

## WASTE CALCIUM SULPHATE-BLASTFURNACE SLAG CEMENTS, WATER RESISTANCE FROM THE MICROSTRUCTURE DEVELOPMENT

J Iván Escalante-García (1), Alexander Gorokhovskiy (1), Ricardo X Magallanes-Rivera (1), Antonio F. Fuentes (1). (1)Centro de Investigación y de Estudios Avanzados (CINVESTAV-IPN) Unidad Saltillo. Saltillo, Coahuila, México. Email: ivan.escalante@cinvestav.edu.mx

Gypsum cementitious materials are intensively used worldwide for its rapid setting and aesthetics; however, the hydration product  $\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$  is soluble in water, thus is limited to indoor uses.

Nonetheless, considering the worldwide need to reduce atmospheric  $\text{CO}_2$  pollution, gypsum cements are among the most attractive alternatives to portland cement (PC), the latter worldwide industry accounts for 5% of the anthropogenic  $\text{CO}_2$  [1]. Gypsum requires only about 25% of the energy required to produce PC; moreover since there is no decarbonation of raw materials, the  $\text{CO}_2$  emissions are considerably reduced.

Gypsum is not only available in nature; it is also a byproduct of many industries, like the production of HF and  $\text{H}_3\text{PO}_4$ , and also from ceramic plants. The objective of this work was to develop an alternative water resistant gypsum based cement based on industrial wastes, turning a problem of waste management into an opportunity of useful materials. Some ways to improve water resistance of gypsum are reported [2], some are expensive and require periodic attention. Previous reports on commercial gypsum with cement and microsilica [3] and phosphogypsum with slag or PC [4,5] indicate the possibility to solve the water solubility problem of gypsum cement in an easier manner. This research was oriented on combining waste materials such as: (1) Gypsum (GW) from wasted molds used in the jiggering process in a ceramic plant and (2) blast furnace slag (BFS) from the production of pig iron. Mortar systems were investigated in cubes of 5cm, the binder was composed of GW (50, 60 and 70%) and BFS (30, 40 and 50%), 10% of PC was added as an activator. The aggregate: binder ratios were 2.3, 3 and 4, using silica sand (SS) and BFS.

Samples were investigated for up to 120 days. The waste cement mortar specimens developed strength, some up to 200kg/cm<sup>2</sup>, and were stable after curing under water; in contrast, samples of commercial gypsum sustained gradual strength losses. The Microstructures (Fig 1-4) and elemental maps (Fig 1) were characterized by Scanning Electron Microscopy, the samples were mounted in resin and polished to 1/4µm. Those samples with BFS as the aggregate indicated relative dense matrices of hydration products. The matrix was composed of gypsum crystals with a rod-like morphology, which formed in the initial hours since it is the most reactive component of the binder; they were finely distributed and embedded in a matrix of calcium silicate hydrates (C-S-H), and other hydration products. The latter resulted from the subsequent participation of the BFS in the hydration reactions. The C-S-H formed is similar to that formed during the PC hydration, and are responsible for strength development and are insoluble in water. The elemental maps help to identify the components of the microstructure. Al is present only in BFS and help to easily define the aggregate grains or unreacted BFS as binder. Ca and S are helpful to identify the gypsum crystals; nonetheless Ca is also present with Si in the C-S-H hydration products. From the maps and microstructural configuration, it can be noted that the gypsum crystals are surrounded by C-S-H, which prevents gypsum dissolution in water. Regarding the interface **aggregate-hydration products**, for BFS sand mortars, it was dense and continuous; a chemical interaction of the cementitious matrix with the BFS aggregates is thought to enhance the bonding and thus the strength (13.8MPa, Fig 2). In contrast, the mortars with SS showed less compact interfacial zones, only physical bonding is expected to take place, thus strength was lower (10.5MPa, Fig 3). In general it was noted that the use of BFS sand was better in terms of strength compared to SS. Increasing the BFS sand contents (compare Fig 2 and Fig 4) resulted in increased strength, 13.8 vs 16.0MPa. In general, the binder in these alternative mortar systems are of much lower cost compared to PC, furthermore are environmentally friendly and advantageous since wastes are not accumulated, but turned into useful materials. Additionally, the improved strength of mortars with higher aggregate BFS contents, further reduce the cost of the materials (since less milling is required) and makes them of lower specific gravity (due to lower BFS density of 1 g/cm<sup>3</sup>) making them potentially thermal insulating materials. Scanning electron microscopy was useful to determine the mechanism of water resistance of these gypsum based cement mortars

### References

- [1] E Gartner, Cem Concr Res 34 (2004) 1489-1498
- [2] I. Odler Special Inorganic Cements, Modern Concrete Technology Series Vol 8 E&FN Spon 2000
- [3] K Kovler, Adv Cem Res. 1998, 10, No 2 Apr., 81-92
- [4] P. Yan, Y. You, Cem Concr Res 28 (1998) 135-140
- [5] M Sing, M Garg, Cem Concr Res 26 (1996) 449-456

Fig 1 System 60%G-40%BFS, cured 90 days  
aggregate:binder 4:1

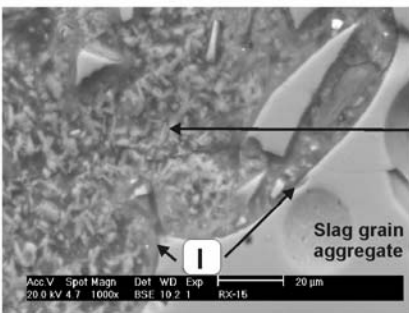
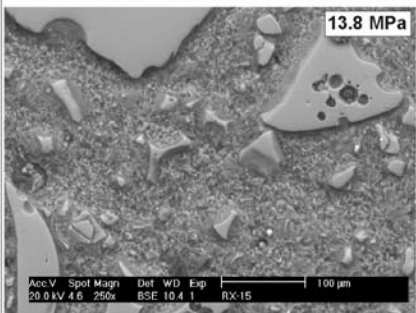
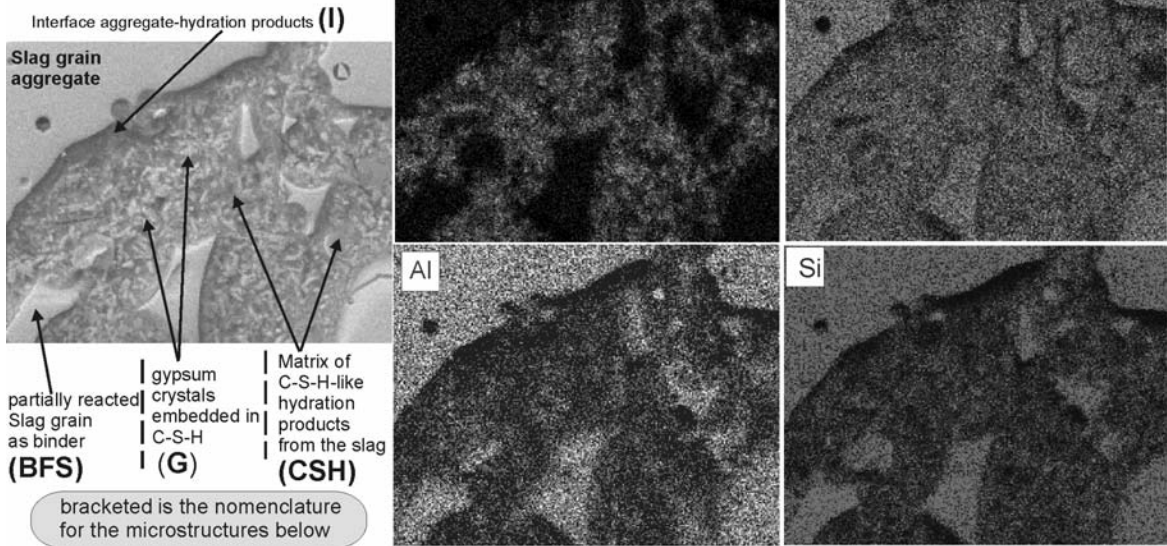


Fig 2 System 70%G-30%BFS,  
cured 90 days  
aggregate:binder 4:1  
aggregate: BFS sand

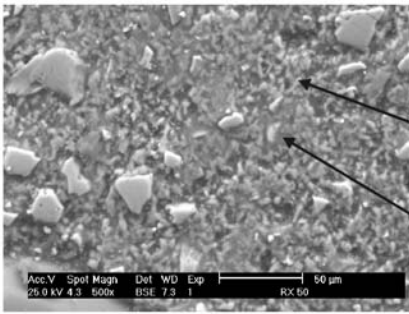
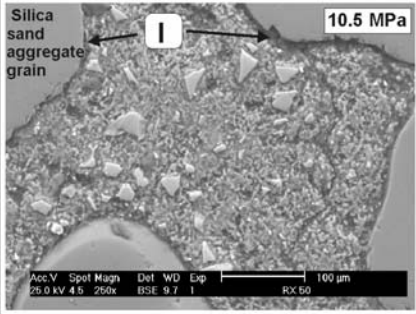


Fig 3 System 70%G-30%BFS,  
cured 90 days  
aggregate:binder 3:1  
aggregate: silica sand

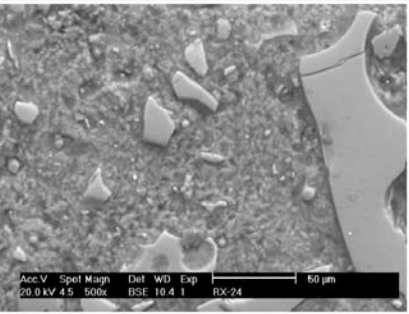
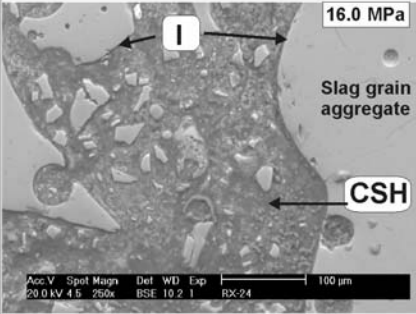


Fig 4 System 50%G-50%BFS,  
cured 90 days  
aggregate:binder 2.3:1  
aggregate: BFS sand