Research Project Brief

Report 26-R52: Addressing Fly Ash Shortage with Limestone Calcined Clay Cement

VTRC Virginia Transportation Research Council

Background

Virginia and other states are experiencing increasing challenges with the availability of supplementary cementitious materials (SCMs), particularly fly ash. These shortages threaten the consistency, cost, and performance of concrete used in VDOT infrastructure. At the same time, increasing emphasis has been placed on reducing the environmental footprint of concrete, which necessitates using SCMs to reduce the global warming potential (GWP). Calcined clays have emerged as promising alternative SCMs that may address both material supply constraints and sustainability objectives. However, their suitability for VDOT concrete had not been evaluated.

Research Objectives

The objective of this study was to evaluate limestone calcined clay cement (LC3)—a ternary blended cement (Type IT) typically containing 30% calcined clay and 15% limestone—and LC2, a similar cementitious system produced by replacing 30% of Portland limestone cement (Type IL) with calcined clay, as viable alternatives to conventional cementitious systems used for concrete applications in Virginia, which incorporate Type IL cement with fly ash (Class F coal ash per ASTM C618) or slag cement.

Approach

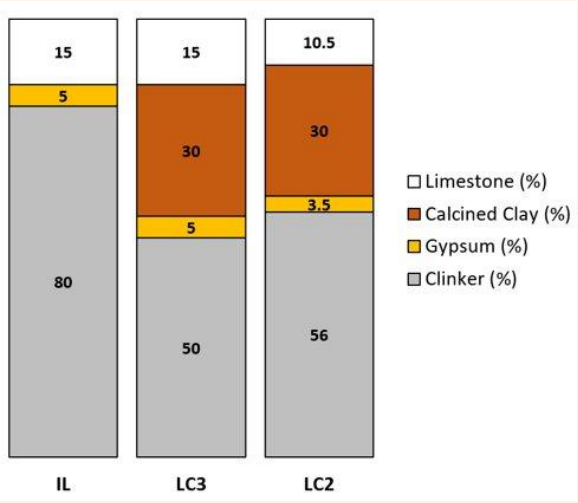
- The physical, chemical, and reactivity properties of calcined clays were characterized.
- The fresh, hardened, and durability properties of VDOT Class A4 General concrete incorporating LC2 and LC3 systems were evaluated.
- The GWP of concrete mixtures was assessed.

Outcomes

Results showed that calcined clays are substantially more reactive than Class F coal ash and more comparable with slag cement. However, their porous micromorphology and high surface area significantly reduce workability, making admixture selection and dosage critical for field placement. At a 30% dosage, a calcined clay produced concrete with performance comparable with or better than mixtures containing 30% coal ash, and air-entrainment behavior was similar to that of the Type IL control mixture—an advantage over fly ash, which often requires higher air-entraining admixture dosages. These findings demonstrate that calcined clays are a viable SCM option that can help alleviate shortages of SCMs.

Research Benefits

This study provides data-driven guidance that can improve long-term material resilience, reduce the environmental footprint of VDOT concrete, and prepare the agency for the adoption of next-generation SCMs and blended cements, including those with calcined clays, which are expected to become more readily available in Virginia in the future.



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Research Findings


Type IL Cement (IL)


Reclaimed Class F Coal ash (RCA)


Grade 120 Slag Cement (SC)


Calcined Clay #1 (CC-1)


Calcined Clay #2 (CC-2)

Summary of Changes Relative to Control IL

Property	Standard	Age (Days)	Concrete Mixtures				
			IL-30CC	LC3	IL-30RCA	IL-50SC	IL-50CC
Slump	ASTM C143	N/A	↓↓	↓↓	↑	↔	↓↓
Air Content	ASTM C231	N/A	↔	↔	↓	↔	↔
Compressive Strength	ASTM C39	7	↔	↓	↓	↔	↓
		28	↑	↓	↓	↑	↔
		196	↑	↑	↔	↑	↔
Permeability	ASTM C1202 AASHTO T358 NT Build 492	28	↓↓	↓↓	↓	↓↓	↓↓
		196	↓↓	↓↓	↓↓	↓↓	↓↓
Drying Shrinkage	ASTM C157	120	↔	↔	↔	↓	↑
Elastic Modulus	ASTM C496	28	↓	↓	↓	↔	↔
		196	↑	↔	↑	↑	↔

↔ = no meaningful change; ↑ = increase; ↓ = decrease; ↓↓ = large decrease

Calcined Clays Suitable

Calcined clays in either LC3 or LC2 systems are suitable for VDOT concrete applications. At a 30% calcined clay dosage, concrete incorporating these systems achieved adequate strength development along with very low permeability.

Sustainability

LC3 lowers the GWP of concrete by an amount comparable with mixtures using a 30% replacement of Type IL cement with Class F coal ash, while delivering similar or better mechanical and durability properties.