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Reduction of Energy Consumption in Manufacturing the Fine Ground Cement

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Abstract: Fine ground cement is a kind of composite binders with a specific surface of 500-550 m^2/kg with a clinker component partially replaced by a silica-containing component (quartz sand, ash, slags, volcanic tuff, etc.). Based on the world-outlined tendencies towards the refocusing of building materials industry to the concretes with low cement content this type of binder shows promise. One of the main factors hampering the widespread of fine ground cements is the increased energy consumption associated with the grinding of its components. During the research we identified patterns of change in the duration of the grinding and the compressive strength of these binders with different contents of siliceous component (quartz sand) depending on their manufacturing method. The possibility of reducing the duration of the production process of fine ground cement by 30% while increasing their compressive strength by 20% was proved.

Key words: Fine ground cements, composite binders, grinding, energy consumption, quartz sand

INTRODUCTION

Currently, there is a global reorientation of building materials industry on the manufacture of concrete with low cement consumption (Pal *et al*., 2003; Felekoglu, 2006; Wang and Lee, 2010). Composite Binders (CB) such as Fine Ground Cements (FGC) and Low Water Demand Binders (LWDB) where a portion (10-90%) of the clinker component is replaced by siliceous component are one of the promising materials that can be the basis for creating high performance concretes (Lesovik *et al*., 2013, 2014; Strokova *et al*., 2013; Suleymanova *et al*., 2013; Sulejmanov *et al*., 2012; Lesovik, 2009). However, there are a number of reasons hampering their widespread use, one of which is a significant energy consumption associated with the manufacture of composite binders.

Currently, there are two ways to produce composite binders (Trunov *et al*., 2012). If the CB is manufactured by a cement factory it will be expedient to use portland cement clinker where in the grinding may be performed using the same mills as those for the manufacture of portland cement. However, such production is uncommon in now a days due to significant costs required for readjustment of the equipment.

The most realistic and releasable method for manufacturing composite binders nowadays is the remilling of commercial portland cement with additives.

It is possible in both cases to carry out single and multi-stage grinding. Single-stage process involves simultaneous filling of all CB components and their joint milling and ignores the difference in particle size and the hardness of the mixture components which may result in increasing the energy consumption of the process, reducing homogeneity of the material grinded and consequently, reducing the qualitative properties of final product.

Multi-stage process involves separate grinding of all components until a specific surface of the finely divided one (e.g., portland cement) and further final joint grinding until a predetermined fineness of the final product. At the same time, the manufacturing process is considerably complicated as compared to single-stage process, however, allows excluding its disadvantages.

The main objective of this research was to compare the duration of grinding and qualitative properties of fine ground cements manufactured by single and two-stage schemes to identify the optimal method of their manufacture.

TECHNIQUE

Fine ground cements were manufactured in a laboratory ball mill by two schemes. The first scheme included joint grinding of portland cement and quartz sand (one-step scheme). The second included regrinding of quartz sand up to a predetermined specific surface (300, 400 and 500 m^2/kg) and further addition of Portland cement thereto and their joint grinding (two-stage scheme). In both cases, the final specific surface of the composite binder was about 500 m^2/kg.

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Analysis of the morphology of the new growths was performed with a high-resolution scanning electron microscope TESCAN MIRA 3 MLU including energy-dispersive spectrometer X-MAX 50 Oxford Instruments NanoAnalysis.

MAIN PART

During the research intended to identify the optimal method of manufacturing fine ground cements, allowing maximum performance of compressive strength of cement stone (R_{comp}) at a minimum energy consumption, quartz sand was used as the siliceous component which was taken in the amount of 30% (FGC-70) 50% (FGC-50) and 70% (FGC-30) of the binder weight.

When analyzing the results obtained, consideration must be given to a number of factors affecting the grinding rate and activity of final binders such as hardness of components their ability to aggregate, the mixing ratio and particle size. The components with a constant particle size, unlike the components with varied granulometric composition will be less prone to aggregation, however, the better the material is ground, the higher its ability to aggregate. In addition, it is necessary to consider the interaction of the components in their joint grinding which will also depend on the hardness of the components and their ability to aggregate. When characterizing the interaction a direct and indirect impact shall be distinguished. Direct impact shall mean an increased adhesion of the particles of the mixture components to each other and their aggregation. If only one component has an ability to aggregate this interaction can either facilitate the grinding process or which is more common, make it more difficult. In direct impact a more solid component may have an abrasive effect on the other. Indirect impact shall mean the impact of the component found in the mixture in excess. Positive or negative nature of this impact depends on the amount of component in the mixture (Ed and Pashchenko, 1991).

The studies have shown that the Time (T) spent to obtain binder with the predetermined specific surface, excluding the manufacturing process, increases together with the proportion of quartz sand in mixture which is natural and is caused by its higher hardness in comparison with Portland cement (Table 1). It should be also noted that two-stage process technology can reduce the duration of grinding on average by 30%. This is due to the fact that most of energy in the process of mixed grinding of components with different grindability is spent on dispersion of a less solid component (Portland cement) which in turn, prevents the destruction of components with higher hardness (quartz sand) and increases the duration of grinding.

Binders produced by applying two-stage technology with the final grinding of quartz sand to a specific surface of 400 m^2/kg are distinguished by minimum time of grinding and maximum compressive strength, excluding the component ratio in the mixture. The increment of strength was 23% for the FGC-30 and FGC-50 and 20% for the FGC-70 after reducing the duration of grinding by 40, 34 and 32%, respectively.

Binders obtained by two-stage technology with the final grinding of quartz sand to a specific surface of 500 m^2/kg have minimum activity indices which can be explained by the fact that the increase of dispersion of silica sand reduces the time of mixed grinding of binder components and consequently reduces the fineness of the cement particles which results in losing the strength. Reduction of this indicator in binders produced by joint component grinding can be explained by the fact that the cement particles included in their composition will be more

Table 1: Properties of fine ground cements produced by different technologies

FGC-30			FGC-50			FGC-70		
Sspec (m^2/kg)	T^* (min)	Rcomp (MPa)	Sspec (m^2/kg^{-1})	T^* (min)	Rcomp (MPa)	Sspec (m^2/kg)	T^* (min)	Rcomp (MPa)
Single-stage grinding								
535	50	12.48	537	35	29.03	528	25	38.70
Two-stage grinding (the specific surface of silica sand 300 m^2/kg)								
540	35	13.32	548	25	31.36	523	18	44.63
	12			5			3	
The specific surface of silica sand 400 m^2/kg								
538	30	15.37	522	23	35.88	518	17	46.27
	15			8			5	
The specific surface of silica sand 500 m^2/kg								
533	36	10.08	527	24	26.50	520	19	30.20
	30			15			13	

[*] Numerator = the total time spent on grinding of the binder (time spent on grinding of quartz sand+mixed regrinding); denominator = the time spent on grinding of quartz sand

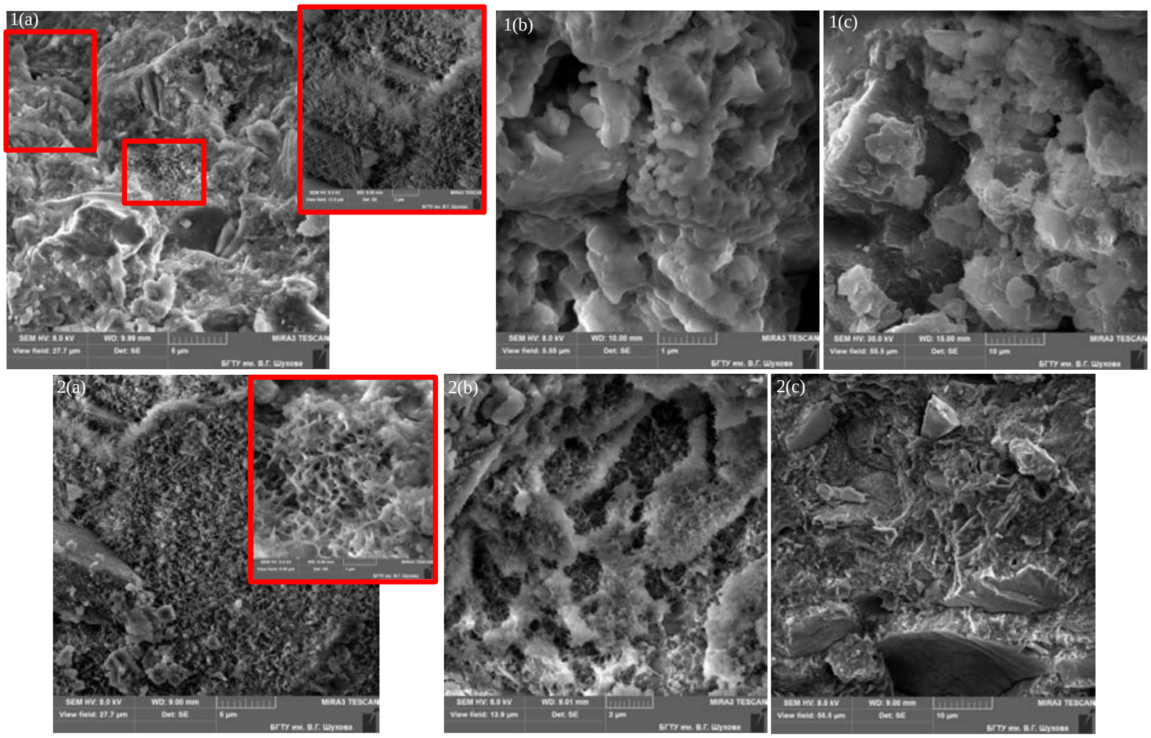

Fig. 1: The microstructure of the composite binders; 1a) FGC-70; 1b) FGC-50; 1c) FGC-30) produced by single and 2) two-stage technology with a final grinding of quartz sand to a specific surface of 400 m^2/kg

fine due to the abrasive action of quartz particles which in turn leads to an increase in water demand and sediment deformation of composite binders and results in losing the strength.

Analysis of the microstructure of the composite binders produced by joint (single-stage) and separate (two-stage) component grinding revealed differences in the nature of the new growths. The most defined structural units were found when considering the FGC-70 due to the large amount of clinker component. The FGC-70 produced by joint component grinding is characterized by a dense mass composed of poorly faceted, poorly crystallized and probably, X-ray amorphous new growths with a loose mesh of columnar newgrowths in the cavities (Fig. 1a). At the same time this type of binder produced by separate grinding of Portland cement and silica sand with further regrinding of the latter up to 400 m^2/kg is characterized by finer needle-like new growths forming a dense system (Fig. 1a). There are also grains of quartz firmly coated with hydration products which indicates a good adhesion of the aggregate grains with the cementing substance.

The microstructure of the FGC-50 produced by joint component grinding is represented by a large number of well-formed crystals of portlandite surrounded by X-ray amorphous substance (Fig. 1b) while the application of separate technology promotes the formation of binding needle-like new growths filling the pore space (Fig. 1b).

Analysis of morphology of new growths was hampered due to insignificant clinker content in the FGC-30 and its more effective moisture content in comparison with the FGC-70 and FGC-50. However, it should be noted that the bulk of this type of binder, prepared by joint component grinding is loose and consists of separate aggregates in the form of flakes surrounded by the pore space with rather poor contacts (Fig. 1b).

While the microstructure of the binder produced by two-stage technology has less pores and microcracks as well as more dense contact zone of quartz sand particles with the bulk (Fig. 1c) which may be due to a more homogeneous granulometry of the particles.

DISCUSSION

During the experiment, we identified the patterns of change in activity and time spent for the grinding of fine ground cement according to the method of manufacturing of composite binders, the amount of quartz sand in the mixture and its initial specific surface.

It has been proved that regardless of the mixing ratio, the use of separate grinding allows reducing significantly the duration of the manufacturing process of composite binders due to reducing the negative impact of particle aggregation. Thus, the final grinding of quartz sand to a specific surface of 400 m^2/kg is the most expedient method which can reduce the time for and consequently, the energy consumption in manufacturing the composite binders on average by 30% with the increase in their activity by 20%.

CONCLUSION

Based on studies of the microstructure of the composite binders, we can make a conclusion that the use of a two-stage process (with the final grinding of quartz sand up to 400 m^2/kg) to obtain a fine ground multicomponent cement promotes the formation of more dense homogeneous structure which determines the strength increment in comparison with CB, produced by one-stage technology.

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REFERENCES

Ed, A.A. and K. Pashchenko, 1991. The Theory of Cement: Monograph. Publishing Hous, Budivelnik, Pages: 168.

Felekoglu, B., 2006. Utilisation of Turkish fly ashes in cost effective HVFA concrete production. Fuel, 85: 1944-1949.

Lesovik, R.V., 2009. Activation of aggregate of composite binders. Bull. V.G. Shukhov Belgorod State Technol. Univ., 1: 87-89.

Lesovik, R.V., M.S. Ageeva and M.I.H. Shakarna, 2013. Efficient binding using composite tuffs of the middle east. World Applied Sci. J., 24: 1286-1290.

Lesovik, R.V., S.V. Klyuyev, A.V. Klyuyev, A.V. Netrebenko and N.V. Kalashnikov, 2014. Fiber concrete on composite knitting and industrialsand KMA for bent designs. World Applied Sci. J., 30: 964-969.

Pal, S.C., A. Mukherjee and S.R. Pathak, 2003. Investigation of hydraulic activity of ground granulated blast furnace slag in concrete. Cem. Concr. Res., 33: 1481-1486.

Strokova, V.V., I.V. Zhernovsky, Y.V. Fomenko and N.V. Makarova, 2013. Regulation of fine grained concrete efflorescence process. Applied Mech. Mater., 357: 1300-1303.

Sulejmanov, L.A., I.V. Zhernovsky and A.V. Shamshurov, 2012. Special composite binders for non-autoclave curing concretes. Bull. V.G. Shukhov Belgorod State Technol. Univ., 1: 39-45.

Suleymanova, L.A., K.A. Kara, K.A. Suleymanov, A.V. Pyrvu, D.D. Netsvet and N.P. Lukuttsova, 2013. The topology of the dispersed phase in gas concrete. Middle-East J. Sci. Res., 18: 1492-1498.

Trunov, P.V., N.I. Alfimova, Y.Y. Vishnevskaya, and E.I. Yevtushenko, 2012. Influence of grinding method on the energy consumption of the manufacturing process and qualitative properties of composite binders. Bull. V.G. Shukhov Belgorod State Technol. Univ., 4: 37-39.

Wang, X.Y. and H.S. Lee, 2010. Modeling the hydration of concrete incorporating fly ash or slag. Cement Concrete Res., 40: 984-996.