Geopolymer Concrete and its Applications

May 2018 Webinar – Questions and Answers

Austroads

This document addresses questions regarding Geopolymer Concrete and its Applications raised during a webinar broadcast in May 2018. The recording of the webinar can be accessed on the Austroads website.

In which environments will carbonation be a problem?

In atmospheric exposure zones, particularly when RH is around 60%.

Slide 22 - Were metasilicates used in powder form or were dissolved in water to produce studied GP mixes?

In the preliminary experimental work we used both liquid sodium silicate (and NaOH) and powder form of sodium metasilicate, but in the final concrete mixes and in the truck mixes only powder form was used. There are two forms of powder, anhydrous form and pentahydrate (with 5 water molecules), and we found the pentahydrate to be better in terms of workability.

Slide 25 - Mix with higher fly ash content (60%) had higher w/b ratio in comparison to other two fly ash/slag mixes. Was there any issue with quality of the fly ash?

No, fly ash was the same in all mixes, possibly the batch of aggregate or sand may have dried out slightly prior to mixing?

If fly ash and slag is already well used in traditional PC based concrete what is the benefit in promoting GC concrete? It will reduce the availability of these materials as a SCM for PC based concrete.

The argument is to use as much geopolymer binder as possible in order to reduce the CO_2 emission rather than using SCMs with Portland cement which does generate CO_2.

The geopolymer concrete gave better performance than OPC concrete regarding chloride penetration and sulfate attack. If OPC + SCM is used, as is generally the case, what does the comparison look like.

See above, the main aim is reducing use of PC for environmental benefits.

Please advise cost comparison of geopolymer concrete with PC?

Please refer to the literature, we did not undertake this exercise for the purpose of this project. However, it is clear that when costs of mining of limestone and clay as well as burning and grinding the clinker are taken into account the cost would be far greater than the cost of geopolymer which uses already available by-product materials, the main coast being the activator.

The results of VPV and permeability by chloride penetration does not support each other. One showed lower permeability for geopolymer and VPV showed higher. What would be the possible reason?

This was explained during the presentation. The geopolymer products are hydrous gel-like materials, and can lose water on heating (as per VPV method), and this appears as if capillary water was lost from the pore structure, thus showing up as a high VPV value. By contrast the gel blocks the pores which allow the passage of chloride ions and makes their path tortuous, thus restricting the path for the passage of chloride and other ions.

Is any modification to the Concrete Manufacturing Plant required?

Probably not a great deal! You'd need your aggregate, fly ash, and slag silos and water as per normal concrete. The sodium silicate can be used in bag form (like silica fume) and even used and mixed on site after the other ingredients have travelled in the truck to the site. Mixing should be thorough and long enough to ensure mixing is uniform.

Will there be allowance for geopolymer concrete in the revised AS 3600?

This is outside our sphere of influence. VicRoads has allowed geopolymer concrete in several applications, and properly designed geopolymer concrete can be used for structural elements. There are barriers though, including recognition by standards and specifiers.

Alkaline and chemical activators pose OH&S risk. Are there further developments to minimise the risks?

Some activators (e.g. highly alkaline liquids) are more risky to handle, but in powder or flake form they can be packaged like silica fume and used in a much safer manner.

Is geopolymer concrete going to be used on any of the large-scale projects? Has it been encouraged in the project specs?

In Queensland geopolymer concrete has been used to build a structure at Queensland University and in an airport pavement, which are significant structures. Whether geopolymer concrete is specified for a structure depends on the confidence and acceptance of the asset owner.

How is the field performance of GP concrete?

VicRoads has used geopolymer concrete in several structures as non-structural members and they have performed well, as described by Fred in the webinar.

RC Pipes only have 10mm cover to steel. RMS have some charts on how long K = 7 mm/ sqrt y so it is nowhere near 100 years as per slide 53. Has this been overlooked?

There are a couple of points to mention here: first, the accelerated carbonation test which is used to produce data in a short time, grossly exaggerates the tendency of geopolymer concrete to carbonation, due it chemical composition, which is different from PC concrete. Natural carbonation of geopolymer concrete would be much slower. Second, the spun RC pipes that Fred presented have a very low porosity, with a low water absorption of 5.5-6% (~~VPV of 14), and these would not carbonate fast, particularly if the amount of activator is optimised.

Moser/Utah University in their book on pipe design (Moser was at Iowa University who came up with the RCP pipe design equations) discuss how the Calcium Carbonate will seal their 2.5mm crack. We made it 3mm but used the same equations. The concrete water retaining structures code also requires the concrete to have crack sealing capability. Geopolymer cannot self seal. How can it be used for pipe etc?

The self-healing of geopolymer concrete is yet to be established as it does not include much Portlandite. Other components may be able to give it self-healing properties, but I have no information on this aspect. Self-healing occurs by way of narrow cracks becoming filled with fluid which becomes super-saturated with lime on evaporation and leaving a deposit of lime, which then becomes carbonated and calcium carbonate fills the crack. When the crack is too wide, and can't be filled with water (e.g., water will flow through it), then self-healing cannot occur. It is doubtful that a 3-mm wide crack would easily heal even if made with PC concrete.

Pasupathy et al from the 2016 Swinburne University has very high carbonation rates for a geopolymer that will lead to a short life for a low cover to steel applications as in RCP pipe. What is the recommended minimum cover?

Unfortunately the binder formulation for geopolymer concrete can be very varied (no standard). You can produce very poor geopolymer concrete if the mix proportions, including w/b ratio and activator type and amount are not appropriate. Such concretes would develop low mechanical strength, high porosity, and would carbonate fast.

Conversely, you can also produce very low porosity geopolymer concrete with high mechanical strength, which would carbonate much slower under natural exposure conditions, and act similar to PC concrete.

The poor formulation should not be used, rather than making it and designing a cover thickness that would make it last longer!

Swinburn wrote a paper in 2016 on two 8-year old geopolymer blends (meets VicRoads geopolymer spec and can be used pipe at VicRoads). As there is no cement the VicRoads blend cannot seal 3mm max cracks in RCP pipe design (As 3725- 2007). Some authors do not believe the accelerated carbonation tests work for geopolymer but as the mix can vary so much it is hard to know if it was just a good mix. Swinburn had two mixes (type 1 and type 2) both meeting VicRoads the spec but the tests were not accereated with 8 years of age available. Type 1 is 1 year until the carbonation front would reach steel in RCP pipe. (K = 8.3 to 9.8 mm/sqrt y) and type 2 was 4 years for carbonation front to reach steel (K = 2.8 to 5 mm/sqrt y). To get to 100 years a 100% cement S50 concrete or 550kg/m3 of OPC cement needed. So yes you have saved a lot of money and have a >40MPa material but 1 year time to carbonation reaching steel is ridiculously low. Box Culverts have to be 100-year designs but can adjust with more cover. How can a geopolymer be used for RCP pipe if 100 years is the target life? How will 3mm cracks seal?

The first conclusion for the paper that has been cited states the following:

> *Carbonation rate of geopolymer concrete highly depends on the mix design of materials. Type 1 geopolymer concrete, with 75% fly ash and 25% GGBFS and additional Na2SiO3 activator, showed a poor resistance against carbonation compared to OPC concrete. In contrast, the performance of Type 2 geopolymer, with 70% fly ash and30% GGBFS and no additional Na2SiO3 activator, was similar to OPC concrete*.

So Geopolymer concrete Type 2 performed the same as the OPC concrete

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