UNIVERSITY TRANSPORTATION RESEARCH CENTER

RESEARCH BRIEF

PROJECT TITLE: ENERGY EFFICIENT AND ENVIRONMENTALLY FRIENDLY CEMENT FREE CONCRETE (CFC) FOR PAVEMENT AND BRIDGE DECK APPLICATION

PRINCIPAL INVESTIGATOR: DR. SULAPHA PEETHAMPARAN

INSTITUTION: CLARKSON UNIVERSITY

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Alkali-activated concrete (AAC) is an emerging technology in the construction materials sector. Cement-free AAC is a promising environmentally-friendly alternative to ordinary portland cement (OPC) concrete. A comprehensive study was performed by researchers at Clarkson University to develop energy efficient and environmentally friendly cement-free concrete mixtures for pavement and bridge deck applications. Alkali-activated concrete (AAC) mixtures were developed using slag and fly ash as the sole binder and sodium silicate as the alkaline activating solution.

The effects of water content, air entrainment, alkali concentration, and curing temperature on the compressive strength of the resulting mixtures was evaluated. It was shown that the compressive strength was mainly dependent on the concentration of alkalis (sodium and silicon oxides) in the activator solution. A multiple linear regression model was developed to predict the compressive strength of sodium silicate-activated slag concrete as a function of the sodium oxide and silica concentration, which showed reasonably good agreement with experimental data (R2=0.90). This model is shown in Fig. 1. A similar model was developed for sodium silicate-activated fly ash concrete, but had poor agreement with experimental data (R2=0.65) due to a limited working range of activator concentrations in fly ash binder systems.

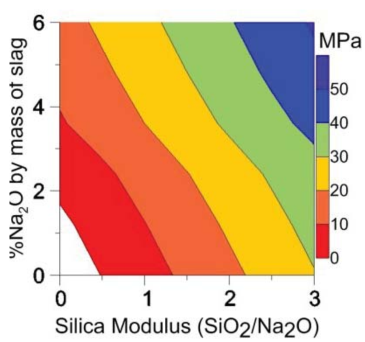

Figure 1: Predicted compressive strength of alkali-activated slag concrete.

Four trial mixtures that had acceptable workability and compressive strength were selected as potential candidates for application in pavement and bridge deck construction. The mixture details are shown in Table 1. The mechanical properties—compressive strength, tensile strength, elastic modulus, and Poisson's ratio—and durability properties—chloride ion penetrability, shrinkage, and susceptibility to deleterious alkali-silica reaction—were evaluated in detail in order to assess the appropriateness of AAC for practical application in transportation construction.

Table 1: AAC Trial Mixture Details

Mix No.	Binder (kg/m3)	Solution/Binder	%Na2O	%SiO2
Slag 0	570	0.40	5.0	3.75
Slag 1	570	0.40	5.0	7.5
Slag 2	570	0.40	2.5	6.25
FlyAsh1	570	0.40	5.0	7.5

*Coarse aggregate bulk volume = 0.50 for all mixtures.

All four trial mixtures had tensile strengths equal to about 21% of the compressive strength, while the tensile strength of OPC concrete is typically about 10% of the compressive strength. The elastic modulus of all four mixtures was much less than typical for OPC concrete, equaling about 600 times the compressive strength. The Poisson's ratio was about 2/3 that of OPC concrete.

The drying shrinkage of AAC cured at ambient temperature was very high, but the shrinkage of heat-cured mixtures was significantly lower. Additionally, all mixtures exhibited deleterious expansion due to alkali-silica reaction. The chloride ion penetrability was measured to be very high, but this was likely due to an incompatibility between the test method and the material.

The AAC trial mixtures have exhibited good mechanical performance. However, additional work is necessary to fully characterize and improve the durability properties of these concretes, particularly with respect to shrinkage, ASR, and permeability.