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Assessment Criteria of Bentonite Binding Properties

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Abstract

The criteria, with which one should be guided at the assessment of the binding properties of bentonites used for moulding sands, are proposed in the paper. Apart from the standard parameter which is the active bentonite content, the unrestrained growth indicator should be taken into account since it seems to be more adequate in the estimation of the sand compression strength. The investigations performed for three kinds of bentonites, applied in the Polish foundry plants, subjected to a high temperature influences indicate, that the pathway of changes of the unrestrained growth indicator is very similar to the pathway of changes of the sand compression strength. Instead, the character of changes of the montmorillonite content in the sand in dependence of the temperature is quite different. The sand exhibits the significant active bentonite content, and the sand compression strength decreases rapidly. The montmorillonite content in bentonite samples was determined by the modern copper complex method of triethylenetetraamine (Cu(II)-TET). Tests were performed for bentonites and for sands with those bentonites subjected to high temperatures influences in a range: 100-700ºC.

Key words: Bentonite, Montmorillonite, Green sands, Growth indicator, Copper complex, Compression strength

1. Introduction

Bentonite is one of the basic binding materials applied in metal casting for making moulds. Moulding sands with bentonite constitute app. 70 – 80 % of sands, in which castings of ferrous alloys, mainly cast irons, are made (Fig. 1) [1]. Foundry bentonites, subjected to a high temperature influence loose their binding properties, which depends not only on a heating temperature but also on the duration of its influence. In addition, bentonites are used in other fields such as: drilling, food industry or crude oil treatment [2, 3, 4]. They find also an application in agriculture, mining, catalysis, cosmetics production, detergents, chemical and pharmaceutical industry and even in the atomic power engineering (in storing radioactive wastes) [5].

Montmorillonite, the main component of bentonite is deciding on its binding properties and thus on the suitability for the foundry practice [6]. Determination of the montmorillonite content in knocked out sand is the basic indicator applied at this sand rebounding in the foundry plant. It decides on the added amount of fresh bentonite (mixture: bentonite – lustrous carbon carrier). However, despite an addition of the determined amount of fresh bentonite, the sand not always achieves the resulting strength. Since the unrestrained growth indicator is a very essential parameter characterising the bentonite binding ability, investigations in this field were undertaken. The compression strength, montmorillonite content and the unrestrained growth indicator were examined for three moulding sands prepared with an addition of various bentonites being applied in the domestic foundry plants.

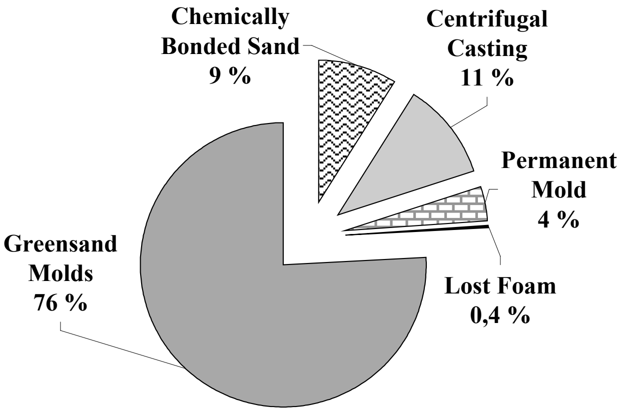

Fig. 1. Fraction of the moulding sands technology in the world casting production [5]

2. Materials and methods

Investigations were performed for three bentonites applied in the Polish foundry plants, and originated from the main European producers. These bentonites were marked: A, B and C.

The chemical composition of bentonites is given in Table 1, while their basic properties in Table 2.

Table 1. Chemical composition of bentonites

	Bentonit A	Bentonit B	Bentonit C
	% mass.		
Al_2O_3	16,00	18,02	16,23
CaO	1,63	3,00	3,19
Cr_2O_3	0,010	0,002	0,006
Fe_2O_3	2,11	3,60	6,80
K_2O	0,80	2,32	0,52
MgO	4,73	3,49	3,18
MnO	0,075	0,11	0,036
Na_2O	2,65	0,31	2,63
P_2O_5	0,034	0,068	0,15
SiO_2	56,65	48,75	49,85
SO_3	0,018	0,024	0,23
TiO_2	0,11	0,33	0,70

Table 2. Basic properties of bentonites

Bentonite	pH	Conductance of electrolytes [µS/cm]	Moisture content (110°C)	Loss on ignition
			[% mass.]	
A	10,41	260	8,5	13,88
B	10,39	858	11,0	17,66
C	10,42	255	9,6	16,20

The montmorillonite content in bentonites was determined by means of the spectrophotometric method of the Cu(II)-triethylen-tetraamine (Cu-TET) complex, developed in the Department of Foundry Engineering, AGH [7]. The bentonite samples used for the montmorillonite content determination were heated to temperatures of 500, 600 and 700°C at a rate of app. 20°C/min and held in the given temperature for one hour. Then the samples were cooled (together with a furnace) and placed in the desiccator, until the examination. The German VDG Ref. Bentonite (Bavarian) of 75 % montmorillonite content was applied as the reference standard at the montmorrilonite content determination [7, 8].

The unrestrained growth indicator was determined according to the technical recommendation of the Institute of Building Technique: AT-15-3945/2005. Examinations were performed for bentonite samples prepared according to the same procedure as samples for the montmorillonite content determination.

For the strength tests of moulding sands with bentonites, the moulding sand samples were held at temperatures: 100, 300, 550, 700°C for one hour, also according to the same procedure as the one described above [8, 9]. The moulding sands compression strength was then determined.

3. The results and discussion

The obtained results of the compression strength (as a relative value in respect to the sand heated to 100ºC), the montmorillonite content and the unrestrained growth indicators for individual bentonites are presented in Fig. 2 – 4.

The montmorillonite content in samples of all tested bentonites heated at temperatures up to 500°C was not decreasing (it was at the same level as in fresh bentonite). However, after heating in a temperature range: 500 – 600°C the montmorillonite content decreased and simultaneously differences between individual bentonites revealed themselves. The largest decrease indicated bentonite B (above 50 % in relation to the initial value, Fig. 3). On the other hand the most resistant to the influence of this temperature was bentonite C (Fig. 4). After one hour of holding in a temperature of 700°C, the montmorillonite content dropped to zero in all bentonites, which were simultaneously loosing their binding abilities.

Bentonites heated in a temperature range from 100 to 400°C, exhibited various changes of the unrestrained growth indicator. Bentonites A and C exhibited increase of this indicator in a temperature range: 200 – 300°C, which was compatible with an increase of the relative compression strength, which moulding sands with the tested bentonites exhibited in this temperature range (Fig. 2 and Fig. 4). Above 300°C there is a decrease of the unrestrained growth indicator as well as a decrease of the compression strength of moulding sands with bentonites A and C. Whereas bentonite B, starting from the sample heated at 100°C, exhibits a systematic decrease of the unrestrained growth indicator (Fig. 3), which corresponds well with the pathway of the compression strength changes of the sand with this bentonite [10]. The unrestrained growth indicator – for all bentonites – starts decreasing significantly only from a heating temperature of 500°C.

Technological investigations performed for moulding sands with A, B and C bentonites exhibited different characteristics of the heating temperature influence on the sand compression strength.

In the case of sands with A and C (Fig. 2 and Fig. 4) bentonites at a temperature of 300°C an increase of the relative compression strength, in relation with the sand heated at 100°C, occurs. Such maximum does not occur for the sand with bentonite B (Fig. 3).

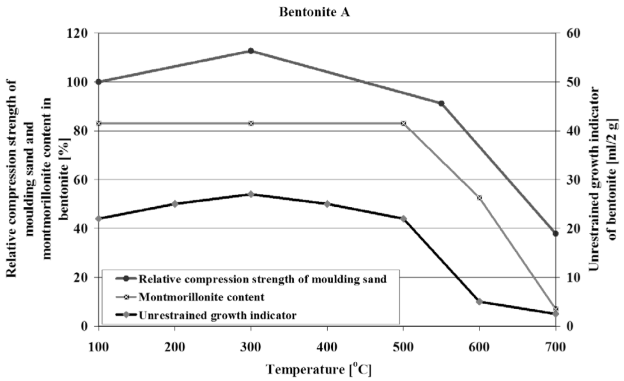

Fig. 2. Results of the unrestrained growth indicator, montmorillonite content and compression strength in dependence of the holding temperature – for bentonite A.

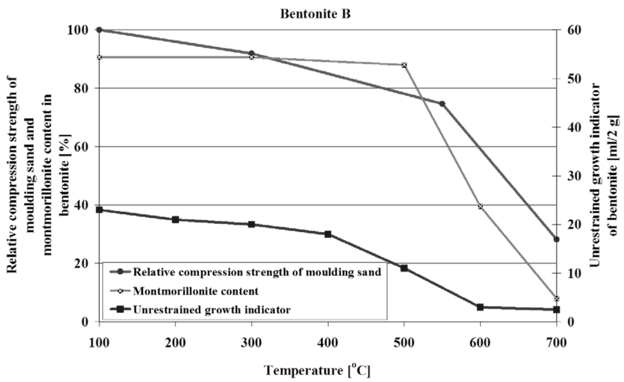

Fig. 3. Results of the unrestrained growth indicator, montmorillonite content and compression strength in dependence of the holding temperature – for bentonite B.

Moulding sands with the investigated bentonites, held at a temperature of 700°C still have approximately 30 – 50 % of their initial strength, whereas the montmorillonite content determined in the pure bentonite, for the same temperature, is at a level of a few percentages. It should be mentioned, for explaining of this situation, that apart from bentonite also high-silica sand is applied in moulding sands as a matrix. It can function as an insulation for a binder ensuring less exposure of bentonite to a high temperature influence, that is why the investigated sand had a higher strength than it would result from the expected thermal degradation degree of bentonite.

As it was shown during investigations the montmorillonite content in bentonite depends not only on the heating temperature (Fig. 5), but also on the length of time of being exposed to this temperature. This fact should be taken into account at investigating the temperature influence on bentonites, and sands with bentonites, properties. In case of the current investigations one hour of holding at the given temperature was assumed as the optimal time. Practically all changes, which could occur in bentonite at the given temperature, were after one hour completed [11, 12].

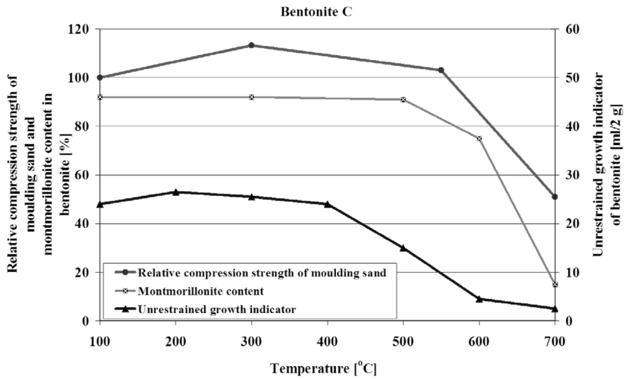

Fig. 4. Results of the unrestrained growth indicator, montmorillonite content and compression strength in dependence of the holding temperature – for bentonite C.

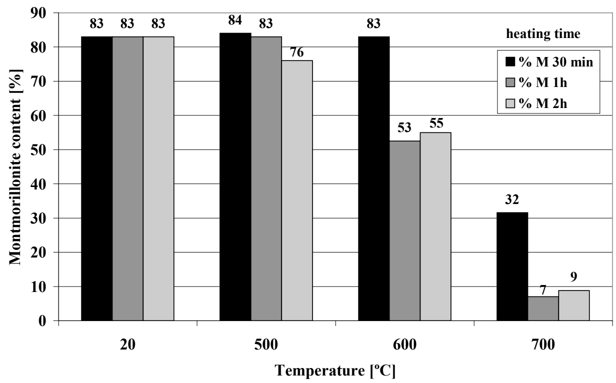

Fig. 5. Montmorillonite content in dependence on the temperature and time of holding for bentonite A

4. Conclusions

The performed analysis of the montmorillonite content indicates that for the given bentonite in the temperature range from 100 to 500°C this content is constant, which does not correspond neither with the compression strength of sands with this bentonite nor with its growth ability. Within this temperature range the compression strength and the unrestrained growth indicator are systematically decreasing.

Moulding sands with bentonites A and C show a certain maximum of the relative compression strength in the vicinity of 300°C. A similar dependence can be seen for the unrestrained growth indicator of these bentonites. When a temperature of 300°C is exceeded, despite still not changing the montmorillonite content, the relative compression strength as well as the growth indicator are decreasing. A different behaviour characterises bentonite B, where both the growth indicator and relative compression strength decrease along the temperature increase starting from 100°C and none maximum is seen [13].

The parameters measured in the presented hereby work, strongly depend not only on the bentonite heating temperature, or sand with this bentonite, but also on the length of time of being exposed to this temperature. It was assumed – for the requirements of these investigations – that one hour of holding at the given temperature is sufficient for an occurrence of all most important changes in the tested samples.

The obtained results indicate that the high montmorillonite content in bentonite subjected to the temperature influence not always decides on its binding properties. Its other parameters should be also determined e.g. the unrestrained growth indicator, which changes - due to heating - are similar to the changes of the moulding sand compression strength [14, 15]. It was also found, that the bentonite behaviour under the temperature influence is diversified, as far as pathways of changes of the binding ability or the growth indicator are concerned, and this should be taken into consideration at selecting bentonite for the foundry industry needs.

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