GGBS on adhesive for tiles systems

CHEMICAL ASPECTS

Ground granulated blast furnace slag (GGBS) is a by-product of the iron oxides reduction. The chemical composition of blast furnace slag is made by different oxide. The major oxide components of slag are calcium, silica, alumina and magnesium. Small quantities of sulphur and other elements are also present. A typical chemical composition of GGBS is showed in Table 1.

CaO	42%
SiO_2	37%
Al_2O_3	11%
MgO	7%
S^{--}	1%

Table 1: Chemical Composition of GGBS

Bibliographical studies lead to the following considerations.

GGBS used on its own shows little hydration. When GGBS is in contact with water, a Si-AI-O rich layer forms on the GGBS particle surfaces. The initial reaction during GGBS hydration produces coatings of aluminosilicate on the surface of GGBS grains within a few minutes of exposure to water and these layers are impermeable to water, inhibiting further hydration reactions. Si-Al-O layer may absorb H+ resulting in an increase in OH- and pH of the solution but this is insufficient to break the Si-O and Al-O bonds to allow formation of the C-S-H, C-A-H and C-A-S-H components. Therefore an activator is necessary. Generally GGBS can be activated adding lime, anhydrite, portland cement or something that can increase the pH, making the system alkaline (pH >7). Then its reactivity can be activated by the calcium hydroxide liberated by the hydration process when mixed with Portland cement.

MORPHOLOGICAL ANALYSIS

Attached to this report it can be found the particles characterization made on a sample of GGBS with MORPHOLOGI G3 (microscope that uses the technique of static image analysis).

The following features were be evaluated:

- *Particle size parameters*:
    - Circle equivalent (CE) diameter: diameter of a circle with the same area as the projected area of the particle image,
    - Length,
    - Width,
    - Perimeter,
    - Area,
    - Max distance,
    - Sphere equivalent (SE) volume: volume of a sphere with the same CE diameter,
    - Fiber total length: the length of the fiber as if it were straightened out,
    - Fiber width.
- *Particle shape parameters:*

- Aspect ratio: the ratio of the width to the length of the particle,
- Circularity: the ratio of the circumference of a circle equal to the object's projected area to the perimeter of the object,
- Convexity: the perimeter of the convex hull of the object divided by its perimeter. The convex hull can be seen as the border created by an imaginary rubber band wrapped around the object,
- Elongation: Calculated as 1- Aspect Ratio,
- High sensitivity (HS) circularity: the ratio of the object's projected area to the square of the perimeter of the object,
- Solidity: the object area divided by the area enclosed by the convex hull,
- Fiber elongation: the expression of the width to length ratio,
- Fiber straightness: value indicating the straightness of the fiber.

• *Particle transparency parameters*:

- Intensity mean: the average of the pixel greyscale levels in the object,
- Intensity standard deviation: the standard deviation of the pixel greyscale levels in the object.

FIRST FORMULATION AND RESULTS

In the fist formulation made with 50% PORTLAND CEMENT 42,5R, 50% GBBS and METAKAOLINO, the calcium hydroxide liberated by the hydration of Portland cement reacts with metakaolin too and there is a surplus of pozzolanic reaction. So the GGBS is not rightly activated.

The consistence of this adhesive is like a gel as result of aluminosilicate coatings on the surface of GGBS grains, produced by GGBS in contact with only water.

Adding 28% of water the system didn't have a good workability. Adding 31% of water workability was better, but there was an excessive slip (about 20 mm, the European Standard UNI EN 12004 imposes a maximum slip value of 0,5 mm).

Furthermore, from the analysis carried out with MORPHOLOGI G3 on samples of portland cement 42,5R and GGBS particles, it can be observed that the GGBS particles are more circular than portland ones. This result could be the reason to have high values of slip.

NEXT DEVELOPMENTS and POSSIBLE SOLUTIONS

1. Remove metakaolin to avoid excess pozzolanic reaction and to activate GGBS.
2. Add lime (calcium hydroxide) to the system.
3. Add 1% of CaO to increase the heat of hydration, the pH of the system and then the reactivity of the GGBS.
4. Replace Portland Cement 42,5R with Portland Cement 52,5R. The system is influenced by heat of hydration. When the heat of hydration is high, the calcium hydroxide liberated by the hydration process of Portland cement is great. Therefore adding Portland Cement 52,5 R to the system could be a way to increase the GGBS reactivity.

In a standard mortar, a mix composed of 50% PORLAND 52,5R and 50% GGBS should be more resistant than a mix made with only PORTLAND (10% more).

5. Add an additive that can be retain the water until the full hydration of the material has accured. This way could also permit the utilization of decreased quantities of water in the mixture, thus appreciably increasing the strength of the hardened system. Such can be realized by adding 0.1% (by weight of the total mixture) of polyvinylpyrrolidone additive.

6. Charge the fillers with higher fine content – BETOFLOW D90 (OMYA) carbonate.

7. Test specific accelerators of GGBS: Anhydride $CaSO_4$ and SodiumSulfate Na_2SO_4.

8. Add a super fluidifying based on melaninsulphonate to increase the GGBS hydration, keeping down the amount of water in the system.

9. Add 0,1% of Precipitated silica (SOLVAY T38AB). The advantages to use it are:

    - precipitated silica has an high specific surface,
    - precipitated silica has pseudoplastic behavior,
    - precipitated silica improves the tyxotropy of the system.