

# GEOPOLYMERS, GEO HYBRIDS & THEIR APPLICATIONS IN CONCRETE REPAIRS

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# GEOPOLYMERS, GEO HYBRIDS & THEIR APPLICATIONS IN CONCRETE REPAIRS OVERVIEW

- Sustainability
- What is a *Geopolymer*?
  - What is a *Geo Hybrid*?
- Advantages
- Applications
- Sika Solutions





### GEO HYBRID MORTARS SUSTAINABILITY

- Sustainability, reduced carbon footprint, green are heard every day in the news cycle
- Concrete and most concrete repair materials are based on Portland cement
- Portland cement production accounts for 8% of global CO<sub>2</sub> emissions<sup>\*</sup>
- 1 ton of cement products results in ~1 ton of CO<sub>2</sub> emissions<sup>+</sup>





\* Ref: Chatham House

+ Ref: Scientific American, 2023

## GEO HYBRID MORTARS GLOBAL PORTLAND CEMENT PRODUCTION VOLUME

• Production has leveled off since 2013, likely the result of increased use of SCM's



- Even with Portland cement production leveling off ...
  - 4 Billion metric tons of Portland cement results in 4 Billion metric tons of CO<sub>2</sub>!



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### GEO HYBRID MORTARS WHAT IS A GEOPOLYMER?

- Geopolymer Portland cement-free binder
- "Geopolymerization" coined by Joseph Davidovits in the later 1970's
- Class of inorganic, polymeric materials that form different chemical units of silicates and aluminosilicates ... similar to Portland cement.
- Showed promise as a low/no CO<sub>2</sub> alternative to Portland cement
- Limitations as a result of scale-up and acceptance

In the late 1970's, Joseph Davidovits, the inventor and developer of geopolymerization, coined the term "geopolymer" to classify the newly discovered geosynthesis that produces inorganic polymeric materials now used for a number of industrial applications. He also set a logical scientific terminology based on different chemical units, essentially for silicate and aluminosilicate materials, classified according to the Si:Al atomic ratio:

> Si:Al = 0, siloxo Si:Al = 1, sialate (acronym for silicon-oxo-aluminate of Na, K, Ca, Li) Si:Al = 2, sialate-siloxo Si:Al = 3, sialate-disiloxo Si:Al > 3, sialate link.





### GEO HYBRID MORTARS WHAT IS A GEO HYBRID?

- Geopolymer like
- Utilizes supplementary cementitious materials (SCM's)
- Carbon footprint greatly reduced vs. traditional repair mortars (20-50%)



**Ref: Portland Cement Association** 



### GEO HYBRID MORTARS HOW DO GEO HYBRID MATERIALS WORK?

 The calcium silicates in Portland cement react with water to form hardened cement paste (sometimes called "gel")

$$C_3S + H_2O \rightarrow C-S-H \text{ gel} + CH$$

 CH (calcium hydroxide) is a by-product of the reaction, provides no strength and results in porosity

## SCM + CH + $H_2O \rightarrow C-S-H$ gel

 SCM's react with water and CH to form more "gel" in the micropores, resulting in lower permeability and increased late-age strength



Ref: Frank Hoffman



### GEO HYBRID MORTARS BENEFITS - SUSTAINABILITY

GWP of 1 kg of formulation



Reduction of Portland cement by > 25% and addition of SCM's

**40%** REDUCTION IN GWP WHEN COMPARED TO SIKACEM-226 CI

\* GWP – Global Warming Potential



### GEO HYBRID MORTARS BENEFITS – REDUCED PERMEABILITY

- Lower permeability
  - Longer service life
  - Reduced corrosion of embedded reinforcement

#### ASTM C 1202 – Rapid Chloride Permeability



ASTM C 1202 Results (56 days) - Holland (2012)



### GEO HYBRID MORTARS BENEFITS – REDUCED EXOTHERM

- Lower exotherm
  - Deeper applications
  - Up to 36" thickness in one application without aggregate extension





### GEO HYBRID MORTARS BENEFITS – IMPROVED CHEMICAL RESISTANCE

- Improved chemical resistance
  - Acids sulfuric acid (pH = 1)
    - All inorganic acids
  - Biogenic corrosion H<sub>2</sub>S





### GEO HYBRID MORTARS BENEFITS – IMPROVED ABRASION RESISTANCE

- Improved abrasion resistance
  - Specifically, underwater





ASTM C 1138 – Underwater abrasion resistance



### GEO HYBRID MORTARS BENEFITS – IMPROVED SERVICE TEMPERATURE

- Higher in-service temperature resistance
  - Up to 1000°F (537 °C)
  - Temperature limitations are a result of sand / quartz aggregate





# GEO HYBRID MORTARS

- Early-age strength development
  - Remember: Portland cement must first react with water for the calcium hydroxide (by product) to form C-S-H gel
- Not rapid set
- Very slow or no cure at cold temperatures
- Can be accelerated, but present safety hazards







### GEO HYBRID MORTARS CHALLENGING APPLICATIONS - WASTEWATER



Ref – ChemTech Int'l



### GEO HYBRID MORTARS CHALLENGING APPLICATIONS – SEWERS



Source - MCSP



### GEO HYBRID MORTARS CHALLENGING APPLICATIONS – SLUICE GATES



Source – RUD



### GEO HYBRID MORTARS CHALLENGING APPLICATIONS – MUNICIPAL SOLID WASTE & RECYCLING







### GEO HYBRID MORTARS CHALLENGING APPLICATIONS – MUNICIPAL SOLID WASTE





### GEO HYBRID MORTARS CHALLENGING APPLICATIONS – SULFUR PITS





Source – Beton LLC

### GEO HYBRID MORTARS CHALLENGING APPLICATIONS – HIGH SULFATE SOILS





### GEO HYBRID MORTARS CHALLENGING APPLICATIONS – MASS POURS



Source – NYSDOT



### GEO HYBRID MORTARS CHALLENGING APPLICATIONS – FOUNDRIES



Source – LMM Group



### GEO HYBRID MORTARS SIKA SOLUTIONS





- SikaMonoTop<sup>®</sup> 4500 Geo Hybrid
- Sikacem<sup>®</sup> 900 W

Sikacrete<sup>®</sup> 6000 Geo Hybrid



### GEO HYBRID MORTARS SUMMARY

- Portland cement production accounts for 8% of global CO<sub>2</sub> emissions
- Geo Hybrid mortars result in 20 50% reduction of GHGs
- Geo Hybrid mortars offer many property improvements vs. OPC-based mortars
- No special mixing, handling or safety considerations
- Comparable cost to current technology





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