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STUDY OF CHANGE IN THE SCM'S STRENGTH PROPERTIES DEPENDING ON THE AQUEOUS-CLAY SUSPENSION'S CONCENTRATION AND MUSCOVITE'S AMOUNT IN ITS COMPOSITION

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ABSTRACT

This article represents the results of the study of change in aqueous clay suspensions' (ACS) electrostatic properties depending on muscovite's concentration in their composition. The influence of ACS' concentration and muscovite's varied amounts in the composition of mechanically activated bentonite clay (Chernogorskoe field) used as a coupling agent in molding sand mixtures for steel and cast iron casting, on the mixture's strength properties has been studied. The increase in the sand-clay mixture's (SCM) strength properties and gas permeability depending on the ACS's and muscovite's concentration has been established.

Keywords: zeta-potential, aqueous clay suspension, strength, friability, muscovite, electrostatic properties, clay.

1. INTRODUCTION

Bentonite clays are one of main nonmetallic mineral resources that are widely used in various industries (Kravchenko and Sapargaliev, 1996), in particular in the foundry production where they are widely used as they are easily decomposed in the liquid medium into elementary particles, i.e. a part of cations detaches from the clay particle's surface and forms hydration shells around it (Zhukovsky and Boldin, 2002; Trofimova and Teterin, 2004; Matveenko and Kirsanov, 2011). The quality and method of preparation of bentonite clays directly influence aqueous clay suspensions' property, which ensures the SCM's high technological properties. The main properties are as follows: compressive strength in a wet condition, gas permeability and humidity (Berg, 1970). Humidity can be monitored in the course of its preparation, but the mixture's gas permeability and strength depend on: the coupling agent's nature, the quantity and condition of clay that is included in it; the method of its preparation and introduction to the SCM; molding sand's grain composition; the mixture's compaction degree and additional factors (Kravchenko and Sapargaliev, 1996; Zhukovsky, 1985; Illarionov and Vasin, 1995). When choosing the mixture's composition, it is necessary to provide the SCM with rather high gas permeability at the mixture's assigned strength (Grigor, *et al*, 2011) sufficient for preventing the mixture's breaks and friability when it is exposed to a flow of molten metal.

When bentonite clay interacts with water, aqueous clay suspensions' electrostatic properties change depending on the preparation method and activation modes. Aqueous clay suspensions' (ACS) electrostatic properties (zeta-potential, surface charge, double electric layer's size, Maxwell-Wagner frequency, etc.), when increased, ensures a rise in stability of a resulted colloidal system (Tumanova and Kvasha, 2011; Belyaev and Yuryev, 2014; Zontag and Shtrenge, 1973; Mamina, *et al,* 2013; De Souza, *et al,* 2010; Trukhan, 2012; Bychkov, *et al,* 2000), which, when considering clay from the point of view of the stability of the ACS (Gelfman, *et al,* 2010; Efimov, 2007), influences the distribution of a clay component in the molding sand mixture and molding sand mixtures' plasticity and strength (Mamina, 1989).

2. EXPERIMENTAL PROCEDURE

As a result of the earlier experiments (Belyaev and Yuryev, 2014), it is established that an optimum activation time in the Retsch PM 400 MA planetary ball mill, at a volume ratio of materials to grinding bodies of 1:1 and when introducing muscovite (from 1 to 6%) of the weight of the bentonite clay being studied is 90 sec. The zeta-potential (electrostatic properties' resulting characteristic) has increased by 28.5% up to 33.41 mV when studying 5% ACSs with the 3% content of muscovite in the composition of clay (Belyaev and Yuryev, 2014; Zontag and Shtrenge, 1973; Mamina, *et al,* 2013). The zeta-potential of bentonite clays (Chernogorskoe field) mechanically activated for 90 sec. with a various amount of muscovite immediately after the ACS' hydration and after 24-hour settling is presented in Figure-1.

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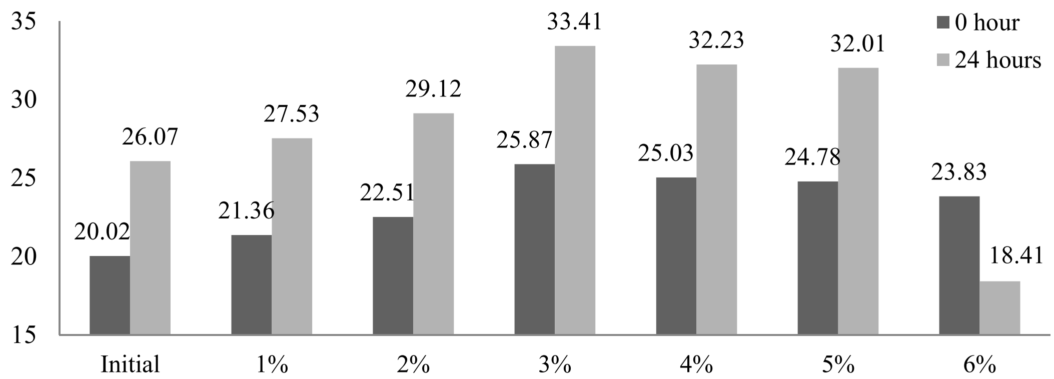

Figure-1. Zeta-potential of the ACS with clay mechanically activated for 90 sec. (Chernogorskoe field) at a various amount of muscovite (1-6%).

Molding sand (Kichiginskoe field) has been used in the process. The grade of molding sand has been identified depending on the clay component's content (GOST 29234.1-91) and the main fraction according to the results of the granulometric analysis of particles in the Fritsch Analysette 22 MicroTecPlus. This sand belongs to quartz ones of grade1K1O102 (according to GOST 2138-91).

The aqueous clay suspensions with concentration of 15; 17.5; 20; 22.5% have been added to quartz sand before achieving the SCM's humidity within 3.5-4%. The ACSs with concentration of 15; 17.5; 20% have been chosen for studying the SCM as they have had viscosity necessary for ensuring the mixture's strength and uniform distribution as per the volume of quartz sand while preparing the molding sand mixture. The ACSs with concentration of 22.5% and higher have high viscosity and, therefore, have not been evenly distributed between the filler's particles in the SCM's volume.

3. STUDY OF THE SCM

The SCM's main technological properties with bentonite clay (Chernogorskoe field) mechanically activated during 90 sec. with various amounts of muscovite (from 1 to 6%) in its composition, while introducing the ACS of different concentration to the SCM, are presented in Table-1. The comparison of the results of this study of the SCM has been carried out with the molding sand mixture of the following composition: 7.5% of initial clay introduced in its loose condition; 3.5% of water, the remaining part - quartz sand. The main technological properties of this molding sand mixture are: compressive strength in a wet condition - $0.5x10^5$ Pa, gas permeability - 100 units (Golotenkov, 2004; Mamina, 1989).

The SCM's ultimate strength in its wet condition with the ACS's concentration of 15% is $0.28x10^5$ Pa, with the concentration of muscovite increased up to 3%, this value increases up to $0.36x10^5$ Pa, due to the fact that muscovite in the ACS serves as a natural chemical activator (Smolko and Antoshkina, 2014; Poluboyarov, *et al.* 2011). The main element of the muscovite structure is a three-layer package consisting of two silicon-aluminum-oxygen tetrahedral layers and internal octahedral layer with bi- or trivalent cations K, Ca, Mg, Al. The effect of introduction of muscovite to the composition of montmorillonite clay, i.e. an increase in the SCM's strength properties, can be observed in Figure-2 and explained by the fact that muscovite is one of components for preparing mullite ceramics that have high strength properties (Ovchinnikov, *et al,* 1972; Kirko and Sobolenko, 1976; Kirko, *et al,* 2016).

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Table-1. SCM's main technological properties.

SCM properties	ACS concentration, %	Mass muscovite fraction in activated clay, %						
		0	1	2	3	4	5	6
Compressive strength in a wet condition 10^5 Pa	15	0.28	0.29	0.30	0.36	0.35	0.32	0.32
	17.5	0.40	0.43	0.44	0.46	0.46	0.45	0.44
	20	0.71	0.79	0.82	0.83	0.82	0.81	0.79
Compressive strength in a dry condition, 10^5 Pa	15	0.54	0.60	0.65	0.66	0.67	0.67	0.65
	17.5	0.68	0.77	0.81	0.87	0.86	0.86	0.81
	20	0.83	0.95	1.03	1.12	1.21	1.26	1.20
Gas permeability in a wet condition, unit	15	171	171	157	153	160	163	161
	17.5	120	129	130	131	131	138	139
	20	88	90	94	102	109	110	115
Gas permeability in a dry condition, unit	15	165	171	173	182	188	192	203
	17.5	141	147	163	169	173	179	184
	20	113	122	130	141	148	150	157
Surface hardness in a dry condition, KPa	15	39.12	42.37	43.91	45.28	45.31	45.98	45.07
	17.5	59.85	71.56	74.57	77.61	77.98	78.12	77.01
	20	76.26	90.11	95.96	103.22	114.32	119.12	116.97
Mixture's friability, %	15	0.100	0.100	0.095	0.090	0.085	0.085	0.085
	17.5	0.080	0.060	0.055	0.050	0.045	0.045	0.050
	20	0.060	0.045	0.035	0.030	0.020	0.020	0.025

A low increase in strength when using a 15% ACS is caused by a small amount of clay for strengthening relations between particles of molding sand. The ACS's concentration below 15% cannot fully open a cationic complex of muscovite [23] that can be estimated while considering the results of the SCM's strength limits with a 20% ACS in its composition.

When introducing a 20% ACS to the SCM's composition, the ultimate strength in a wet condition increases from 0.71×10^5 up to 0.83×10^5 Pa. The ultimate strength in a dry condition increases from 0.83×10^5 up to 1.21×10^5 Pa, which is about 45%.

The SCM's gas permeability increases due to the fact that muscovite has a form of particles (scales) that are easily split into small leaflets and when its share grows in the SCM, the casting mold's ability to pass gases increases.

Figure-2 shows that the SCM's ultimate compressive strength begins to decrease when the concentration of muscovite in the ACS's composition reaches more than 5%. A strength change in the mixture's surface layer resulting from adding muscovite may be estimated according to a change in the SCM's surface hardness. When the mixture's surface hardness is not sufficient, its particles are washed away by a metal flow in the course of filling, which can result in creating different defects (obstructions, nonmetallic inclusions, burn-on, etc.).

The SCM's surface hardness has been studied by Hong Kong University of Science and Technology (HKUST), based on the international traineeship grant from RUSAL JSC, on the NHT2 Nanoindentation Tester. The results are presented in Table-1 and Figure-3 (*a*).

When considering the data obtained during the study, it is obvious that the SCM's hardness values increase on average by 15-20% in proportion to an increase in the aqueous clay suspension's concentration.

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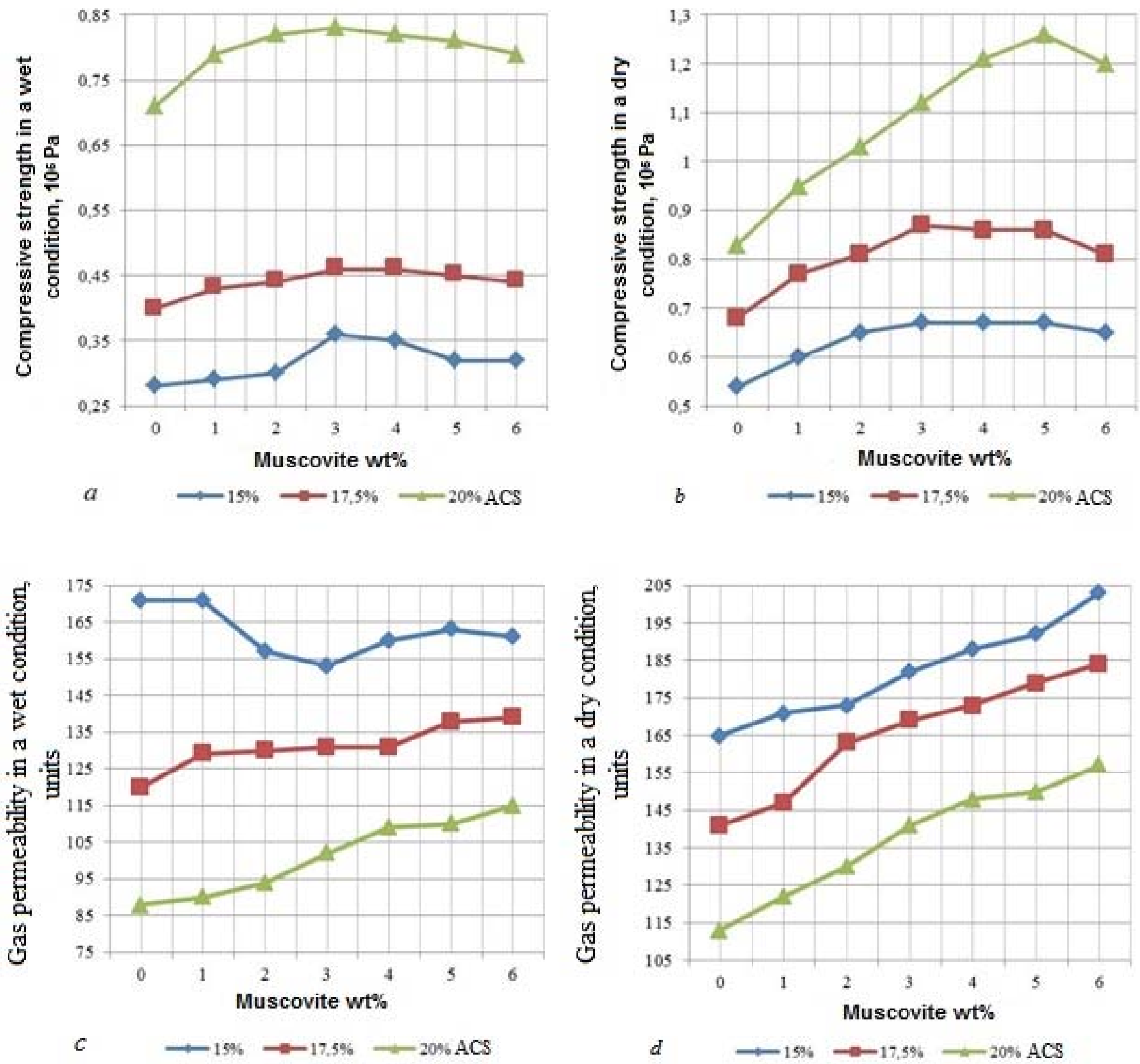

Figure-2. The SCM's main technological properties at the ACS's various concentration are: *a* – ultimate compressive strength in a wet condition; *b* – ultimate compressive strength in a dry condition; *c* – gas permeability in a wet condition; d – gas permeability in a dry condition.

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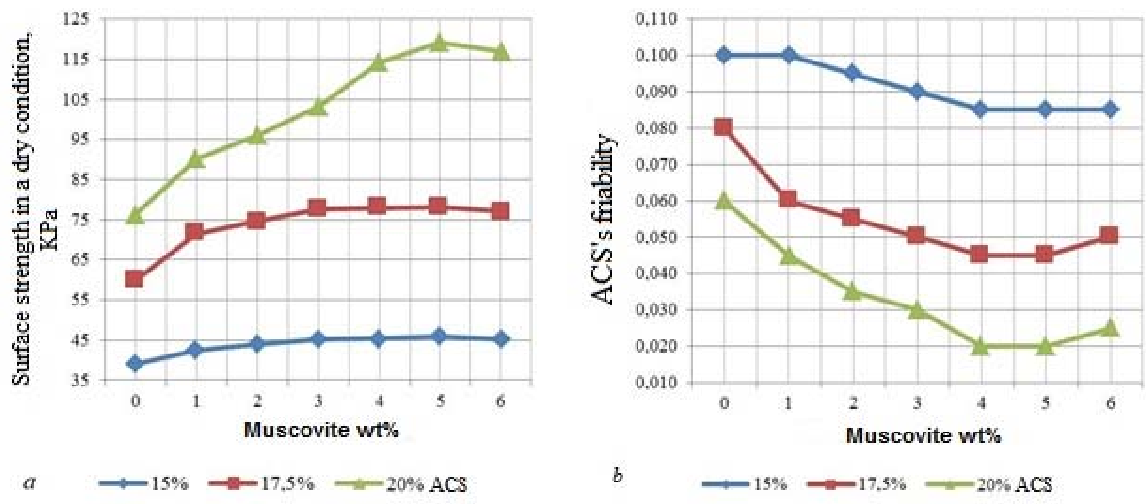

Figure-3. Strength properties of the SCM's surface layer at the ACS's various concentration: *a* - surface strength in a dry condition; b - friability.

4. CONCLUSION

a) The influence of a various amount of muscovite in the composition of bentonite clays applied in the foundry production, on the ACS's electrostatic properties has been determined. 3% of muscovite introduced to bentonite clay mechanically activated for 90 sec. (Chernogorskoe field) allowed increasing the zeta-potential by 30% (up to 25.87 mV), for suspensions immediately after hydration and by 28% (33.41 mV) for suspensions after 24-hour settling.

b) The influence of a various amount of muscovite and the ACS's concentration in the composition of activated bentonite clays for the foundry production, on the SCM's strength properties has been identified. The ultimate strength in a wet condition has increased by 17% (from $0.71*10^5$ up to $0.83*10^5$ Pa), the ultimate strength in a dry condition by 45% (from $0.83*10^5$ up to $1.21*10^5$ Pa) with the ACS's concentration of 20% and muscovite content of 5%.

c) It is established that the ACS's optimum concentration with addition of muscovite are suspensions with concentration of 20% that ensure a maximum increase in the mixture's strength properties. When the ACS's concentration is lower than 20%, the molding sand mixture has less strength due to a small amount of clay in its composition for strengthening relations between the particles of molding sand, which in turn increases the molding sand mixture's gas permeability. The results presented in Table-1 allow choosing the molding sand mixture depending on required technological properties. When the ACS's concentrations are higher than 20%, the suspension's high viscosity does not allow it to be evenly distributed between the sand particles.

d) It is determined that surface hardness increases from 76.26 up to 119.12 KPa for the SCM with activated clay containing 5% of muscovite, introduced by the 20% ACS (increase by 55% in comparison with the SCM without muscovite). Increased surface hardness results in reducing the SCM's friability from 0.060 up to 0.020% (for the SCM with activated clay containing 5% of muscovite and introduced by the 20% ACS), which allows us to indirectly conclude about a reduction in defective casting activities connected with the molding sand mixture's breaks or friability and ingress of a molding material's particles into the liquid melt. This composition of the SCM is recommended to be applied as a lining in the steel and cast iron casting.

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