Waste-to-Energy Ash-Based Lightweight Geopolymer Aggregate

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Background and Motivation

- Waste-to-Energy (WTE) plants produce millions of tons of residues annually, of which fine combined ash (FCA) presents the most potential for reuse as a building material
- FCA is a rich aluminosilicate source, which makes it an appropriate precursor for geopolymerization
- Metakaolin (MK) is also a naturally occurring, abundantly available source of aluminosilicate
- The geopolymers produced from WTE FCA and MK show promise as a sustainable lightweight aggregate (LWA) replacements for ordinary Portland cement (OPC)-based concretes

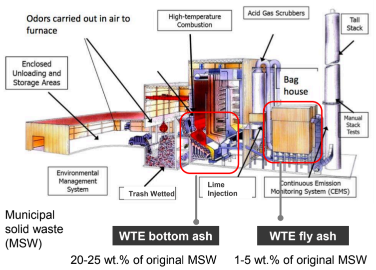


Fig. 1: WTE plant[1]

Geopolymerization

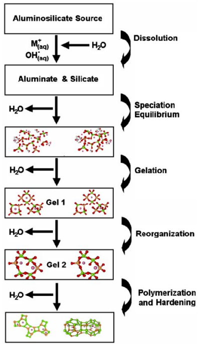


Fig. 2: Geopolymerization Process[2]

Geopolymerization is the reaction of an aluminosilicate precursor under alkaline conditions to produce a hardened binder

- Aluminate, silicate and lime dissolve from FCA and MK and form oligomer networks
- Oligomers then form polymers and harden to produce cementitious materials

Geopolymers avoid high CO_2 emissions associated with OPC production and produce binder from waste by-products of industrial processes

Fabrication

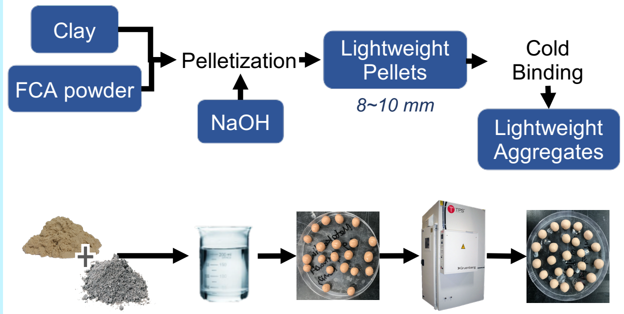


Fig.3: LWA Fabrication Process

Experimental Program

Goal: Determine influence of MK and FCA on geopolymer LWA mechanical properties

	Fly ash %	Metakaolin %	Activator	Liquid/Solid ratio
Control	0	100	8M NaOH	0.7
Low	10	90	8M NaOH	0.7
High	30	70	8M NaOH	0.7

Table 1: Experimental Program

Determine if aggregates have comparable mechanical properties to standard natural aggregates

- Compressive strength and density testing
- Abrasion testing

Identify microstructural and phase differences, and examine differences in fracture surfaces

- XRD
- FTIR
- SEM

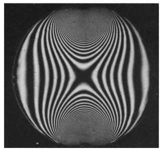


Fig. 4: LWA Stress Fields under Tension[3]

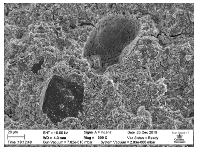


Fig. 5: SEM of 30% FCA – 70% MK aggregate[1]

Results

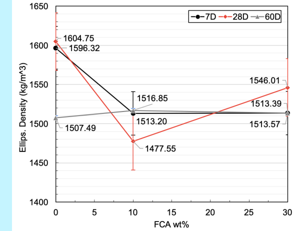
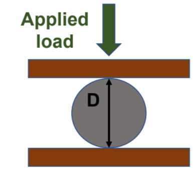


Fig. 6: LWA Tensile Strength v. FCA wt%



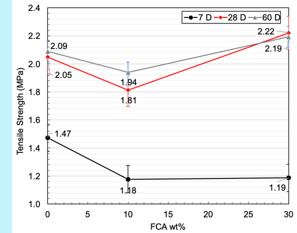


Fig. 7: LWA Ellips. Density v. FCA wt%

- Higher FCA content improves both tensile strength and density of geopolymer LWAs over a period of 60 days
- Specimens fail under tension rather than compression (Fig. 4)

Discussion

- 30% FCA replacement leads to strength comparable to 0% FCA
  - No significant increase in strength beyond 28 days
  - Different composition of precursor likely leads to generation of new gel phases (Fig. 2)
- All geopolymer LWA systems exhibit density within the range of conventional LWHS concretes, i.e. 1450-1850 kg/m^3
- The use of FCA and MK in geopolymer LWAs results in an eco-friendly alternative to to commercial lightweight aggregates
  - Sintering at higher temperatures rather than cold-binding may have implications on strength
  - Different FCA compositions and activator contents may also affect mechanical properties and curing times
  - Improper pelletization may introduce stress concentrations

References

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