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THE EFFECT OF ADDITIVE "B" ON THE PROPERTIES OF CO_2-HARDENED FOUNDRY SANDS WITH HYDRATED SODIUM SILICATE

The results of own studies concerning the application of a new additive to the CO_2-hardened sodium water glass foundry sands are presented. The new additive, which is a composition of aqueous solutions of modified polyalcohols, has been designated by the symbol "B" and is used as an agent improving the sand knocking out properties. The scope of studies included various mechanical and technological properties of foundry sand mixtures, such as permeability, friability, life cycle of cores and knocking out properties.

Two types of water glass with different values of the silica modulus and density, designated as R145 and R150, were tested. Moulding sands used in the tests were made with the additive "B". For comparison, a reference sand mixture with water glass but without the additive "B" was also prepared.

Keywords: foundry industry, moulding sand, hydrated sodium silicate, additive "B"

1. Introduction

Water glass as a binder for moulding and core sands has been used in the foundry industry for many years [1]. Hydrated sodium silicate, together with other binders used in the technology of cast iron and non-ferrous metals, is one of the most popular and commonly applied inorganic binders [2-7].

With the ever more stringent requirements of environmental protection, increasingly important are becoming these technologies that, apart from the required technological parameters, are also the least harmful to the environment. In the family of moulding and core sands, the sand with water glass seems to be precisely this type of product [8-9].

The main reason for the promotion, manufacture and use in the past, present and future of moulding sands with silicate binders is a wide scope of their beneficial properties, mainly the safe use of these sands without any imminent health hazard to workers involved in the process implementation. This is largely due to the absence of the emission of compounds such as BTX (benzene, toluene, p-xylene, o-xylene) and PAHs (polycyclic aromatic hydrocarbons). Moreover, foundry processes based on the silicate binders are considered cost-efficient, due to a relatively low cost of production and a number of technical improvements that have eliminated the old constraints, resulting mainly from the sand flowability inferior to other types of moulding sands, and excessively high final strength of moulds and cores.

This technology, while offering a cheap and environmentally friendly method for the manufacture of foundry moulds and cores, has also some drawbacks, which include poor sand collapsibility and reclamability, mechanical in particular [10-12].

2. Research programme

In the technological studies, two types of water glass were used, i.e. R 145 and R150 with the silicate modulus and density of M = 2.5 and $\rho = 1.45 \div 1.48$ g/cm^3, and M = 2.0 and $\rho = 1.50 \div 1.53$ g/cm^3, respectively. The sand mixture was hardened by ambient temperature CO_2 blowing. The time of blowing the samples of the tested moulding sands was 20 s at a CO_2 pressure of 2 to 3 atm.

The test programme has involved the preparation of moulding sands with additive "B", which is a composition of aqueous solutions of modified polyvinyl alcohols. A reference moulding sand was the sand with water glass but without the additive "B". Moulding sand were based on the 1K silica sand from Szczakowa (now DB DB Cargo Polska) mine with the main fraction of 0,20/0,40/0315. All moulding sands were prepared in a ribbon-type laboratory mixer, model LMR-2. The base sand was mixed with water glass or with a composition of water glass and "B" additive for a time of 90 s.

The ready moulding sands were evaluated for their technological properties, including the determination of permeability P, friability S, compressive strength R_c and bending strength R_g, bench life and collapsibility. The compressive strength and bending strength were measured after the maturing period of

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3 and 24 hours. Other technological properties (with exception of the core bench life roughly estimated at 29 days since the date of manufacture) were determined after 24 hours of the sample maturing.

3. Test results

As part of the research programme, moulding sands with water glass R 145 and R150 and with variable amounts of additive "B" were prepared and hardened by CO_2 blowing. Reference sands were made with the addition of both water glass grades, i.e. R145 and R150, but without the additive "B". The mechanical properties of sand mixtures were tested on samples after the maturing time of 3 and 24 hours, while other technological properties were measured after the lapse of 24 hours since the time of the sand hardening.

The composition of the tested sand mixtures was as follows:

– silica sand – 100.0 parts by weight,
– sodium water glass R145 and R150 – 3.0 parts by weight,
– additive "B" – 0.10; 0.15 and 0.20 parts by weight.

Scanning examinations were done for the sands with water glass without and with the additive "B". The examinations covered fractures of the sand samples made from the above-mentioned sand mixtures. The aim of the examinations was to determine the type of the "silica-binder" bond and the type of mechanical destruction that takes place in the water glass-bonded sands.

The sand mixtures with hydrated sodium silicate undergo a cohesive type of destruction, that is, the destruction where the adhesion forces prevail over the forces of cohesion. This type of destruction occurs inside the layer of binder in the smallest cross-section.

3.1. Permeability

The sand permeability was determined in an LPiR-3e apparatus.

Introducing additive "B" to the sand slightly reduced its permeability, although the amount added had no significant effect on changes in this parameter (Fig. 2).

3.2. Friability

Studies were conducted using an LS-1 apparatus for the determination of friability according to the Polish Standard BN-77/4024-02.

Fig. 3 shows changes in the friability of samples made from the examined sands depending on the amount of additive "B". The presence of additive "B" results in a significant decrease

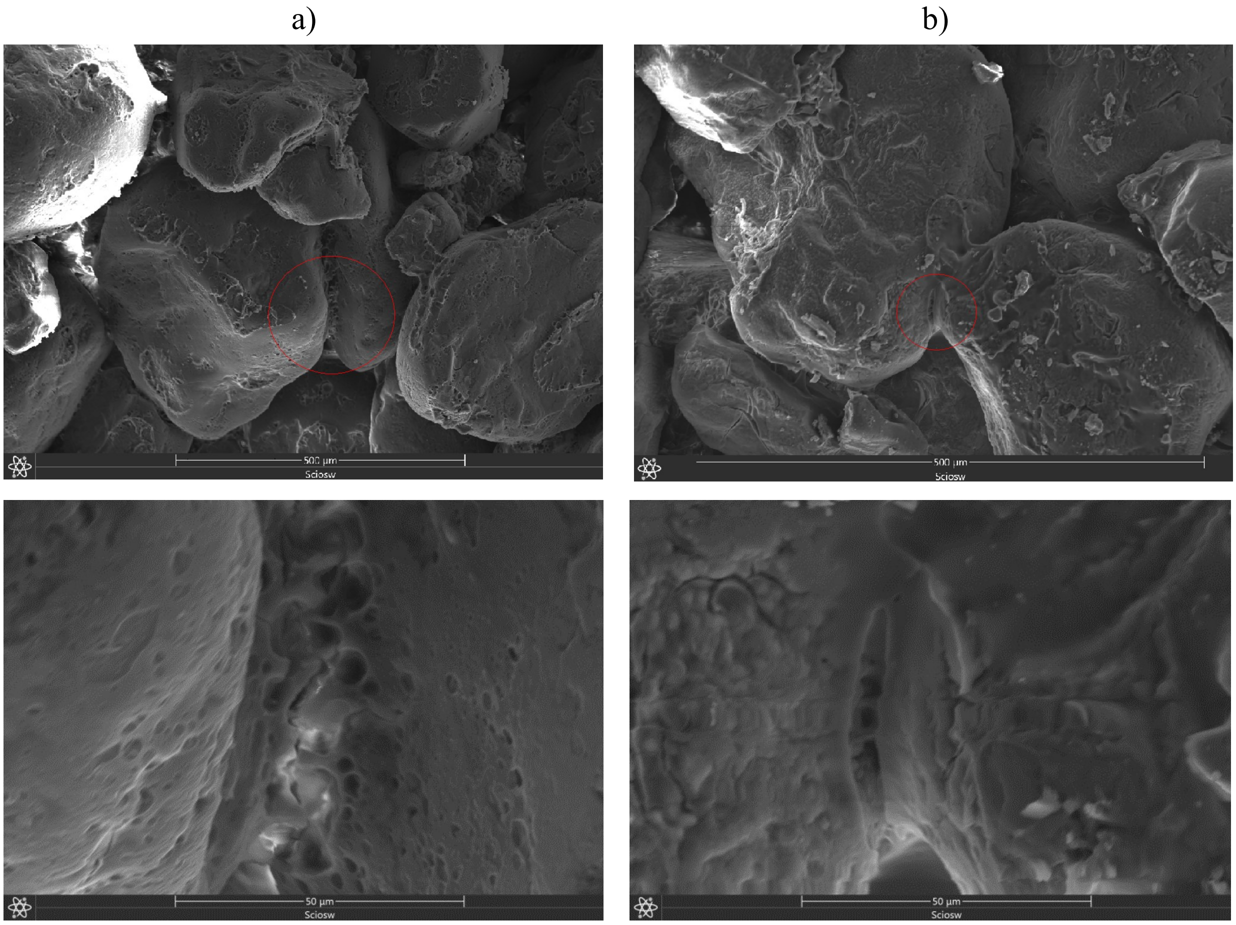

Fig. 1. The surface morphology of moulding sand with water glass: a) the initial state without additive „B", b) the state with additive „B"

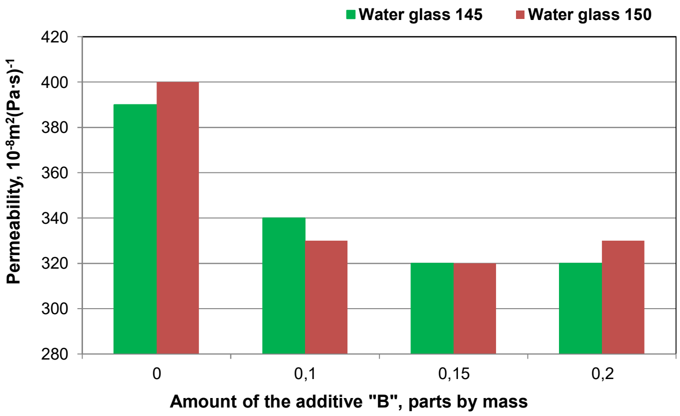

Fig. 2. The effect of additive „B“ on the sand permeability

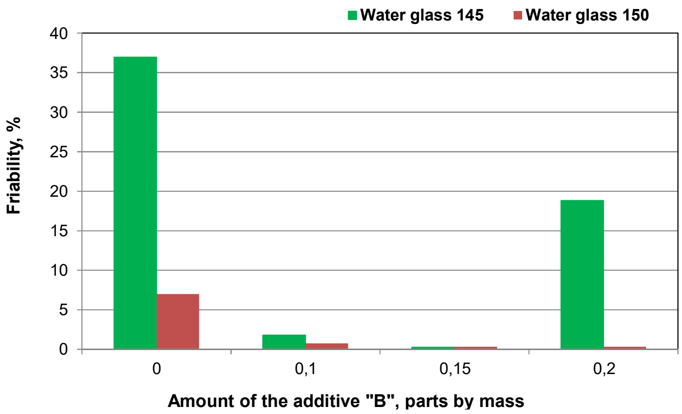

Fig. 3. The effect of additive “B” on the sand friability

of the friability. The highest drop of friability of about 90% has been observed in the moulding sands containing additive “B” in an amount of 0.1 to 0.15 parts by weight. Increasing the additive content in the sand increases the value of friability. It should be remembered that the lower is the value of friability, the better is the forecast for the cores to achieve high resistance to the abrasive and crushing effect.

3.3. Compressive strength

Compression tests were performed in a universal LRuE-2e apparatus for testing the mechanical properties of moulding sands.

Figs. 4 and 5 show the compressive strength of the sand with water glass added in an amount of 3.0 parts by weight. The sand with water glass R145 (Fig. 4) has achieved its maximum strength after 24 hours, when the amount of additive “B” was 0.15 part by weight. In the sand with water glass R150 (Fig. 5), introducing additive “B” in an amount of 0.1 and 0.15 parts by weight has practically left the strength values at the same level, while increasing the amount of this additive to 0.2 part by weight reduced the compressive strength by approximately 33% after the lapse of 24 hours.

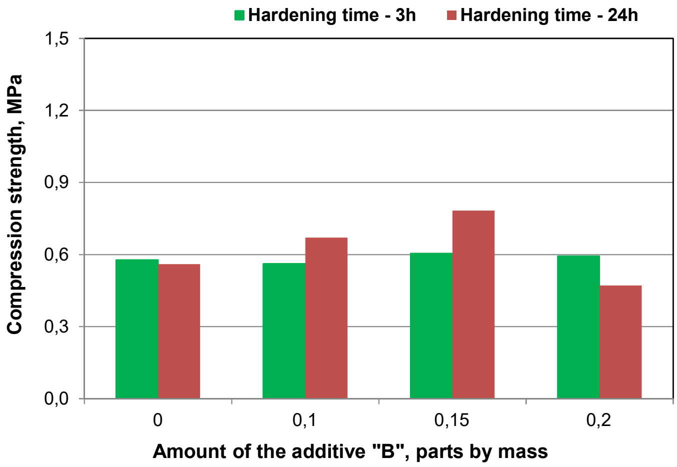

Fig. 4. The effect of additive “B” on the compressive strength of sand containing 3.0 parts by mass of water glass R145

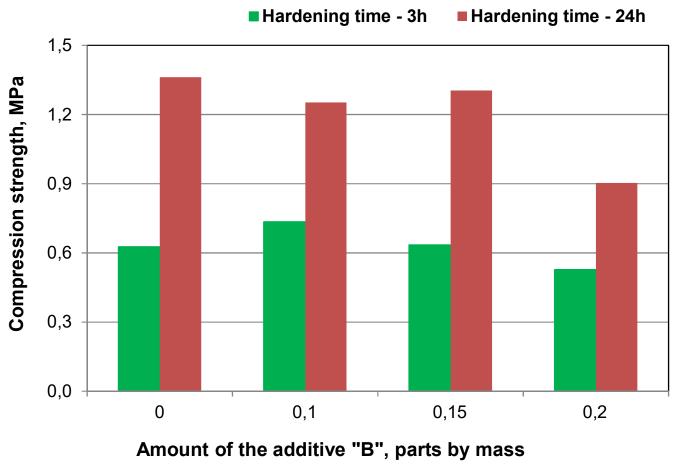

Fig. 5. The effect of additive “B” on the compressive strength of sand containing 3.0 parts by mass of water glass R150

3.4. Bending strength

Figures 6-7 show the effect of the content of additive “B” on the bending strength of the tested sands. All sands were observed to gain their maximum strength when the amount of the additive was 0.1 part by weight. The sand with water glass R150 showed the bending strength superior to the same sand containing water glass R145. The bending strength of the sand with water glass R150 and the additive “B” introduced in an amount of 0.1 part by weight was higher by about 60% compared to the reference sand mixture prepared with water glass but without the additive “B”.

3.5. Testing the life cycle of foundry cores

The life cycle of foundry cores made from the sand with water glass is limited because of the hygroscopicity of the gel formed as a result of the water glass hardening, which reduces the binding properties [13,14].

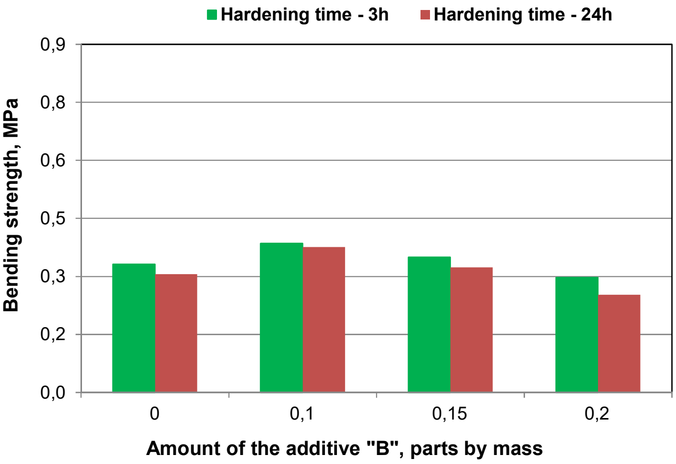

Fig. 6. The effect of additive „B“ on the bending strength of sand containing 3.0 parts by mass of water glass R145

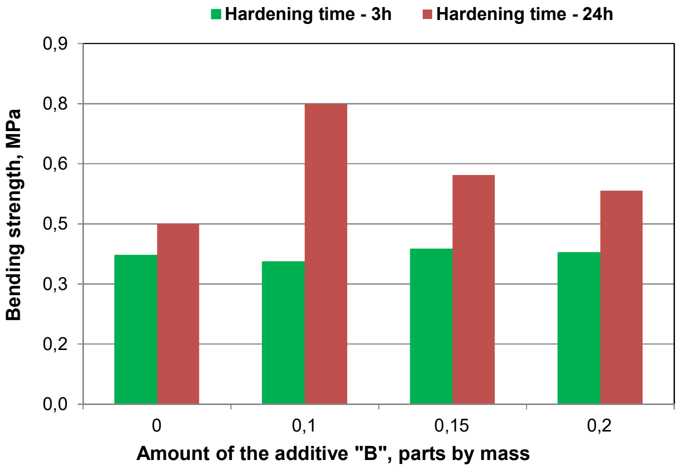

Fig. 7. The effect of additive „B“ on the bending strength of sand containing 3.0 parts by mass of water glass R150

Figure 8 shows the effect of the sand maturing time on the life cycle of cores determined by compression test. The cores were made from the sand with water glass R145 without and with the additive “B”.

The initial maturing time of the sand samples amounting to 10 days has increased the compressive strength. During that period, the highest value of compressive strength was obtained by the core sand made with water glass but without the additive “B”. After the lapse of 10 days, the compressive strength of the core sand was undergoing a gradual decrease. Within this period of the sand maturing, the highest compressive strength had the cores containing additive “B” introduced in an amount of 0.2 part by weight. Different character of changes in the value of compressive strength was observed in the sand containing additive “B” introduced in an amount of 0.1 part by weight. In samples of the sand with this composition, the value of compressive strength was continuously decreasing with the longer time of maturing.

3.6. Testing the sand knocking out properties

Sand mixtures with water glass R145 and predetermined content of additive “B” (0.15 part by weight) were evaluated for their knocking out properties. The method recommended by the Polish Standard PN-85/H-11005 for an assessment of the knocking out properties consists in a technological test, in which a measure of the examined parameter is the work (Lw) needed to remove the core from casting.

Moulds and cores for the knock out test were prepared from the sand with water glass R150 and additive “B”, and for the

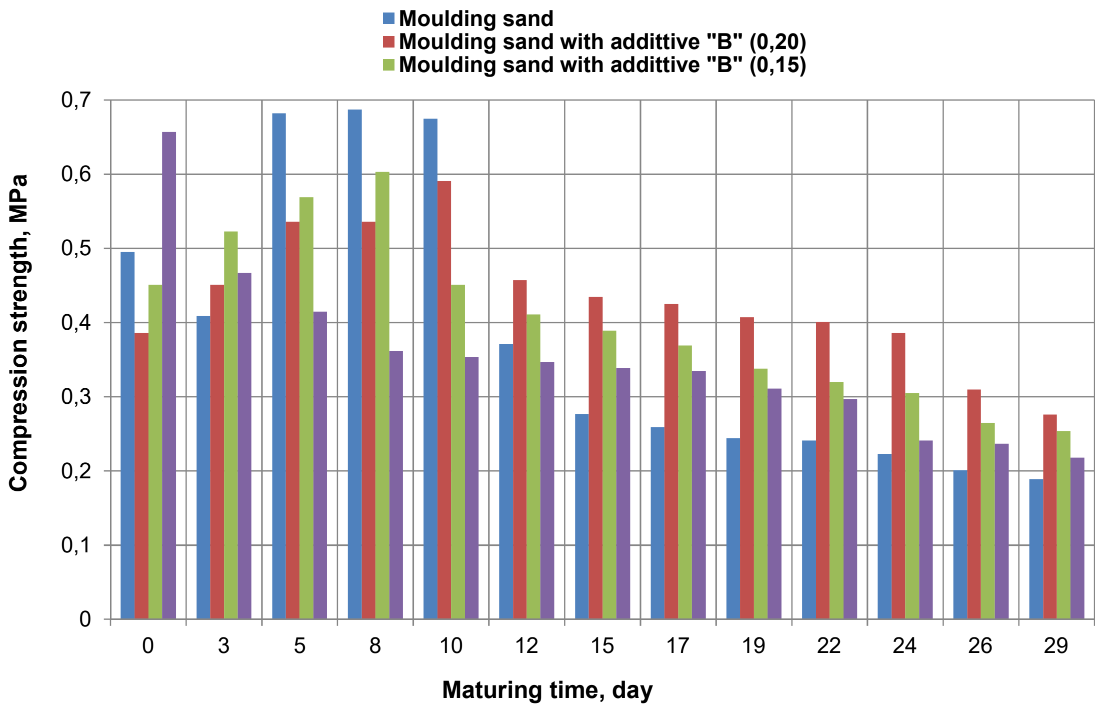

Fig. 8. Maturing time vs compressive strength of test samples made from the reference moulding sand and from the moulding sand with additive “B”

sake of comparison also from the sand with water glass R150 but without the additive "B". Test castings were made from an AlSi9 alloy, whose pouring temperature was 726^{o}C.

The ready test castings after knocking out and cooling to ambient temperature were placed together with cores in an apparatus for testing of the core collapsibility, and the number of the weight blows needed to remove the core from the casting was measured. The results are shown in Table 1.

TABLE 1

Average number of the weight blows and the work of knocking out the test castings

Sand type	Average number of the weight blows, n	The knock out work, J
Moulding sand with water glass R145	31	49,6
Moulding sand with water glass R145 and additive „B" introduced in an amount of 0.15 part by weight	18	28,8

Compared with moulding sand without the additive, the sand with additive „B" exhibits much better knocking out properties. The presence of the additive reduces the knockout work by about 60%, compared with the work needed to knock out the sand without the additive.

4. Summary

(1) The permeability of the reference sand after the lapse of 24 hours since the moment of hardening is from 300 up to $400 \cdot 10^{-8}$ $m^2/Pa \cdot s$, depending on the type of water glass, while the permeability of the sand with additive "B" is from 320 to $340 \cdot 10^{-8}$ $m^2/Pa \cdot s$, depending on the type of water glass and the amount of additive.

(2) The friability of the reference sand after the lapse of 24 hours since the moment of hardening is from 7% up to 37%, depending on the type of water glass, while the friability of the sand with additive "B" ranges from 0.2% to 19%, depending on the type of water glass and the amount of additive.

(3) The compressive strength of the reference sand after the lapse of 24 hours since the moment of hardening is from 0.6 MPa to 1.3 MPa, depending on the type of water glass, while the compressive strength of the sand with additive "B" ranges from 0.5 MPa to 1.3 MPa, depending the type of water glass and the amount of additive.

(4) The bending strength of the reference sand after the lapse of 24 hours since the moment of hardening is from 0.3 MPa up to 0.45 MPa, while the bending strength of the sand with additive "B" is from 0.25 MPa up to 0.8 MPa, depending on the type of water glass and the amount of additive.

(5) Comparing the results of technological studies of the sands it can be stated that for moulding sands hardened in the CO_2 process, the best results were obtained when the amount of the additive was 0.15 part by weight.

(6) The life cycle of cores made from the sand bonded with water glass R145, as determined by the compressive strength, is approximately 10 days. Similar stability characteristics have cores made from the sand bonded with water glass R145 and additive "B", although, depending on the additive content in moulding sand, their compressive strength is lower by 15% to 3%, compared to the compressive strength of cores made from the sand without this additive.

(7) Comparing the knocking out properties of sands with additive "B" and without this additive confirms the fact that the presence of additive "B" allows for a significant improvement of the knocking out properties of the tested sands. The work of knocking out the sand with additive "B" is lower by 40% than the work of knocking out similar sand without this additive.

Acknowledgements

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