Studies on Aluminosilicate of Palygorskites Group Used as a Binder in Green Sands System

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Abstract

The possibility of application of aluminosilicate from the palygorskite (attapulgite) group as a potential substitute for bentonite in green sand system application were evaluated. The effectiveness of the application of this aluminosilicate as a binder in sand grains was determined based on the results of the determination flowability, apparent density, permeability, compacability, wear resistance and compressive, tensile and shear strength of the green sands with attapulgite participation or with a mixture of bentonite-attapulgite. The results with the properties obtained for the green sand bonded by bentonite were compared. Based on these results, it was found that attapulgite as a main binder material in the green sand does not guarantee the respective properties of moulding (e.g. it was observed low green strength properties, high apparent density of mixture, low compaction and very low wear resistance). It was recognized that the natural form of attapulgite require modification in order to obtain the appropriate properties of moulding sands, which is the subject of future work within the scope of the development application of aluminosilicate in foundry industry.

Keywords: Foundry engineering, Binders, Green sand system, Aluminosilicates, Polygorskite, Attapulgite

1. Introduction

Aluminosilicate from the group attapulgite types, called attapulgite, a fibrous aluminosilicate with the chemical formula $Mg_5[Al]Si_8O_{20}(OH)_2-(OH_2)_4\cdot4H_2O$, is characterized by a high sorption capacity at 15-30 mval/100 g and, like zeolites, having molecular sieve properties [1, 2]. Attapulgite, just like bentonite, is widely used as an absorbent, catalyst carrier, disinfectant, adhesive, in addition to food, medicine *etc*. and recently, as a polymers filler [3]. The smallest structural unit are single crystals with a length of fiber diameter of 10-30 nm, 500-2000 nm. Each individual crystal is composed of multiple layered units, which are made up of tetrahedra joined two silicon atoms and two oxygen atoms [4]. Between adjacent layers are located five

aluminum atoms tetrahedrally linked with five oxygen atoms. The individual structural units are connected to oxygen atoms to form a crystalline structure as fibers. The individual nanocrystals fibrous are arranged to bundles, which can agglomerate and in the form of large particles are becoming visible in the microscale [5]. Interesting structure and associated with it extensive use gives grounds to try the application of attapulgite as a substitute for bentonite in green sands system. This work is one of the stages of research on its properties in the context of the application in foundry. Published data also show that it is possible to carry out the modification of the structure in a hybrid aluminosilicate-polymer material system. This treatment is carried out mainly in order to improve the adhesion properties and heat stable polymeric materials reinforced with mineral material [6]. This fact has already been taken into consideration by authors and

modification of the aluminosilicate-polymer material system is the next stage of work in this area.

2. Experimental

2.1. Materials

The material used in this study were:
1. silica sand (BK D 0,16 - 0,32 MM, Sibelco Europe),
2. activated bentonite (Bentonite Specjal, ZGM „Zębiec"),
3. attapulgite- naturally occurring mineral.

2.2. Preparation of moulding sands mixtures

Three moulding sands were prepared in the laboratory roller mixer (LM-1 type), applying the following amount of adding materials (table 1) :

Table 1.
The moulding components in green sands in part by mass

Symbol of moulding sand	Bentonite (B)	Attapulgite (A)	Silica sand	Moisture content, %
B	6,0	-	100	1,31 - 2,80
A	-	6,0	100	1,80 – 4,10
B+A	3,0	3,0	100	1,80 – 3,65

All dry ingredients were mixed by 3 minutes in the mixer with water addiction. After that, moulding sands were sieved and protected against drying in Aulich container.

Thus prepared material was used for the study of selected properties. Cylindrical samples were compacted by three times hitting of the standard rammer.

In each case, after completing the measurement of parameters of the moulding sand for specific moisture content, the whole of mixture was placed into a laboratory mixer and moistened proper amount of water. Then it was mixed, sieved and selected properties were investigated for the mass with increased water content.

The relative humidity of air in the laboratory during measurement was in the range of 35-48% and the temperature was 23-25°C.

2.3 Methods

The following properties were tested:

Apparent density

Determination of apparent density (ρ_0) was performed by measuring the volume and weight of cylindrical shapes prepared with the studied green sand. After removing the sample from the metal sleeve for forming the standard cylindrical-shaped samples (ϕ50, h=50 mm) it was measured to the nearest 0,2 g. Then, ρ_0 was calculated according to the formula

$$\rho_0 = \frac{Q}{V_c} \qquad (1)$$

where : Q – material mass, kg (g),
V_c - volume of material with the pores, m^3 (cm^3) [7].

Permeability

In the fast method for determining permeability (P^w) the pressure present in the space under the test samples indicated by the gauge in an electrical apparatus for determining permeability LPiR1 type was measured [7].

Dietert flowability

Determination of the green sand flowability by H. W. Dietert A and F. Valtier method with standard hand rammer with a sensor of degree deformation of normalized cylindrical samples between the fourth and fifth hit of the weight of the standard hand rammer. It was assumed that the smaller the deformation, means the greater the flowability of green sand. The numerical value of liquidity was calculated from the formula (2) [7]:

$$P_D=100-40x, \%. \qquad (2)$$

where: x - the loss of height of cylindrical shaped sample, mm.

Compactability

Measurement of compaction (Z) was carried out using a laboratory press. A metal sleeve measurement, filled up by testing moulding sand falling from the hopper located above the sleeve, was put in the fixing hole laboratory press. Turning on press was cause of increase the pressure in the hydraulic pump and compacting green sand through the piston. Z value is read in % on the scale of the apparatus [7].

Green Compression Strength, Green Shear Strength and Green Tensile Strength

Determination of the strength properties of the moulding sands were performed on a universal apparatus for determining the mechanical properties of the LRU type (MULTISERW Morek) according to PN-83 / H-11073 / EN. Suitable mounting jaws and handle allowed the measurement of compressive (R_c^w), shear (R_t^w) and tensile strength (R_m^w) on normalized cylindrical-shaped samples. The results are given in MPa [7].

Wear resistance

Wear resistance (S) were tested in the apparatus for determining the wear resitance LS type. Standardized fitting cylindrical was weighed to the nearest 0,1 g and placed on rollers LS apparatus. Then radiant lamp and roller rotating motor were turned on for 5 minutes, so that the part of matrix grains were detached from the surface of the green sand sample. After the time an engine was turned off and the green sand fitting was removed from the rolls and re-weighed. Wear resistance (S) in % was calculated from the formula (3) [7]:

$$S = 2 \cdot \frac{Q_1 - Q_2}{Q_1} \cdot 100 \ \%. \qquad (3)$$

where: Q_1 - fitting mass before the test, g,
Q_2 - fitting mass after the test, g.

Determination of moisture content

The moisture content of the moulding sand weight was measured in three chambered laboratory dryer. There was weighted 50 g (together with the measuring container) of tested green sand nearest to 0,01 g. Then the weighing of the material was introduced into a drying chamber heated to 105-110°C. It was dried to a constant weight. After property drying time for the testing material the dried sample was removed from the dryer and was cooling to ambient temperature. Then, it was again weighed to the nearest 0,01 g. The moisture content (W) of the material was calculated according to formula (4) [7]:

$$W = \frac{a-b}{a} \cdot 100\% \qquad (4)$$

where: a - the mass of material before drying, g,
  b - the mass of material after drying, g.

3. Results and discussion

The results of determinations of selected properties of moulding masses of different composition are shown in Figures 1-7.

Green sand and bentonite (B) was tested in the humidity range of 1,3%, but for investigation of the properties of green sand with attapulgite and mixture of bentonite-attapulgite (A and B+A, respectively) humidity in the upper range, i.e. above 1,8%, was required. At lower water content of these mouldings there was no significant effect of the matrix binding and the preparing of samples was difficult.

In the figure 1 were summarized the apparent density changes of moulding sands B, A and B+A in depending on the moist content. It is noted that the bulk density of moulding sand A and B+A was significantly higher compared to the moulding sand B (Fig. 1) and the minimum values was shifted to higher moist content. It followed that the Attapulgite strongly swell in contact with water and reduces the number of pores in the moulding sand.

The permeability of mass B increased to a maximum 300 units of the 1,85% moisture content and the moulding sand B+A reached maximum 275 units of the 2,4% moisture content. The green sand with binder in the form of natural attapulgite over a range of moisture has not reached the maximum (A, Fig. 2). This demonstrates that, between the grains of the matrix and didn't form permanent bond by attapulgite.

Also, the maximum permeability of moulding sand A and B+A are in a much higher moisture contents (Fig. 2).
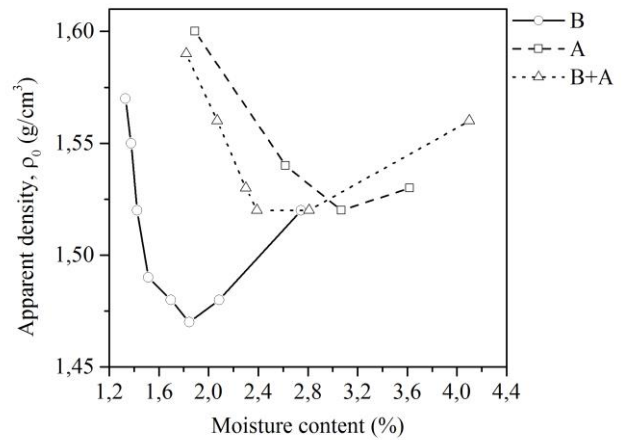

Fig. 1. Apparent density of green sands with different composition : B- green sand with bentonite, A – green sand with attapulgite, B+A – green sand with mixture of bentonite-attapulgite
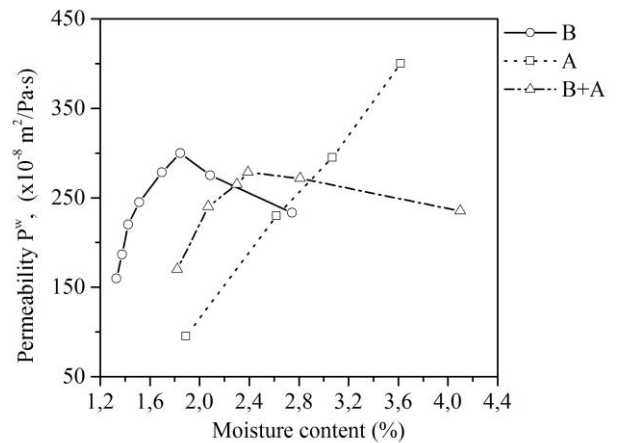

Fig. 2. Permeability of green sands with different composition: B - green sand with bentonite, A - green sand with attapulgite, B+A - green sand with mixture of bentonite-attapulgite

The lack of effective bonding of grains also was impacted on the flowability of the masses (Fig. 3). Flowability of of moulding sand A at 1.8% moisture content was comparable to the flowability of dry silica sand and it was approx. 100%. With increasing water content in moulding sand, this value decreased to a minimum at 85% at the 3,0% moisture content. Flowability value for moulding sand B+A was 90% initially and then decreased and stabilized (only slightly increasing the moist) at 82% above 2,5% moisture content.
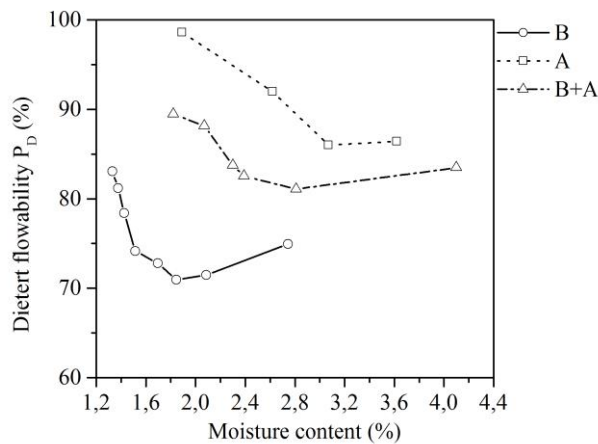
Fig. 3. Dietert flowability of green sands with different composition: B - green sand with bentonite, A - green sand with attapulgite, B+A - green sand with mixture of bentonite-attapulgite
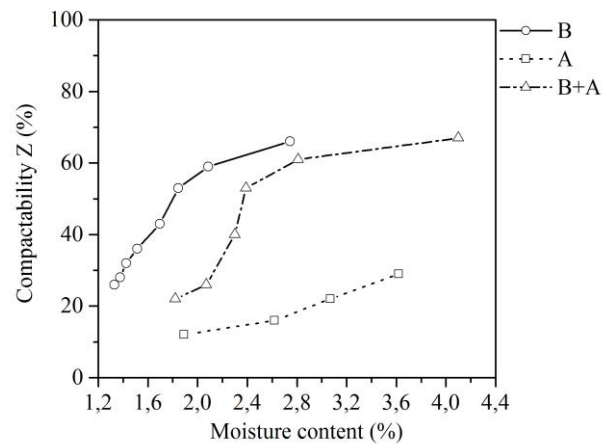

Fig. 4. Compactability of green sands with different composition: B - green sand with bentonite, A - green sand with attapulgite, B+A - green sand with mixture of bentonite-attapulgite

Based on the data presented in Figure 4, it was found that the moulding sand with attapulgite were significantly less susceptible to compaction than the moulding sand with activated bentonite (Fig. 4). The compactability of moulding sand B reached 22% of the initial value of moisture content and with increasing water content in the moulding sand (1,3-2,8%) increased to approx. 65%.

Growth compactability (Z) of moulding A was less intense, i.e. there was recorded a proportional increasing of the compactability of 12% to 29% in depending on water content. Moulding sand B+A was rapidly responded to the changing humidity (1,8-2,8%) initially, which resulted in an increase in Z from 21% to 69%. Above the 2,8% increase in compactability moisture was not as significant (B+A, Fig. 4).

The green compressive (R_C^w), green tensile (R_m^w) and green shear strength (R_t^w) of moulding sands are shown in Figures 5 - 7.

On the basis of the course changes R_C^w, R_m^w and R_t^w in green sands, it was found that the moulding sand B reached the highest values of strength properties in a relatively low humidity (1,5 – 1,7%), $R_C^w = 0,17$ MPa, $R_m^w = 0,025$ MPa and $R_t^w = 0,034$ MPa, respectively.

However, the work moisture content used in practice relates to higher operating value approx. 2 to 3% [7], wherein strength properties in the moulding sand with bentonite were significantly lower: $R_C^w = 0,10$ MPa, $R_m^w = 0,015$ MPa and $R_t^w = 0,025$ MPa, respectively.

Based on the analysis of the strength test results, it was found that the moulding sand with attapulgite was characterized by the lowest value of R_C^w, R_m^w and R_t^w, wherein showed no significant sensitivity to changes in humidity (A, Fig. 5-7). The maximum strength of moulding with a mixture of bentonite-attapulgite were in the area of higher moisture content as compared to the green sand with bentonite and it had much lower value (B+A, Fig. 5-7).
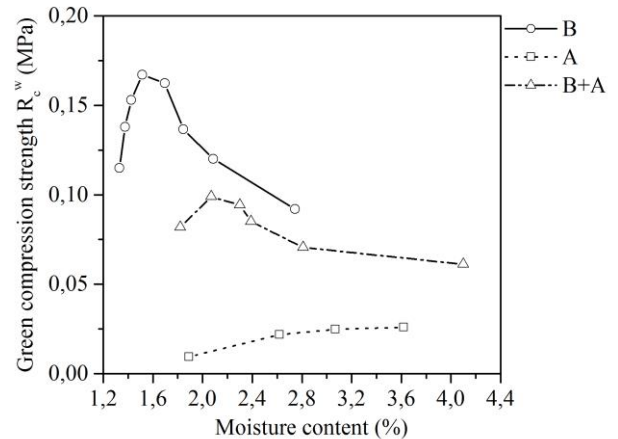

Fig. 5. Green compression strength of green sands with different composition: B - green sand with bentonite, A - green sand with attapulgite, B+A - green sand with mixture of bentonite-attapulgite
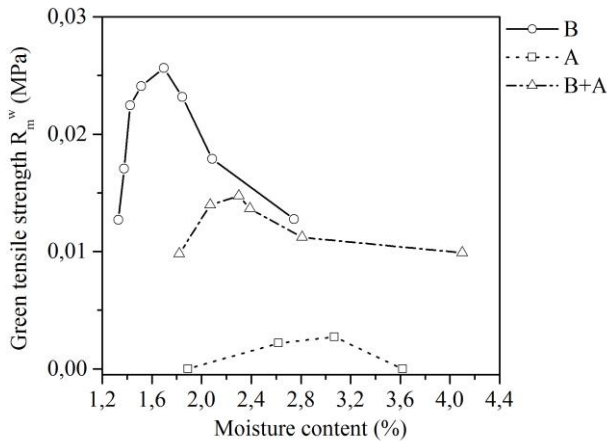
Fig. 6. Green tensile strength of green sands with different composition: : B - green sand with bentonite, A - green sand with attapulgite, B+A - green sand with mixture of bentonite-attapulgite
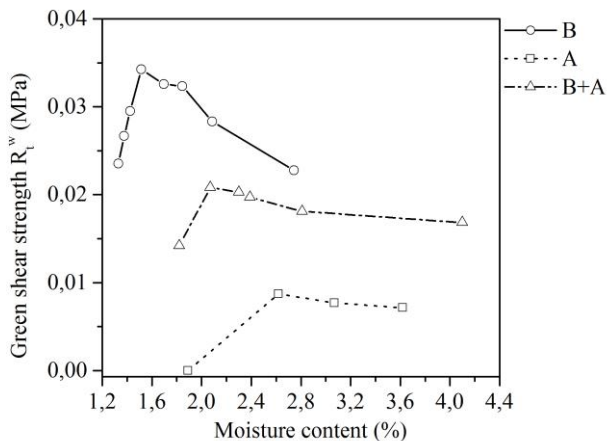

Fig. 7 Green shear strength of green sands with different composition: : B - green sand with bentonite, A - green sand with attapulgite, B+A - green sand with mixture of bentonite-attapulgite

Figure 8 shows the results of wear resistance (S). S form moluding sand A was 100% and even during the preparing samples its showed scant binding capacity of the matrix and their putting in the measuring device in its entirety was impossible. Comparison of results had revealed that the both of moulding sand B and B+A were characterized by low wear resistance under relatively low humidity (1,5% and 1,8%). It wasn't until at the moisture content approx. 2,8% wear resistance had reached a value characteristic for the green sand (S value of less than 20%).
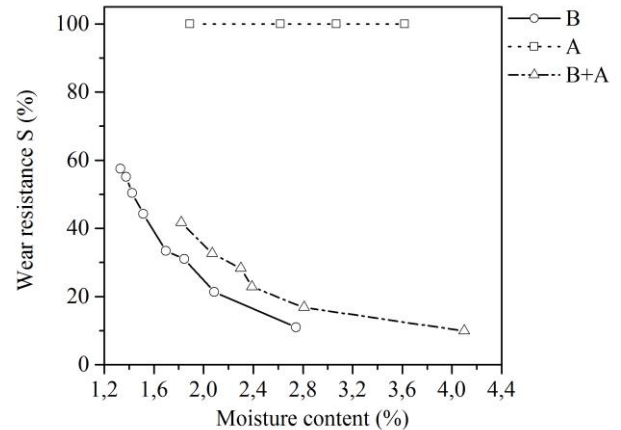

Fig. 8. Wear resistance of green sands with different composition: B - green sand with bentonite, A - green sand with attapulgite, B+A - green sand with mixture of bentonite-attapulgite

5. Summary

On the basis of obtained results it was clearly alleged, that the use of natural aluminosilicate from palygorskites group (attapulgite) as a substitute for conventional bentonite in the green sand system was not satisfactory. Attapulgite as a replacement of activated bentonite does not guarantee the appropriate properties of moulding sands. Analysis of the obtained results of moulding sands i.e. green compressive strength, green tensile, green shear strength, the measurement of permeability, apparent density, compactability, flowability and wear resistance showed that despite capability of swelling and forming colloidal solutions [1-4] attapulgite in its pure form can't be used as a substitute for bentonite in the green sand system.

Also, it can be concluded that the mineral mixtures with attapulgite participation can extend the applicability of it in green sand system. In addition, based on literature data mainly concerning the possibility of improving the adsorption properties of attapulgite [6, 8], there has been taken the research to modify the structure of this aluminosilicate and consequently obtain a new material for use in green sand system.

Acknowledgements

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