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The comparison of silicate binder refractory concretes with alumina binder concretes

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Abstract

Nowadays refractory products and materials are used widely in different industries, plants and furnaces. Refractory concrete is one of the refractory products which is considered as an unzinpered refractory product. Refractory concretes can be categorized by different parameters. Silicate binder and alumina binder refractory concretes are two kind of refractory concretes which are the subject of this research. Various researches, tests and analysis of variation of refractory characteristics with increasing the temperature show that with respect to silicate binder concrete, alumina binder concrete shows better physical and chemical properties and better refractory specifications in high temperatures and so is used more in manufacturing the refractory products.

Keywords: refractory concrete, silicate binder, alumina binder

1. INTRODUCTION

According to an international definition, refractory products consist of nonmetallic ceramic materials (also the ceramics with a single metallic phase) which have seger cone temperature more than 1500° C. Silicate binder and alumina binder refractory concretes are two types of refractory products which are the subject of this research. The results show that the heating process and high temperatures can affect some properties of these materials. The changes in some physical and chemical properties in high temperatures have been studied in this research and the difference between some general characteristics and temperature-related specifications of silicate binder and alumina binder refractory concretes have been compared [1].

2. DEFINITION OF REFRACTORY CONCRETE

The refractory concrete is a special type of concrete for high temperature usage, which consists of special aggregates, binders, plasticizer liquid and special admixtures if needed, and is considered as an unzinpered refractory product. Special binders are used in this type of concrete which are different in ordinary concrete structures. In normal or low temperatures, reaction between plasticizer liquid and binder harden the mixtures. In these concretes, like other types of concretes, water is necessary for forming and hardening process. During heating process the excess water will flow out of the concrete and by this reason, the amount of water should be carefully optimized in mixture design. Using admixtures and other chemical compounds can improve the curing process and reaching to some special properties [1,2].

3. CLASSIFICATION OF REFRACTORY CONCRETES BASED ON BINDER TYPE

Based on binder type, refractory concretes are classified to four below categories [2]:

1. Silicate binder concrete (like ordinary Portland cement and slag cements);
2. Alumina binder concrete (like alumina cement or high alumina);
3. Chemical binder concrete (like water-glass binder, phosphate binder, magnesia binder or organic binders);
4. Thermal binder.

In this paper, the properties and differences of silicate binder and alumina binder refractory concretes are studied.

4. SILICATE BINDER CONCRETE

4.1. GENERAL CHARACTERISTICS OF SILICATE CONCRETE

In general, silicate binder (such as ordinary Portland cement and slag cements) refractory concretes make durable mixtures which are effective in high temperatures. Basically, all types of silicate cements can be used in refractory concretes but, due to temperature classifications and probability of heating process during the hardening stage, Portland cement is generally used. With increasing very fine fillers in concrete mixtures, the usage of silicate binder is recommended. To increase the functional temperature (the functional temperature of Portland cement refractory concretes is about 1100° C), very fine fillers should be used in mixture. These fillers improve the stability of concrete in high temperatures, decrease drying shrinkage of concrete surface and stick the free CaO to hydrophobic particles and as a result ,so the transmission of the lime is controlled. With respect to selected aggregate for the mixture proportion, the range of specific gravity of silicate binder concretes is between 2.4 to 2.6 gram per cubic centimeters for the ordinary products and 2.6 to 2.8 for preheated ones [1]. According to the standards, for using these types of concretes in refractory industries, the compressive strength of silicate binder concretes after 28-day curing must be at least 15 MPa. In silicate binder concrete structure, different hydrophilic particles in preheated samples can be found [3]. With increasing the volume percentage of aggregate and subsequently increase of voids content, the amount of these new phases will increase in concrete mixture. Also, the increase of preheating temperature to approximately 900°C will result in increase of porosity of concrete; but in higher temperature, porosity will decrease (figure 1). Abrasion resistance of silicate binder refractory concretes is less than zinpered products and for applying this kind of concrete in high friction surfaces, fibers must be used or the amount of porosity must increase; for the reason that concretes with high porosity show better efficiency in high friction surfaces and erosion. One of the preferences of silicate binder concretes in comparison with zinpered product is less amount of permeable gas which is a destructive matterial in refractory industries [1].

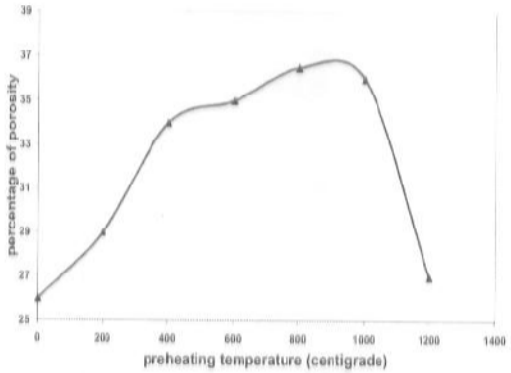

Figure 1. Effect of preheating temperature on percentage of porosity.

4.2. THE EFFECT OF TEMPERATURE INCREASE ON SILICATE BINDER CONCRETE PROPERTIES

In refractory industries, the heating of silicate binder concrete will result in some changes in structure and properties of the concrete. This study shows that after preheating process, the compressive strength of silicate binder concrete decreases to temperature of 800°C and then increases. Also, to temperature of 400°C, the bending strength increases and between 400°C and 1500°C, it decreases to zero (figure 2). The reason of this is the softening phenomenon (plastic creep) which happens in high temperatures. Furthermore, the increase of temperature of preheating process will result in linear decrease of compressive strength. Curing process and temperature of preheating have important effects on strength of concrete. With increasing the preheating temperature, the loading strength of concrete decreases and under severe loading, deformations may happen [3]. Additionally, by improving the curing condition, the concrete will be more efficient under heavy loadings. Figure 3 shows that curing with high temperatures steam and autoclave, increases the loading strength of concrete to a great extent [3].

To 300°C, the silicate binder concretes show no sign of deformation and then with increasing the temperature some deformations appear in concrete and the degree of these deformations depends on the amount of load, time and temperature; in that with increase of each of these parameters, the deformation will become larger. Length change or volume change of concrete depends on contraction of binder, residue expansion of aggregates and the amount of volume change in concretes with different aggregates. Tests for preheating process of refractory concretes show that with increasing the temperature, the heat conductivity of concretes increases whereas in ordinary concretes, increase of temperature do not affect the heat conductivity (figure 4) In addition, with increase of temperature, the permeability of concretes will increases [1].

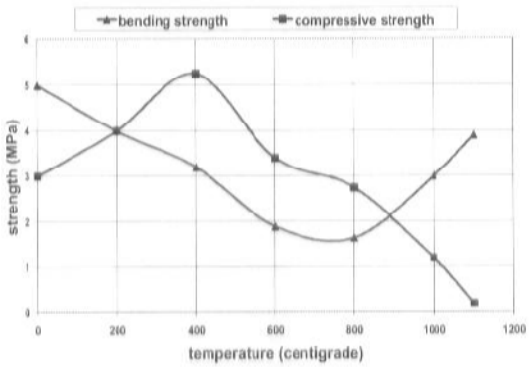

Figure 2. Variation of strength of silicate binder concrete with increase of the temperature

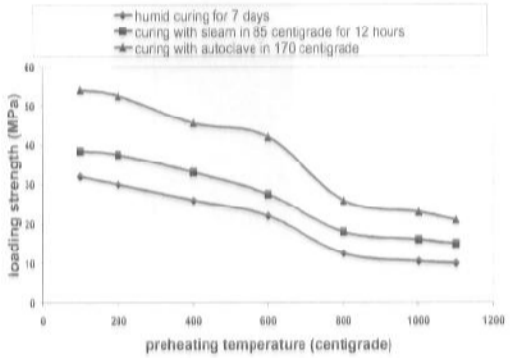

Figure 3. Loading strength of silicate binder concrete with different preheating temperature

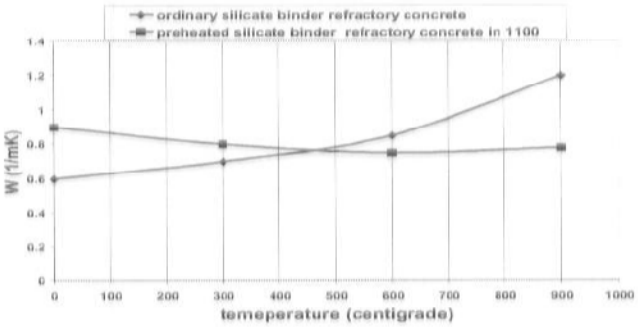

Figure 4. Coefficient of heat conductivity of silicate binder concrete in different temperatures

5. ALUMINA BINDER CONCRETE

5.1. GENERAL PROPERTIES OF ALUMINA BINDER CONCRETE

Generally, alumina binder concretes are famous for their refractory characteristics and are called high temperature refractory concretes. These concretes are produced with different amount of alumina. Alumina cements consist of alumina (Al_2O_3) in low content (45 to 50 percent), normal content (50 to 75 percent), high content (70 to 85 percent) and very high content (more than 85 percent) and are generally used as surfacing material in refractory industries. The effective hydrophobic phases in these cements are $CaO.2Al_2O_3$, $CaO.Al_2O_3$ and $12CaO.7Al_2O_3$ which exist in cement in different contents. With respect to type and quantity of cements used, alumina binder concretes are classified to two groups: alumina-binder concrete (AC) and high alumina-binder concrete (HAC) [5]. Like silicate binder concrete, by increasing the amount of filler in mixture, the refractory resistance will be better. Applying changes in gradation of aggregates and adding some extra amount of filler to the mixture result in producing concretes with less than 20 percent of porosity. Although this process improves the strength and abrasion resistance of the concrete in high temperatures. Moreover, adding fine particles of silica to the mixture, In accordance to standards, improves the quality of concrete. It is important to mention that silica particles produce some melted phases in high temperatures and these phases invisibly decrease the refractory resistance but, if the dosage be controlled under the determined limits of specifications, no weakness will appear [1].
In contrary to silicate binder concrete, the specific gravity and apparent specific gravity of this concrete consist of a wide range and they are mostly dependant of specific gravities of aggregates. The amount of CaO in alumina binder concretes (AC) and high alumina-binder concretes (HAC) decrease from 10 percent to 5 percent and as a result, the amount of destructive melted material (which is a product of heating) decreases during the heating process. Also tests show that in comparison with silicate binder concrete, the alumina binder concrete reaches to more compressive strength during equal curing condition and because of this preference, in refractory industries, the alumina binder concrete is more applied in surfaces with heavy loadings [1].
With respect to silicate binder concrete, one defect of alumina binder concrete is the coarse particles of alumina cement which do not absorb the water and do not hydrate completely. By milling, the coarse particles of alumina cement convert to fine particles and become more efficient and make more strong mixture [1].

5.2. VARIATION OF ALUMINA BINDER CONCRETE PROPERTIES WITH INCREASING THE TEMPRATURE

As usual, the alumina binder concretes show changes as the temperature increases and as an example their porosity after complete evaporation of water reaches to the range of 25 to 40 percent. During the hardening process some variations which are dependant of time and temperature, appear in concrete structure and at last produce some consistent compounds such as $Al_2O_3.3H2O$ and $3CaO.Al_2O_3.6H_2O$ [5]. While increasing the temperature until reaching to 400°C, the compressive strength of preheated alumina binder concrete decreases and after 400°C it begins to increase. Unlike silicate binder concrete the bending strength of alumina binder concrete continuously decreases with increasing of temperature (figure 5). The refractory resistance of these concretes under severe loadings is greater than silicate binder concrete. In these concretes the ordinary samples starts to soften in lower temperatures than the preheated samples and consequently they reach to melting point in a lower time and temperature. This situation, which depends on the kind of aggregate and filler and their refractory properties, usually happen between 1250°C and 1350°C, because the weakened texture can not bear any extra load [3]. Like silicate binder concretes, until 300°C, the alumina binder concretes do not show any deformation sign and after this temperature, the increase of the temperature, time and load would result in larger deformations. Like silicate binder concretes, the coefficient of heat conductivity in alumina binder concrete depends on heat conductivity of aggregates, cement and other parts of mixtures. Figure 6 shows that in these concretes, the increase of the amount of alumina in cement result in larger coefficient of heat conductivity. Also, during the heating process, this coefficient increase continuously [1].

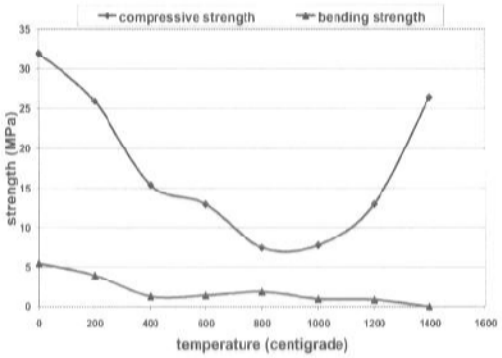

Figure 5. Strength of alumina binder concrete in different temperatures

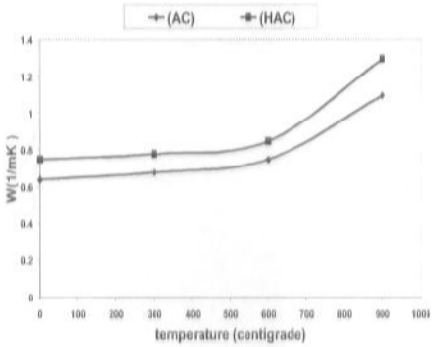

Figure 6. Coefficient of heat conductivity of alumina binder concrete in different temperatures

6. CONCLUSIONS

Finer particles of silicate binder concrete hydrate better than alumina binder concrete and unlike the alumina binder concrete, the specific gravity of silicate binder concrete vary in a special range. In both kinds of concrete, the addition of filler result in improvement of refractory specialties and better abrasion resistance and by increasing the volume of aggregates, more new phases will be formed during the heating process. Also, the increase of temperature, time and load cause the increase in deformations in heating process and the heat conductivity coefficients depend on type of aggregates and with increasing the temperature, this coefficient increase in both concretes. The alumina cements contain less amount of lime with respect to silicate cement and so produces less melting material in heating process. The alumina binder concrete has larger compressive strength, bending strength and abrasion resistance and show better refractory resistance in high temperatures with respect to silicate binder concrete and as a result, with respect to specialties and preferences of alumina binder concrete to silicate binder concrete, the application of these concretes to manufacture different refractory concrete mixtures in different industries, result in improvement of refractory specifications and increase of lifetime of products.

7. REFERENCES

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