

Research Methods:

The proposed work will be completed in five stages:

1. ***Literature Review:*** The research team will summarize the state of the art and practice related to the use of CSA cement in the precast concrete industry. The literature review will also identify best practices for delaying hydration in CSA cement and parse all available information related to shrinkage and creep in CSA cement and concrete.
2. ***Design:*** The research team will finalize designs for both the precast bridge girders and the concrete mixtures. The CSA concrete mixture will make use of citric or boric acid retarding admixtures to provide an initial setting time near 45 minutes. The portland cement concrete mixture will replicate the strength of the CSA concrete mixture.
3. ***Casting:*** Four full scale precast concrete girders will be cast by Olympus Precast in Bluffdale, UT. Two girders will be cast with portland cement concrete and two with CSA concrete. Members of the research team will observe mixing, casting, and demolding. Following casting, the research team will meet with key Olympus personnel to discuss the suitability of existing equipment and workflow to precasting with CSA concrete and to identify any potential operational changes that may be necessary.
4. ***Full Scale Testing:*** Full scale testing of precast portland cement and CSA concrete girders will be completed at the Systems, Materials, and Structural Health (SMASH) Lab at Utah State University. One girder of each type will be tested at 28 days. The remaining girders will be tested at much later ages in order to observe prestress losses and to allow monitoring of other losses over time. Mechanically, girders will be tested to obtain estimates of flexural and shear behavior, at midspan and ends, respectively. This will ideally allow for multiple tests per girder. Additionally, estimates of transfer length will be obtained.
5. ***Reporting:*** A final report detailing the objectives, scope, and outcomes of the work will be prepared following completion of the project.

Expected Outcomes:
The proposed work will determine if CSA cement can improve sustainability in the precast concrete industry by lowering embodied energy, carbon emissions, and resource depletion. Additionally, the benefist of CSA will be determined regarding productivity within the precast concrete industry. Finally, this work will contribute to reduced life cycle costs and increased service life in precast concrete structures.

Relevance to Strategic Goals:

- Economic Competitiveness
- Environmental Sustainability

The proposed work directly contributes to the FAST Act strategic goal of Environmental Sustainability by reducing the carbon footprint and embodied energy associated with precast concrete industry. It contributes to the strategic goal of economic competitiveness by improving service life and reducing life cycle costs of precast bridge elements. Finally, it contributes to the strategic goal of livable communities by improving technologies related to accelerated bridge construction (ABC).

Educational Benefits:
A team of undergraduate students will support the experimental phases of the project. The project will be discussed as an example of emerging technologies related to precast concrete in the University's precast concrete design course. Design examples will be developed and made available through the course's website.

Tech Transfer:
Results and findings from the proposed work will be disseminated at domestic and international conferences, including the Annual Meeting of the Transportation Research Board. Furthermore, important findings will be reported to the global concrete and transportation communities through publications in international journals. Results will be summarized in a final project report following the completion of the proposed work. The research team will work with the USU Local Technical Assistance Program (LTAP) to facilitate education and outreach related to the use of CSA cements in local industry.

Work Plan:

1. Literature Review
2. Design
3. Casting
4. Full Scale Testing
5. Reporting

The proposed work will be completed in one calendar year according to Table 1.

Table 1. Timeline and milestones

Task	Description	Month											
		1	2	3	4	5	6	7	8	9	10	11	12
1	Literature Review	■	■										
2	Design		■	■	■								
3	Casting				■	■	■						
4	Full Scale Testing						■	■	■	■	■		
5	Reporting											■	■

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Project Cost:

Total Project Costs:	$119,467.02
MPC Funds Requested:	$59,733.51
Matching Funds:	$59,733.51
Source of Matching Funds:	CEE Department Salary

References:

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