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Assessing the Impact of Binder Components' Dispersion on the Properties of Composite Materials Based on Milled Slag and Clay

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Abstract

The article studies the forming the structure of certain composite materials.

Keywords: heat-resistant composite materials, components' dispersion, location of particles, strength characteristics

1 Introduction

In a combination with clays of optimum mineralogical structure milled metallurgical slags in the presence of an alkaline activator are capable to form the hardening structure that is a basis to receive clay-slag composites [1-3].

Extremely important role in formation of durability, contraction and crack resistance is assigned to compositions' polystructure. Influence of the polystructure on kinetics of hardening process with qualitative assessment of durability's formation needs to be considered by proceeding from scale levels of components’ particle sizes, clustering and structural topology of the relative arrangement of particles [4].

The topology of components’ placement in mixed binder’s structure at the equal mass content of clay and close dispersion’s slag is rather simple. Ideally slag and clay particles are placed practically in chessboard order.

More composite options of particles’ placement arise at different dispersion, that is to say options arise at their various calculating concentration caused by more fine grinding of less fissile component of a binder (clays) or its higher mass dosage in comparison with slag.

2 Experimental study

Let's consider mixed binder’s topology on condition of an arrangement of more rough slag particles in the elementary cubic laying or close to it.

The clay of the Issinsk field of the Penza region and milled metallurgical slag (Lipetsk) with optimum properties and structure were used as binder’s components.

At a ratio slag:clay=60:40 and specific surface area of slag=320 m^2/kg, 580 m^2/kg, and clays – 320 m^2/kg, 596 m^2/kg or 840 m^2/kg, an average particle size, accepting its conglobate, will be respectively equal: for slag – $6{,}46\cdot10^{-6}$m, $3{,}57\cdot10^{-6}$m, for clay – $7{,}41\cdot10^{-6}$m, $3{,}97\cdot10^{-6}$m and $2{,}82\cdot10^{-6}$m.

The ratio *C* – quantities of clay particles to slag particles can be calculated if calculating particles’ quantities of each component are known. They can be calculated like:

$$n_s = \frac{6m_s}{\pi \cdot \rho_s \cdot d_s^3} \quad (1)$$

$$n_c = \frac{6m_c}{\pi \cdot \rho_c \cdot d_c^3} \quad (2)$$

Where n_s, n_c - quantity of slag and clay particles;

m_s, m_c - masses of slag and clay in a mixed binder in unit shares;

ρ_s, ρ_c - slag and clay density;

Then the ratio between quantity of clay and slag particles will take form:

$$C = \frac{n_c}{n_s} = \frac{m_c \cdot \rho_s \cdot d_s^3}{m_s \cdot \rho_c \cdot d_c^3} \quad (3)$$

or using a specific surface area

$$C = \frac{m_c \cdot \rho_c^2 \cdot S_c^3}{m_s \cdot \rho_s^2 \cdot S_s^3} \quad (4)$$

where *Sc, Ss* - specific surface areas of clay and slag:

3 Results and discussion

Substituting the received values of *m* and *S* in a formula (4) and taking into account the ratio of binder components Clay (C):Slag (S) =0,4:0,6, we will receive:

• for Ss=320 m^2/kg and Sc=840 m^2/kg with C=0,048, that is 20,83 particles of clay are the share to one particle of slag;
• for Ss=320 m^2/kg and Sc=320 m^2/kg with C=0,88, that is 1,14 particles of clay are the share to one particle of slag;
• for Ss=320 m^2/kg and Sc=596 m^2/kg with C=0,136, that is 7,35 particles of clay are the share to one particle of slag;
• for Ss=580 m^2/kg and Sc=320 m^2/kg with C=5,22, that is 5,22 particles of slag are the share to one particle of clay;
• for Ss=580 m^2/kg and Sc=840 m^2/kg with C=0,25, that is 3,57 particles of clay are the share to one particle of slag;
• for Ss=580 m^2/kg and Sc=596 m^2/kg with C=0,8, that is 1,25 particles of clay are the share one particle of slag.

In the first case the sphere from more shallow particles of clay is located round each particle of slag. Thus, there is a thin layer of clay particles between particles of slag.

In the second case (as well as in the sixth) one particle of slag is the share to 1 particle of clay. Framework of material will consist of adjoining particles of slag and clay, particles of binder's components will settle down almost in chessboard order. And, if in the first case a possibility of contact of slag particles among themselves is practically excluded, there is because of a lack of clay particles expense a creation of a framework with regulated particles' arrangement is impossible. It is also worth noticing that it is possible only conditionally to call clay by particles as in this case particles actually are strong units: clay was milled in a dry form to the given fineness and its specific external surface area much below, than the true specific surface area of clays that reaches 40-80 m^2/g.

For the hydration durability and durability on dry condition the third case represents particular interest where clay has maximal, higher surface, than slag (tab. 1).

Compression strength, both in initial, and in normative terms of hardening, as appears from the received results, increases with dispersion's increase of self-contained hardening binder's component – slag.

At the same time at excess of a specific surface area of clay over a slag surface strength characteristics raise that possibly is explained by the best conditions for binding of clay's thin particles by slag hydrosilicate and hydroaluminate calcium new growths or by products of clay and slag interaction in an alkaline condition of NaOH.

Table 1: Physics-mechanical properties of clay-slag composites with various degree of binder's components dispersion

№	Density in the dried-up state, g/cm3	Porosity, %	Mix, humidity %	Formation type	Ssp, m2/kg Slag/clay		Compression strength in the wet state in 28 days, MPa	Compression strength in the dried-up state, MPa	Thermal resistance, cycle	Loss of strength after an incideration, %	Softening coefficient Ksoft
1	1,95	29,17	12	Pressing P=20 MPa	1:1	320/320	20,0	36,6	6	43,2	0,54
2	2,00	27,32			1:1,86	320/596	31,1	52,7	9	12,3	0,58
3	2,02	26,51			1:2,6	320/840	49,3	57,7	6	23,8	0,85
4	2,01	29,91			1:0,53	580/320	27,2	45,8	7	57,2	0,59
5	2,03	26,22			1:1	580/596	41,4	55,5	7	53,2	0,74
6	2,1	23,63			1:1,4	580/840	51,7	63,8	8	53,0	0,81
7	1,75	36,36	34	Vibrocompaction	1:1	320/320	12,4	19,4	7	62,9	0,63
8	1,77	35,63			1:1,86	320/596	12,4	22,1	6	45,7	0,56
9	1,83	33,45			1:2,6	320/840	17,2	21,8	7	47,5	0,78
10	1,81	34,18			1:0,53	580/320	12,4	28,2	7	68,1	0,47
11	1,82	33,82			1:1,1	580/596	13,3	32,4	6	81,5	0,38
12	1,88	31,63			1:1,4	580/840	18,7	32,7	6	78,0	0,57

It is necessary to give preference to the third structure between two pressed structures – the third and sixth, that are close on indicators of durability in 3, 28 days of normal hardening and strengths in dry condition. For it slag dispersion, equal 320 m^2/kg, significantly reduces energy consumption on a grinding in comparison with slag with Ssp=580 m^2/kg. Besides, the loss of durability after incineration is also lower than the sixth structure has and depends a little on components' dispersion in the researched interval.

If to take into consideration a thermal resistance of an unfilled matrix, it does not exceed 6-8 cycles for all structures and its increase is connected with optimization of filling the matrix with a heat-resistant material and creating crack-proof structure of composite according to Komokhov P. G. [5].

4 Conclusion

Thus, studying of topological characteristics of formatting heat-resistant clay-slag binder's structure allows to pick up optimum structure of a heat-resistant clay-slag binder from the point of view of improving strength and operational material's characteristics. Maximum efficiency can be reached if slag with Ssp=320-350 m^2/kg and clay with Ssp=600-800 m^2/kg at ratio Ss/Sc=1,8-2,5 will be used.

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