UTILIZATION OF FLY ASH IN CONSTRUCTION BY IMPROVED CHEMICAL BONDING

S. Banerjee, email: subratab@hotmail.com, Telephone: (630) 682-5727, Fax: (630) 682-5804

Answer Technology, Inc., 1879 Jahns Drive, Wheaton, IL 60187

ABSTRACT

Fly ash reacts with phosphoric acid in the presence of magnesium oxide and the rate can be controlled by boric acid. The controlled reaction product results in a hard mass like portland cement concrete that has the strength similar to concrete but has the indentation softness of driving a nail. In this process, the fly ash is bound both by chemical bonding and physical encapsulation. The bonding process takes place irrespective of the carbon content or any type of toxic, hazardous or heavy metals present and the reaction product is not leached by water. The physical and chemical results regarding the bonded mass and the process of making prefab blocks to be used for building construction will be described.

INTRODUCTION

Phosphate bonded ceramics has been known and practiced in dental applications since the turn of the century [1]. Kingery [2] was the pioneer in introducing phosphate bonding with metal oxides for refractory applications. Siliceous material forms a bonding with phosphoric acid. Different metal oxides behave in variety of ways in reacting with phosphoric acid or monoaluminum phosphate. Some of the oxides set at room temperature and some others set at elevated temperatures. Reaction product between magnesium oxide and phosphoric acid or aluminum phosphate does not set at room temperature although it reacts violently but calcined magnesium oxide reacts with phosphoric acid and sets at room temperature with evolution of heat. The concept of chemically bonded phosphate ceramics is based on the initial reaction of calcined magnesium oxide with phosphoric acid. This reaction helps in chemically bonding fly ash, where most of the metals are present in oxide form. It has been well demonstrated [3,4] that the phosphoric acid not only chemically bonds the components of fly ash but also physically encapsulates them to form a rigid body that is not leached out in the presence of water. The principles of the ceramic bonding and formation of the castable to make frefab shapes will be discussed.

PHOSPHATE-BONDED CERAMICS

Several types of cements and mortars[5] based on phosphoric acid and phosphates can be formed from different types of reactions with other oxide materials. Magnesium oxide reacts with different types phosphoric acid and variety of phosphoric acid salts producing a wide range of compounds some of which are water soluble and some of them are not so soluble. Crystalline phosphate species found in magnesium phosphate cements formed from reactions with different acids and phosphates consist of a variety of different species such as, dittmarite, hayesite, newberyite, phosphorresslerite, schertelite, stercorite, and struvite.

Soluble and insoluble phase formation has also been considered in the design of the proposed material. As mentioned earlier, magnesium phosphate formed from magnesium oxide and phosphoric acid is soluble in water, and the insoluble phase is formed only in the presence of aluminum or ammonium phosphates. However, in recent studies[6,7] with magnesium oxide and phosphoric acid in the presence of the controlling agent, boric acid, the insoluble newberyite, $MgHPO_4.3H_2O$ phase is formed. Both physical and chemical bonds are formed, providing the durable fly ash compound resistant to leaching of the contaminants.

PHOSPHATE-BONDED FLY ASH PREFAB BLOCKS

Based on the above principle, castable ceramic pieces are formed by combining fly ash with calcined magnesium oxide and boric acid and then adding the mixed material into predetermined amount of phosphoric acid solution in water (50/50). Since the reaction is associated with evolution of heat, care is taken so that the temperature does not rise to generate foaming. Various kinds of fly ash were taken for the reaction including bottom ash and fly ash containing different amounts of carbon. For confirmation of the indifference of the reaction to the amounts of carbon present in fly ash, activated carbon was added up to 5% in the mix and was found that the reaction products were indifferent to the amount of carbon present. Range of compositions of the castables used for the prefab blocks is:

	%
Fly ash	50-70
Activated carbon	0-5
Calcined magnesium oxide	20-30
Boric acid	3-4.5
Phosphoric acid (50% soln.)	15-20

The mixed castables were then poured into molds for testing. After the wet mix was allowed to set overnight (>24 h), the pieces were demolded and dried at 110°C overnight. The pieces were then tested and the following physical data were obtained:

Bulk density, g/cc	1.70 - 1.78
Open porosity, %	14 - 22
Compressive strength, kg/cm^2	350 - 460

Leaching behavior of the phosphate bonded castables were studied by exposing the specimens into deionized water and acid solutions over a period of three months(8) Determination of the leachate components (such as Cd, Cr, Ni, Pb, Hg, Ce) were studied after the three-month period of immersion. It was found that the leachate components were 5 to 20 times lower than the regulatory limits for each components. Weight losses (gains) and compressive strengths were determined after the immersion period. It was observed that the weight gains (only in acid solutions) were 0 to 2%. The compressive strength of specimens immersed in deionized water gained hardly any strength whereas the specimens immersed in acidic water gained about 20 to 25%. This is due to the fact that the castable retained some unreacted MgO that possibly went to react in the acid solution providing the increased strength.

CONCLUSION

Prefabricated construction pieces can be prepared by reacting fly ash from various sources irrespective of their carbon content by reacting with phosphoric acid solution in the presence of MgO and boric acid by carefully controlling the reaction temperature. The resultant product is lighter but the compressive strength is similar to portland cement concrete and is resistant to water leaching.

References

1. H. Fleck, "Chemistry of Oxyphosphates," Dental Items of Interest, 24, 906, 1902.
2. W. D. Kingery, "Fundamental study of Phosphate Bonding in Refractories," J. Amer. Cer. Soc. 33, 8, pp. 239-250, 1950.
3. A. S. Wagh, S. Y. Jeong and D. Singh, "Development of Value-Added Products from Alumina Industry Mineral Wastes Using Low-Temperature Setting Phosphate Ceramics," Presented at the 4th.. Int. Conf. Alumina Qual. Workshop, June 2-7, 1996.
4. A. S. Wagh, D. Singh, S. Y Jeong, R. Strain, H. No and J. Wescott, "Stabilization of Soil and Waste Water with Chemically Bonded Phosphate Ceramics," Presented at Waste Mgnt. Annl. Mtg. March 2-6, 1997.
5. A. D. Wilson and J. W. Nicholson, "Acid-base Cements," Cambridge University Press, pp. 222-235, 1983.
6. D. Singh, A. S. Wagh, and L. Knox, "Low-Temperature-Setting Phosphate Ceramics for Stabilizing DOE Problem Low-Level Mixed Waste," Part I and Part II, pp. 1853-1862.
7. A. S. Wagh, et al., "Mechanical Properties of Magnesium Ammonium Phosphate Cements and their Zeolite Composites," Cement-Based Materials, pp. 139-52.

8. D. Singh, A.Wagh, S. Y.Jeong and M.Dorf, “Leaching Behavior of Phosphate Bonded Ceramic Waste Forms,” Proc. Amer. Cer. Soc. 1996.