Arch. Metall. Mater., Vol. 61 (2016), No 4, p. 2097–2102

DOI: 10.1515/amm-2016-0337

I. IZDEBSKA-SZANDA*, J. KAMIŃSKA*,#, M. ANGRECKI*, A. PALMA*, W. MADEJ*

AN INNOVATIVE METHOD FOR THE DEHYDRATION HARDENING OF MODIFIED INORGANIC BINDERS

The results of research on the possibility of using a gaseous medium (hot air) as a hardening agent for inorganic binders were discussed, and tests on the reclamation of waste moulding sands were carried out. The research programme also included the use of a modernized test stand for hardening of foundry sands with gaseous agents and a pilot plant for the sand reclamation.

Cores made on the test stand were examined for the basic technological properties and were also used in moulds for the trial knocking out of castings.

Two types of binders were tested, i.e. a modified water glass designated as Binder A and, for comparison, a reference material which was hydrated sodium silicate R145. The hardener for the sand mixtures was hot air (the dehydration of water glass). Trials of the sand reclamation were carried out in a laboratory pilot plant, installed and operating at the Foundry Research Institute. The obtained reclaim was added in different amounts to the sand mixtures subjected to technological tests. The next step included the manufacture of test moulds, pouring them with aluminium alloy, and knocking out of castings to test the collapsibility of moulds and cores.

Keywords: moulding sands, inorganic binder, water glass, hardening with gaseous agents, dehydration

1. Introduction

With the ever more stringent requirements of environmental protection, increasingly important are becoming these technologies that, apart from the required technological parameters, are also least harmful to the environment [1-5].

Among various moulding and core sands, the sands with water glass seem to be precisely this type of product. In addition, foundry processes used in the manufacture of sands with silicate binders are considered cost-effective, due to a relatively low cost of production and a number of technical improvements that have eliminated the problems faced so far, resulting mainly from the sand flowability inferior to other types of moulding sands, and excessively high residual strength of moulds and cores. Yet, the inorganic nature of this binder creates various problems regarding the sand collapsibility and later reclamation [6-8].

It is possible to improve selected properties of the sands with water glass, such as the collapsibility, strength, resistance of moulds and cores to the effect of external factors, and also the reclamability by modification of the base sand composition, the choice of the best sand hardening technique, modification of binder, or the use of proper additives. In many domestic and foreign research centres, studies are carried out to mitigate the negative characteristics of foundry sands with water glass [9-12].

To alkaline silicates could be used as a binder for foundry must convert sol → gel. It can be done in two ways [13]:

a) The creation of the gel on an irreversible reaction - hardening chemicals. The basis of curing a chemical reaction with liquid CO_2 (according to the g patent L. Petržela):

$$\underbrace{Na_2O \cdot mSiO_2 \cdot nH_2O}_{\text{water glass (sol)}} + CO_2 / H_2CO_3 \rightarrow Na_2CO_3 / NaHCO_3 + \underbrace{Si(OH)_4}_{\text{gel}} .... \quad (1)$$

b) The creation of the gel based on the reversible reaction - curing physical. The basis of the cure is the dehydration of the rise thin, glassy and anhydrous film-gels, sodium silicate grains to quench materials:

$$Na_2O \cdot mSiO_2 \cdot nH_2O + energia^{-H_2O}_{+HO_2} \leftrightarrow Na_2O \cdot mSiO_2 .... \quad (2)$$

The advantage of reversible processes of dehydration is to achieve high strength properties, much higher than in the case of chemical cure, with minimum consumption of binder (min. Na_2O content). This fact shows better susceptibility to decay cores in foundries, and as a result significantly better knocking out.

2. The manufacturing technology of moulding sands hardened with gaseous agents - the choice of sand composition

In the first stage of the research, cores made on the test stand were subjected to basic technological studies. The same cores were also used in moulds tested for the knocking out properties. The test results are compared in the tables and graphs below.

Two types of binders were used in the studies, i.e. modified water glass designated as Binder A and hydrated

* FOUNDRY RESEARCH INSTITUTE, DEPARTMENT OF TECHNOLOGY, 73 ZAKOPIANSKA STR., 30-418 KRAKOW, POLAND

Corresponding author: jadwiga.kaminska@iod.krakow.pl

sodium silicate R145 used as a reference material. The sand hardener was hot air (the process of dehydration).

Moulding sands for the mechanical and technological tests were based on medium-grain size 1K silica sand from the Szczakowa mine of the main fraction 0.20/0.40/0.315.

The hot air for the sand blowing was preheated to 60, 70 and 80°C. The test sand compositions are listed in Table 1.

TABLE 1

Test sand compositions

Sand type	Sand composition, % by weight	Air temperature, °C	Blowing time, s
Sand with Binder A	Silica sand – 100 % by weight Binder A – 2,0; 1,5 i 1,0 % by weight	80, 70, 60	90, 120, 150, 180
Sand with water glass R145	Silica sand – 100 % by weight Water glass R145 – 1,5 % by weight	80, 70, 60	90, 120, 150, 180

The sand specimens were made under laboratory conditions using a modernized PS1 core shooter, installed and operating at the Foundry Research Institute (Fig.1).

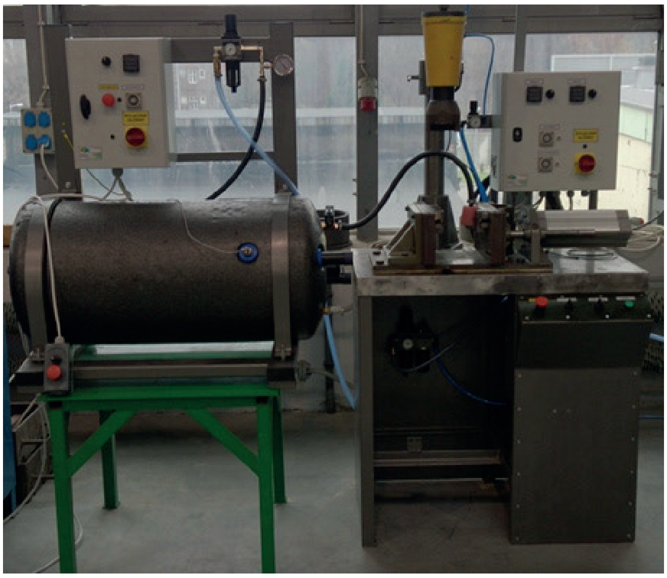

Fig. 1. A laboratory PS1 core shooter operating at the Foundry Research Institute

3. Test results

3.1. Testing of compressive strength

Compression tests were made after 3 and 24 hours of the sand hardening, but in this article only the results obtained after 24 hours of hardening are discussed. Figure 2 shows the results of tests carried out on the sands after 24 hours of hardening with the stream of hot air preheated to 60°C. In the case of the sand containing 1.5 parts by weight of Binder A, the time of blowing with hot air prolonged from 90 to 180 seconds has increased the sand strength. The response to the longer time of blowing of the sands containing other amounts of binder was only an insignificant change in the mechanical properties.

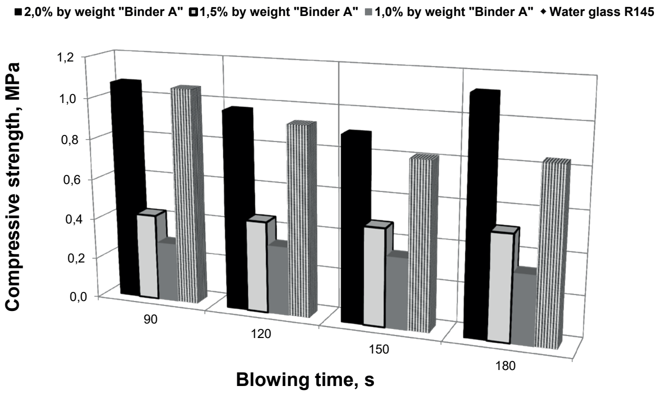

Fig. 2. Compressive strength Rc of specimens after 24 hours of hardening, 60°C

Figure 3 compares the strength properties of sands hardened with the stream of hot air preheated to 70°C. After 24 hours of hardening, the sands with the highest content of Binder A (1.5 and 2.0 parts by weight) had the strength nearly three times higher than the sand with the unmodified water glass.

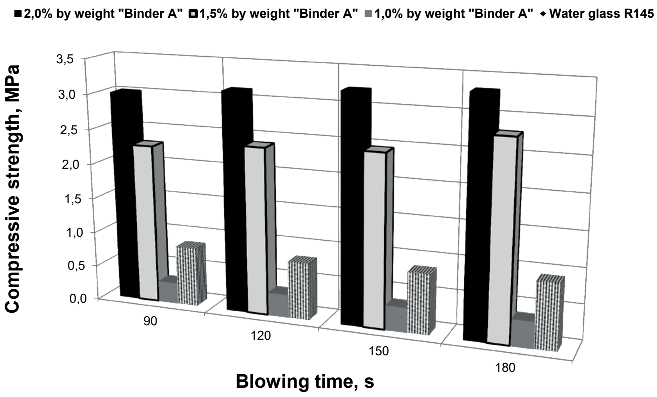

Fig. 3. Compressive strength Rc of specimens after 24 hours of hardening, 70°C

Figure 4 compares the strength properties of sands hardened with the stream of hot air preheated to 80°C. The results of compression test show a similar pattern of the strength growth as in the case of the sand hardened with the stream of hot air at a temperature of 70°C. The lower values of strength are most likely caused by the collapse of bonds between the modifier and water glass.

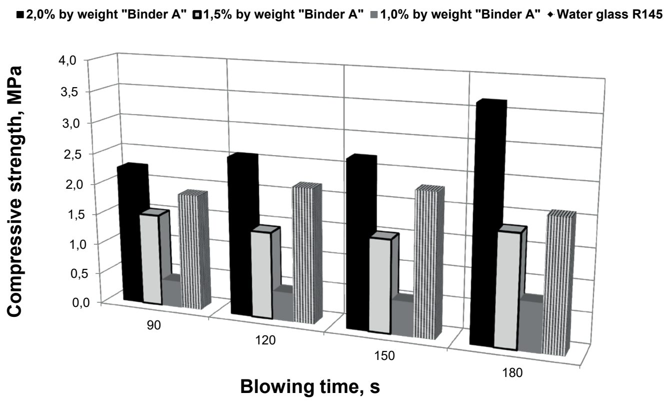

Fig. 4. Compressive strength Rc of specimens after 24 hours of hardening, 80°C

3.2. Studies of the knocking out properties of moulds and cores

The knocking out properties of moulds and cores made from the sands containing new binder hardened with a gaseous agent were determined in two ways, i.e. according to the PN-85/H-11005 standard, and by measuring the residual compressive strength.

Moulds and cores for the knocking out tests were made from the sand with modified water glass (Binder A) and, for comparison, from the sand with pure hydrated ethyl silicate R145.

Cores were made from the sands containing 1.5 parts by weight of Binder A, hardened by blowing for 120 seconds with the stream of hot air preheated to 60, 70 and 80°C. For cores made from the sand with unmodified water glass, the following parameters were adopted: binder content - 1.5 parts by weight, air temperature - 70°C, blowing time – 120 seconds.

Castings were poured from an Al-Si alloy (AlSi9 alloy). The alloy temperature at the end of the melting process before removing the crucible from the furnace and pouring of mould was 750oC. Test castings after knocking out and cooling to ambient temperature were placed together with cores in a device used for the determination of core collapsibility, counting the number of bob blows necessary to remove the core from casting.

Table 2 and Figure 5 show the results of measurements of the knocking out properties of the tested sands.

TABLE 2

Number of bob blows and work necessary to knock out the test castings

Sand type	Number of bob blows, n	Knock out work, J
Sand with Binder A - air temperature 60°C	4	6,4
Sand with Binder A - air temperature 70°C	3	4,8
Sand with Binder A - air temperature 80°C	5	8,0
Sand with water glass R145	12	19,2

The chart shows that water glass modification significantly improves the sand knocking out properties. The work needed to knock out the specimens made from the sand with Binder A is two to three times lower than the work needed for knocking out the specimens made from the sand with unmodified water glass.

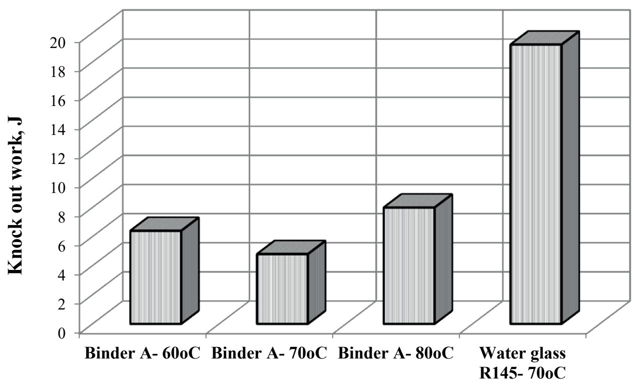

Fig. 5. Knocking out properties compared for sands with Binder A and sands with unmodified binder evaluated according to PN-85/H-11005

Measurements of the residual (final) strength were carried out on two sand mixtures: the sand with Binder A and the sand with water glass R145 (fig. 6). The specimens were made under the following conditions: binder content - 1.5 parts by weight, blowing time – 120 seconds, air temperature - 70°C.

The method for the residual strength measurement describes more accurately the sand collapsibility by describing also the mechanism of this phenomenon. The graph shows that modification of water glass reduces the residual strength of the sand within the entire range of the heating temperatures. The reduction of the residual strength Rtkc ranges from 35 ÷ 50% and depends on the moulding sand heating temperature. The most significant drop occurs in the temperature range of 300 - 700°C.

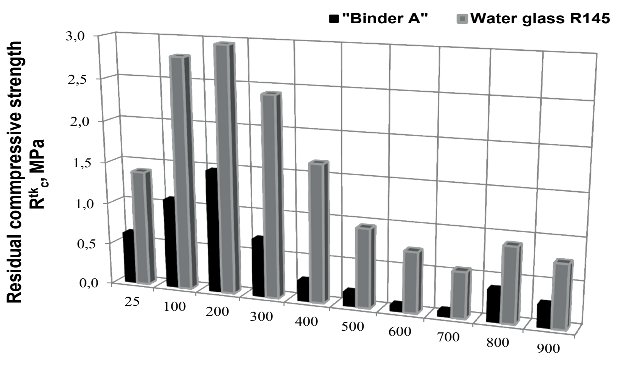

Fig.6. The residual compressive strength compared for sands with Binder A and sands with water glass

3.3. The reclamation of sands with modified water glass

During this stage, trials were carried out to investigate the reclamability of CO_2- hardened sands with the addition of new binder.

The reclamation trials were carried out in a laboratory

TABLE 4

The results of mechanical and technological tests carried out on the sand mixtures based on green sand and on reclaim

Tested sand mixtures, % by weight	P, 10^{-8} m^2/Pa.s			R_c, MPa			R_g, MPa			Knock-out property, J
	1h	3h	24h	1h	3h	24h	1h	3h	24h	
Silica sand – 100 Binder A – 2,5 Hardening CO_2	300	320	320	1,0	1,1	1,2	0,4	0,5	0,6	30
Sand/ Reclaimed sand 1 – 50/50 Binder A – 2,5	400	320	320	0,9	1,0	19	0,4	0,4	0,5	103,10
Sand/ Reclaimed sand 1 – 30/70 Binder A – 2,5	360	320	320	0,8	1,2	2,4	0,4	0,5	0,7	112,5
Reclaimed sand 1 – 100 Binder A – 2,5	400	380	400	0,4	1,5	2,8	0,5	0,6	0,8	123,34
Sand/ Reclaimed sand 2 – 50/50 Binder A – 1,5	-	320	340	-	1,4	2,6	-	-	-	51,2
Sand/ Reclaimed sand 2 – 30/70 Binder A – 1,5	-	360	320	-	1,5	2,8	-	-	-	62,4
Reclaimed sand 2 – 100 Binder A – 1,5	-	380	340	-	1,7	3,1	-	-	-	70,4

pilot plant installed and operating at the Foundry Research Institute. The obtained reclaim was added in various amounts to the sand mixtures, and ready mixtures were subjected to the technological tests. The same mixtures were used for foundry moulds poured with aluminium alloy. The next step comprised knocking out of moulds and cores. The conducted studies have shown that the use of reclaim as a substitute for green sand in mixtures hardened with the gaseous CO_2 deteriorates the sand knocking out properties. Therefore, attempts were made to introduce further adjustments to the composition of the sands containing the reclaim and reduce the amount of the added binder. The results of these and earlier studies are compared in the tables below.

Table 3 shows the results of mechanical and technological tests carried out on the mixtures prepared with pure green silica sand and with the sand containing 30, 50 and 100% of reclaim obtained from the reclamation process of moulding sands with modified water glass hardened by hot air blowing and for comparison by CO_2 blowing.

The tested CO_2-hardened sands with Reclaim 1 contained 3.0 parts by weight of Binder A, while sands hardened with the stream of hot air contained 2.0 parts by weight of modified water glass. The time of blowing with CO_2 was 20 seconds, and with the stream of hot air preheated to 70°C - 120 seconds.

All tested sands based in part or in whole on the reclaim were characterized by higher strength parameters than the sand mixtures based on pure silica sand. Although containing less binder, the sand mixtures with Reclaim 2 hardened by hot air blowing were characterized by higher compressive strength than the sands based on Reclaim 1 containing more binder and hardened by CO_2 blowing.

Sand mixtures with Binder A hardened with the stream of hot air were characterized by high strength parameters combined with satisfactory knocking out properties. Therefore the obtained results enable stating that the sand mixtures made under these conditions can be used for both moulds and cores.

Acknowledgements

The article is based on the research carried out under the ZAMAT Strategic Project No. POIG.01.01.02-00-015/09 entitled "Advanced materials and technologies for their manufacture."

4. Conclusion

Studies have confirmed that the use of modified water glass in foundry sands hardened with the stream of hot air allows achieving favourable technological parameters, both at ambient and elevated temperature.

Among the tested sands, the best mechanical properties were obtained in the sands hardened with hot air preheated to 70°C with the addition of binder A in an amount of 1.5 and 2.0 parts by weight. Hence it follows that in the sand mixtures with modified water glass hardened with the stream of hot air preheated to an optimum temperature it is possible to use less binder than in the sands hardened with CO_2 or esters (Flodur).

The new technology (hardening with the stream of hot air) greatly improves the knocking out properties of foundry sands relative to the sands using the same binder but hardened with CO_2, conferring at the same time adequate technological parameters.

With mechanical reclamation applied to these sands, it is possible to use up to 70% of the reclaim in the manufacture of foundry moulds and cores. Higher amount of the reclaim (above 70%) rapidly deteriorates the sand mouldability (bench life).

REFERENCES:

[1] J.L. Lewandowski, Tworzywa na fory odlewnicze, Wydawnictwo Akapit, 1997, Kraków.

[2] M. Holzer, et al., Wpływ dodatku regeneratu na jakość odlewów i szkodliwość mas formierskich i rdzeniowych nowej generacji, Wydawnictwo Naukowe AKAPIT, 2015, Kraków.

[3] R. Dańko, Archives of Foundry Eingineering **10**(2), 33-38 (2010).

[4] B. Stypuła, A. Kmita, M. Hajos, Materials Science **20**(1), 3–9 (2014)

[5] I. Izdebska-Szanda, A. Baliński, New generation of ecological silicate binders. Procedia Engineering **10**, 887–893 (2011).

[6] F. Pezarski, E. Smoluchowska, Z. Maniowski, I. Izdebska-Szanda, T. Bogacz, Solidification of Metals and Alloys **43**(2), 427-432 (2000).

[7] J. Kamińska, J. Dańko, Archives of Foundry Engineering **12**(2), 65-70 (2013).

[8] J. Wang, Z. Fan, el. At. China Foundry **4**(1), 26-30 (2007).

[9] R. Purgert, A. Baliński, J. Sobczak, et al., Archives of Mechanical Technology and Materials **26**(1), 1-10 (2006).

[10] A. Kmita, B. Hutera, Archives of Foundry Engineering **8**(2), 45-50 (2014).

[11] K. Granat, D. Nowak, M. Stachowicz, Archiwum Technologii Maszyn i Automatyzacji **30**(1), 19-27 (2010).

[12] K. Major-Gabryś, St. M. Dobosz, et al., Archives of Foundry Engineering **25**(1), 130-134 (2012).

[13] P. Jelinek, VII Konferencja Odlewnicza Technical 5-13 (2005).