Properties of Geopolymer concrete

The properties and durability of geopolymer concrete made using flyash have been extensively explored by various universities in Western Australia, as well as around the world.

Published scientific findings have repeatedly concluded that the performance of concrete made from geopolymer cement (GPC) is comparable to that of concrete made from Ordinary Portland cement (OPC).

The most important characteristics that affect the properties of the GPC and resulting geopolymer concrete, are the type, amount and reactivity of the amorphous alumino-silicate pozzolanic particles in materials such as flyash.

The flyash is activated with alkaline reagents such as caustic soda or lye, one of the common names for sodium hydroxide (NaOH), combined with soluble sodium or potassium silicate chemicals, to cause an ambient temperature polymerisation reaction resulting in the formation of cementitious material.

Water-to-geopolymer solids ratio

Work done by Rangan & Hardjito devised the Water-to-Geopolymer Solids Ratio (W/GPS) for Class F flyash. It was found that as this ratio increases, the workability of the mixture also increased as it contained more water; but this results in a decrease in the compressive strength of the geopolymer concrete.

With a fixed W/GPS ratio, Hassan found that the slump value is dependent on the ratio of sodium silicate (Na_2SiO_3) to sodium hydroxide (NaOH), as well as the concentration of NaOH used.

Optimal workability was achieved when the W/GPS ratio was more than 0.22, in addition to the use of a low water absorption grade of aggregates. It was found that workability can be improved by using a naphthalene-based superplasticizer additive.

Silicate-to-flyash ratio

Work done by van Riessen found that the compressive strength of geopolymer concrete increases as the ratio of Na_2SiO_3/flyash is increased, but also decreases as the binder/sand ratio approaches more than 0.5.

Applying the findings of this study, he was successful in creating GPC concrete which achieved a compressive strength of 100 MPa. It was also found that a 20–30% increase in the compressive strength was achieved by first sieving the flyash and only using the smallest particles.

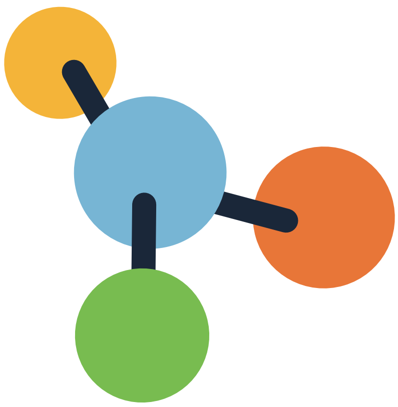
Shrinkage and heat of hydration

GPC concrete has a much lower shrinkage and heat of hydration when compared to OPC concrete.

Additionally, the chemistry of GPC concrete can provide a better resistance to both heat and to chloride attack, making it very suitable for concrete products designed for fire rings, or saline or marine environments, for example.

The Colliecrete project will address the findings of such prior research and use it to build a specific understanding and optimisation of geopolymer cements and geopolymer concretes manufactured from Collie flyashes and other local industrial waste materials.

Ultimately, the project aims to create geopolymer products with unique Intellectual Property (IP) that meet all the required specifications for targeted specific applications.



Geopolymer concrete standards and testing

The most important properties of concrete are durability and workability.

Parameters such as compressive strength and tensile strength measure durability; while a test called 'slump' is used to assess the workability.

Setting time and curing time are important to both workability and durability.

The Colliecrete project will assess, measure and compare all laboratory test and trial products against published industry standards.

Strength

The compressive strength of concrete is measured by how much force is required to crush it, which is important in the design of structures such as bridges and buildings.

In pavements and pavers on ground, the design is usually based on **flexural strength** (how much force the concrete can withstand in bending before it breaks), and some applications require a degree of **tensile strength** (how much it can be pulled before failing).

Compressive strength is the most common assessment, measured by casting three identical, specific sized cylindrical moulds of the concrete in a prescribed manner, and then applying a measured compressive force to the cured concrete until it breaks. This test is repeated on the three samples at 7, 14 and 28 days' curing time respectively.

Compressive strengths of 5-20MPa are typically suitable for non-structural products such as pavers, blocks and footings, 15-30MPa for residential structures, 30-60MPa for commercial structures, and 70MPa and over for high strength applications such as bridges and dams.

Workability

The ease or difficulty of pouring and moulding concrete is called workability. Slump is measured by filling a cone-shaped mould of specific height and width with the wet concrete in a prescribed manner, and then lifting the mould off and seeing how much the wet concrete cone shape collapses down (slumps).

Ideal consistency concrete (**medium slump**) does not crumble as it is discharged, but flows sluggishly without segregation of coarse aggregate from the finer material.

Mixtures of such consistency are suitable for most work, but some applications require concrete that flows more easily (**high slump**) or less easily (**low slump**).

Setting and curing time

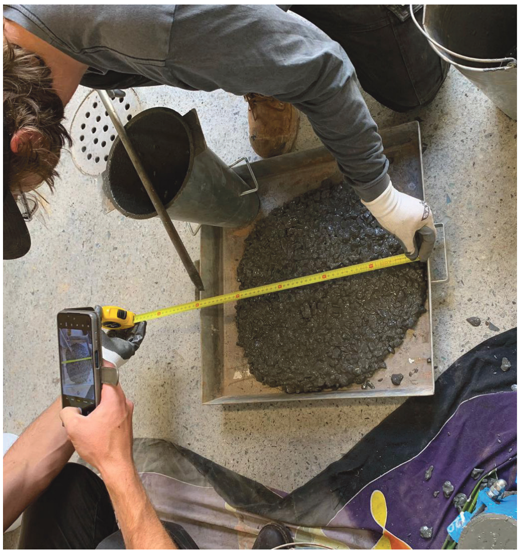
Workability, strength, setting time (the time taken to initially harden so moulds/formwork can be removed), and curing time (the time taken to gain sufficient initial strength), are all interrelated.

Development of a 'recipe' for a concrete product must counterbalance all of these parameters.

Other tests

Other more complex laboratory tests will be used for the research and due diligence purposes.

This may include tests such as flyash particle size distribution, chemical analysis to determine silica, alumina, calcium and other elemental ratios, microscopy and morphology to understand the type and nature of the flyash particles, and environmental impact testing to provide assurance that no unacceptable levels of heavy metals or radioactivity leaching from the geopolymer are experienced.



Applicable industry standards

Industry requirements for concrete are currently demonstrated through Australian Standards such as *AS1379 Specification and Supply of Concrete*, *AS 1012 Methods of Testing Concrete* and industry standards such as *ATIC SP43 – Cementitious Materials for Concrete*.

Specifically, for geopolymer concrete, Austroads has also prepared *Research Report AP-R531-16: Specification of Geopolymer Concrete: General Guide (2016)* and the Concrete Institute of Australia has prepared the guidelines *Geopolymer Concrete; a Recommended Practice (2011)*.

Main Roads WA has detailed specification documentation for specific concrete applications such as pavement, culverts, and kerbing.

Application of Concrete Standards and Specifications

Geopolymer concretes such as that being developed by the Colliecrete Project are innovative products, not yet definitively covered by Standards or published Concrete Specifications, nor yet commonly used or accepted commercially.

As no Australian Standard for geopolymer concrete currently exists, the accepted way of comparing geopolymer concrete against existing concrete specifications is to consider it as Special Class Concrete.

In the specification of geopolymer concrete, the main aspects that need to be considered include:

- the formulation, particularly the binder phase and the aggregate phases;
- performance of the concrete in various tests; and
- workmanship components.

It should be noted that Colliecrete products may involve the simultaneous mixing of all ingredients into a concrete batch without adding a separate cement phase to the aggregates and water in the way that normal OPC concrete is usually produced.

Geopolymer concretes are designed and manufactured to physically perform just like conventional OPC concrete. Both the liquid mixtures and the hardened concretes look and perform physically in a similar manner, although in general, the chemical resistance of geopolymer concretes is far superior.

Standard tests for the mechanical properties of OPC concrete including slump, setting and curing, weight per unit volume, compressive strength, flexural and tensile strength, drying shrinkage, and creep, have been shown to be appropriate for geopolymer concrete as well.

Taking into account all of the Australian standards, concrete industry guidelines, and relevant authority viewpoints, it is Colliecrete's strong view that it is fully appropriate to consider geopolymer concretes produced in Western Australia containing zero Portland cement, such as those developed by Colliecrete, to be covered by AS1379:2007 as Special Class Concretes.

The standard parameters for assessing concretes will be used for testing, assessing and documenting Colliecrete geopolymer concretes according to the Australian Standards AS1012 series, as well as the other Australian Standards and Industry Guidelines as appropriate.