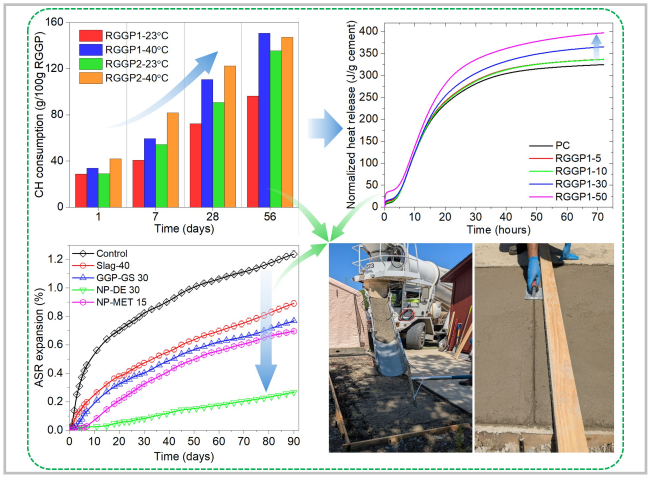
Research Summary

Recycled Ground-Glass Pozzolan (RGGP) for Use in Cement Concrete - and Comparison with Other Alternative Constituent Materials

Research Need

To improve the sustainability of concrete in a practical and cost-competitive way, there is an increasing need to reduce the use of cement in concrete. Commonly used cement replacement materials, such as fly ash and slag, are industrial byproducts that still contribute to the carbon footprint. Recycling waste glass as a pozzolan in concrete is promising; however, there remain knowledge gaps in cement hydration, mix design, quality, and the long-term durability of concrete.



Goals/Objectives

The overall research objective of this project is to evaluate the viability of recycled ground glass pozzolan (RGGP) as a suitable pozzolan for the replacement of cement and as an alternative to traditional supplementary cementitious materials (SCM) to improve the sustainability, quality, and long-term durability of concrete for MassDOT projects. The goals and objectives of this project include:

- A literature review of the current state and existing knowledge gaps.
- A comprehensive understanding of the pozzolanic reactivity of RGGP.
- Insights into the hydration behavior of Portland cement systems containing RGGP.
- Development of mix design formulations of concrete containing RGGP and other SCMs.
- Evaluation of fresh, physical, mechanical, and durability properties of concrete containing RGGP and other SCMs.
- Validation of RGGP-based concrete via casting at ready-mix plants and field tests.
- Specifications and recommended applications of RGGP and RGGP concrete.

Methodology

- Characterization and Enhancement of Pozzolanic Reactivity of RGGP. To characterize the reactivity of RGGP, chemical and mineral compositions, amorphousness, and reaction kinetics between RGGP and calcium hydroxide were investigated.

- The Pozzolanic Roles of RGGP and other SCMs in cement hydration. The evolutions of hydration heat and reaction products were experimentally and thermodynamically tested.

- Concrete Mix Design and Property Evaluation. Ten concrete mix formulations were developed followed by evolutions of fresh, hardened, and durability properties.

- Field Tests. Concrete sidewalks were cast and tested to evaluate the field performance of high-performance concrete containing RGGP.

Key Findings

- The high pozzolanic activity of RGGP was confirmed by its calcium hydroxide consumption, while its activity was strongly influenced by particle size, chemical composition, and temperature.
- The experimental tests and thermodynamic modeling highlighted the pozzolanic role of RGGP in enhancing cement hydration and modifying reaction products, supporting its use in high-volume cement replacement strategies.
- The incorporation of RGGP can result in decreased flowability of fresh mortar, making it necessary to add water reducers or superplasticizers to maintain workability.
- Significant strength increases were obtained from mortar and concrete at 30% and 25% cement replacement levels, respectively.
- Substantial reductions in permeability, chloride penetration, and early-age autogenous shrinkage were obtained in the presence of cement alternative materials.
- The results from both the mortar bar test and accelerated concrete cylinder test confirmed the promising roles of RGGP, other SCMs, and early age carbonation in ASR mitigation.

Use of Findings

- Based on the project findings, ten concrete formulations using RGGP, slag, Class N pozzolans, and nanosilica were developed by modifying the MassDOT-approved high-performance concrete mix design, which have been cast into concrete specimens at a ready mix plant for performance validation.
- The laboratory-tested concrete mix with 25% RGGP ordered from a MassDOT-approved ready-mix plant was cast into sidewalk slabs.
- The outcomes of this project have been used to confirm that MassDOT's current adoption of recycled ground-glass pozzolan and other alternative constituent materials in standard specifications is acceptable.

Project Information

This project was completed as part of the Massachusetts Department of Transportation (MassDOT) Research Program with funding from Federal Highway Administration (FHWA) State Planning and Research (SPR) funds.

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Project Start Date:
September 2023

Project Completion Date:
September 2025

MassDOT Research Project Number:
122821

Key Words:
Glass, pozzolan, concrete, performance

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