GEOPOLYMER CONCRETE IN RMC – A CHALLENGE!

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Introduction

Worldwide there is an increasing interest in lowering the carbon footprint of concrete. A possible alternative might be an alkaline-activated binder, nowadays also known as geopolymer binder. From literature, we might learn that a geopolymer binder can perform extraordinarily depending the composition of the binder and hardening conditions. However, experience also shows that the workability of geopolymer concrete is hard to control. Consequently, when a contractor is asking to deliver fresh geopolymer concrete on a building site, all parties involved are facing a 'great challenge'. A major contractor in civil engineering in the Netherlands, Van Hattum and Blankevoort, took the initiative for a trial project. Together with Mebin-RMC, ENCI BV and HeidelbergCement Technology Center a field trial project was organised. The scope of the project was focused on two questions:

- Is it possible to produce a fresh geopolymer concrete mix in an ordinary ready mixed concrete plant (RMC-plant), load a truck mixer, transport the concrete to a jobsite and cast the fresh concrete into a formwork?
- Is there an opportunity to achieve an environmental benefit by lowering the carbon footprint of the concrete compared to the traditional concrete?

The field trial aimed at comparing the performance of a reference concrete (Table 1) with two types of geopolymer concrete by:

- Production in a ready mixed plant: two types of geopolymer concrete, one based on a dry activator- and one on a wet activator system;
- Transporting the geopolymer concrete to the construction site over a period of time of at least 30 minutes. (Figure 1);
- Casting of 4 L-shaped wall elements per type of (geopolymer) concrete (Figure 2).

Composition and Workability

The following requirements on the concrete were defined:

- Strength Class C35/45 (No air entrained concrete);
- Compressive strength for demoulding 15 MPa after 2 days;
- Target workability: S3 (100 – 150 mm) and F4 (490 – 550 mm);
- Workability up to 90 minutes, for transport, pouring and compacting

Figure 1: RMC-plant and construction site

Figure 2: L-shaped elements (in position)

Table 1: Composition of reference concrete and geopolymer concrete

Constituent	Reference Concrete	Geopolymer Concrete	
		Dry binder	Wet binder
CEM I 52.5 R	70 kg	…	…
CEM III/B 42.5 N	280 kg	…	…
Fly ash	…	235 kg	235
GGBFS	…	75 kg	75 kg
Activator + retarder	…	90 kg	140 kg
Super Plasticiser	0.7 kg	…	…
Water	160 kg	120 kg	70 kg
Sand 0-4	790 kg	680 kg	680 kg
Gravel 4-16	565 kg	300 kg	300 kg
Gravel 16-32	540 kg	890 kg	890 kg

A remarkable difference is the amount of coarse material in the geopolymer mixes compared to the reference concrete. This is a necessity due to the high viscosity of the paste consisting of powder and activator. The geopolymer mixes were very sticky. This is also the reason that during the initial laboratory tests the target level for the flow is increased to 600 mm. An increase of fineness would make the geopolymer mix hard to handle.

Production and Field trial

Reference concrete

Besides producing the L- shaped wall elements, the first field trial with the reference concrete was used to train the workers to work with the PPE in order to handle geopolymer concrete safely. For the 4 elements in total 6 m^3 were needed, mixed in two batches of 3 m^3.

Geopolymer Dry binder system

The batching of the Dry binder system started with problems. The silos filled with ggbfs, activators and retarder (Figure 3) could not be emptied fast enough. Therefore, the batching of the 6 m^3 took about 50 minutes in total. Sampling at the back of the truck and transportation to the site took another 30 minutes. The workability was checked on site and was found to be reasonable to start pouring the geopolymer concrete. However, within the next 10 minutes the workability showed a fall back and the threshold for compacting was reached (Figure 5). There was no option than to break down the trial. However, a sudden loss of workability after the designed workability time of 90 minutes was taken into account and therefore emergency actions were defined; about 3 m^3 of water and 1 ton of coarse aggregate were dosed into the back of the truck mixer in order to fully clean the truck before complete setting took place. The L-shaped elements could not be finished (Figure 6) but at the RMC-plant all the scheduled test specimens were cast. The demoulding revealed, in case of the geopolymer test specimen, that an ordinary release agent (Sika AR1) was not able to prevent a strong bond to the steel moulds. Vaseline turned out to perform much better.

Figure 3: Dosing equipment at batching plant

Figure 4: Personal protective equipment on site

Figure 5: Print of poker vibrator, end of open time

Figure 6: Unfinished elements

Due to the experience in this first trial with geopolymer concrete, a few adjustments were applied; the most important was the installation of nozzles on the silos. Starting the production for the second trial, an unexpectedly high moisture content in the fine aggregate (approx. 9 l/m^3) led to segregation of the first batch of 3 m^3. The second batch of 3 m^3 was according specification and showed a good cohesion. The trial was finished within the timeframe of 90 minutes and the concreting went very smoothly.

Geopolymer Wet binder system

Based on the lessons learned from the first two trials with the Dry binder system, concreting with the Wet binder system was done in an improved way. However, the activators, especially the sodium-silicate, had an extremely high viscosity. An unforeseen situation appeared when unloading the truck on site. The Wet binder system, much stickier than the Dry binder, adhered to the inner drum surface and vanes of the truck mixer. It was not possible to empty the truck completely and similarly to the first Dry binder trial, the drum had to be cleaned with an excess of water and coarse aggregate.

Test results and Findings

The main challenge of producing geopolymer concrete in a RMC-plant, transporting it and subsequently casting it into elements was successful. A mix design for a workability (open time) of 90 minutes is possible. The applied mix design turned out to be intolerant for delays. Fresh geopolymer concrete properties are characterised by high stickiness. Additional to the elements, during the trial separate specimens were produced for mechanical and durability testing. A conclusion so far is that the ambient cured geopolymer concrete samples considerably underperform the laboratory results in strength (Figure 7 and 8). Resistance to freeze-thaw with deicing salts appears to be a major drawback, not only confirmed by laboratory tests but also on the elements after two years of exposition.

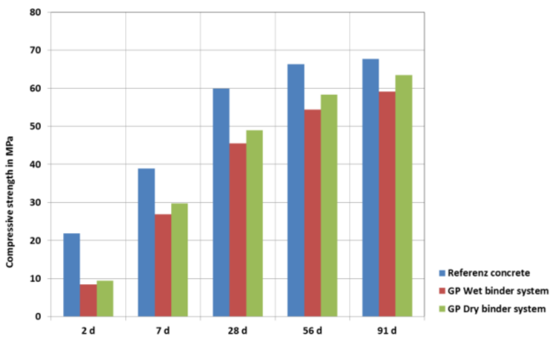

Figure 7: Initial Laboratory Results

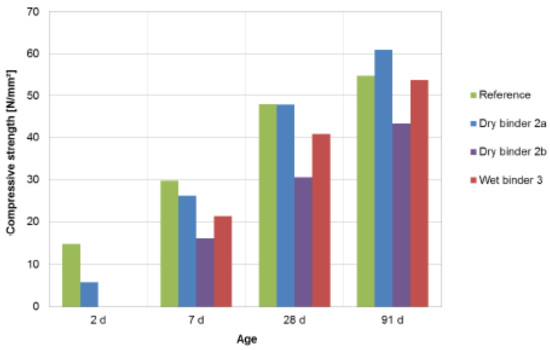

Figure 8: Strength Results Field Trial

General durability needs to be intensively examined and existing test procedures may not fit or need to be adjusted. The main objective of using a geopolymer binder is lowering the carbon footprint of the concrete. It turned out to be very difficult to receive the required data concerning the activators from the chemical industry in order to assess a Life Cycle Analysis (LCA). However, with the limited available data on the carbon footprint of the activators a very rough estimate can be made and shows that some environmental benefit might be achieved. A major drawback is the lack of standards and regulations. The Eurocodes are not applicable for designing a construction with a geopolymer binder.