ARCHIVES
of
FOUNDRY ENGINEERING

Published quarterly as the organ of the Foundry Commission of the Polish Academy of Sciences

ISSN (1897-3310)
Volume 8
Issue 2/2008

61 – 66

13/2

Investigating the kinetics of the binding process in moulding sands using new, environment-friendly, inorganic binders

I. Izdebska-Szanda*, F. Pezarski, E. Smoluchowska
Department of Technology, Foundry Research Institute, ul. Zakopiańska 73, 30-418 Kraków, Poland
* Corresponding author. E–mail address: e-mail: irsza@iod.krakow.pl

Received 08.02.2008; accepted in revised form 29.02.2008

Abstract

The article discusses the results of an investigation carried out on the chemically bonded and CO_2 blown moulding sands using selected, modified inorganic binders. The investigations make an important part of the work conducted within the framework of a statutory activity to optimise the sand technology using new, modified, inorganic binders.
The presented results of the investigation of the self-setting sands with new inorganic binders show changes in basic technological parameters in function of time and with varied content of the binding agents.
The, very important for a foundry, effect of ambient conditions (temperature and humidity) on the kinetics of the binding process of the self-setting sands with these binders was discussed.
In the case of sands hardened with CO_2, attention was drawn to the problem of mould and core surface quality, expressed in terms of the friability, very important for the quality of castings made under industrial conditions.

Keywords: Innovative materials and foundry technology; New inorganic binders; Strength; Bench life; Friability.

1. Introduction

The growing demand for environmental protection and the related costs make inorganic binders more and more interesting.

The main representative of these binders - the hydrated sodium silicate known under a common name of water glass - is a non-toxic and cheap binder but, compared with sands with organic binders, its main disadvantages are poor knocking out properties, low plasticity and poor reclamability, inferior to that of the sands with organic binders.

This is the reason why numerous scientific and research centres as well as the manufacturers of binders carry out intense research on the development of new, or modification of the so far existing, inorganic binders. The main aim of the research is to improve the technological properties of these binders and the knocking out properties of sand mixtures prepared with these binders, reducing at the same time their content in a moulding mixture. New inorganic binders are developed, e.g. the inorganic binder of a trade name CORDIS, assigned for the manufacture of cores on core shooters [1], an inorganic binder used in Hydrobond system [2], or Rudal - a geopolymer inorganic binder [3]. In the case of sodium silicate, the studies carried out by various research and development centres are mainly focussed on an improvement of the knocking out properties of sands prepared with this binder and on the possibility of reducing its content in a sand mixture. Some attempts have also been made to introduce special additives directly to the sand [4,5], or to modify chemically the ethyl silicate in a way such as to obtain, through a change in its strength parameters, specifically at high temperatures, an improvement in the knocking out properties of the ready sand mixture [6,7]. Chemical modification of sodium silicate is one of the tasks included in a research program of the Technical Universities in Koszyce (modifiers based on calcium compounds and their respective hydrates) [8] and in Ostrava (additives based on products of the reduction of monosaccharides and special additives of an organosilicate type) [9, 10].

At the Foundry Research Institute in Kraków, the modification of sodium silicate has been done using, among others, some organofunctional additives of the type of polymers and copolymers of acryl and polyvinyl alcohol, the presence of which is expected to improve the knocking out and technological properties of the sands, on one hand, while enabling, on the other, a reduction of the binder content in sand [6,11, 12,13].

The problem to solve is the time of the sand hardening until stripping of the mould. The best (in respect of technological properties) modified sodium silicate of grade 150MC has, in spite of high mechanical strength, the time of binding too long to satisfy the requirements imposed by numerous foundries.

As mentioned in the numerous publications at home and abroad, besides the content of binder and hardener, the time of binding also depends on ambient temperature and humidity and on the sand components. Therefore, within the framework of statutory activities, complex research works have been carried out by the Foundry Research Institute in Kraków [14] to optimise the sand technology using new inorganic binders, taking also into consideration a modification of the binding composition and the effect of additives, temperature and humidity on the technological properties of the resultant sand mixtures.

2. Main guidelines and objective of the studies

When it comes to the choice of technology, the aspects most important for a foundry include the price of a binder and its non-toxic behaviour as well as the quality of moulds and cores, the long or short time of binding, knocking out properties and reclamability.

Therefore, within the framework of a statutory work on optimising the technology of moulding sands with inorganic binders [14], comparative studies were carried out on the three selected inorganic binders, and the kinetics of their binding process referred to ambient conditions was investigated.

Investigations covered moulding sands with inorganic binders based on hydrated sodium silicates modified with morphoactive additives (viz. 150MC and 145MC) developed by Foundry Research Institute, and a binder, based on mineral polymers, offered in the domestic market as a substitute for sodium silicate (Rudal A), hardened with both liquid (self-setting sand mixtures) as well as gaseous (CO_2) hardeners.

Owing to the studies carried out by Foundry Research Institute on the kinetics of the sand binding process using new modified inorganic binders, it has been possible to prove a difference that exists between the individual binders and the scope of their application related to the requirements imposed by potential users, which are various foundry plants.

In the case of self-setting sands, the investigations revealed the possibility of controlling the sand composition through reduced binder content and the choice of a best hardener, studying the effect of ambient conditions on the sand parameters.

3. Investigations of the kinetics of the sand binding process using new binders

3.1. Self-setting sands

Investigations covered the mechanical tests performed in function of time with different content of the binder and hardener and under varied environmental conditions. Each time also the bench life was determined, as shown in the diagram below.

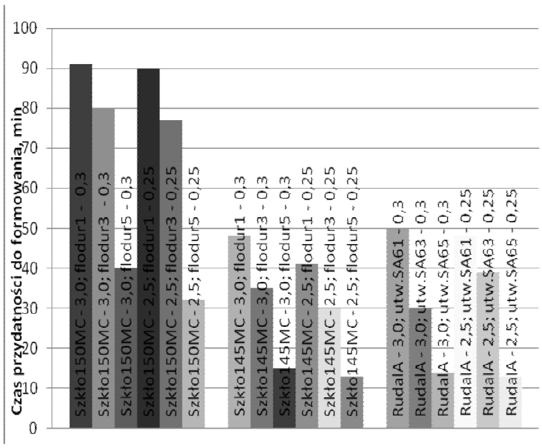

Fig. 1. The sand bench life in function of the number and type of the binding agents

The diagram shows the range of the sand bench life time control through application of the different types of the hardeners and binders, added in different ratios.

The kinetics of changes in the technological parameters for all the three examined binders has been plotted in the form of graphs, taking as an example the compression strength. The kinetics of changes in the bending strength yields similar results.

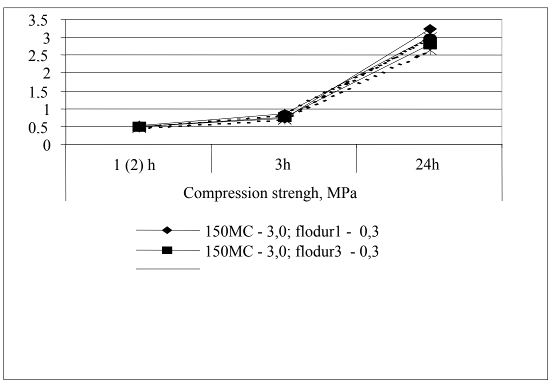

Fig. 2. Kinetics of changes in the compression strength of sodium silicate, grade 150MC

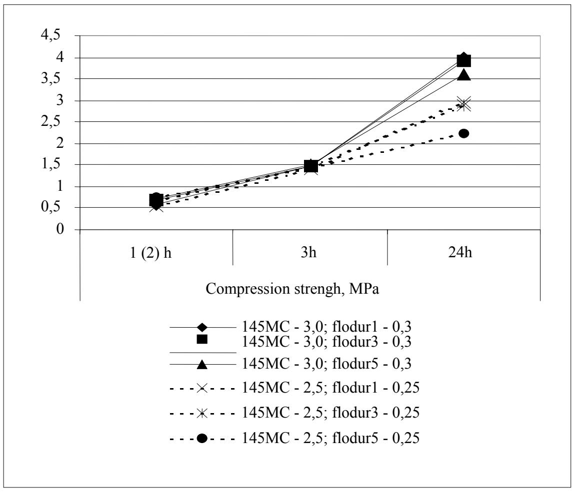

Fig. 3. Kinetics of changes in the compression strength of sodium silicate, grade 145MC

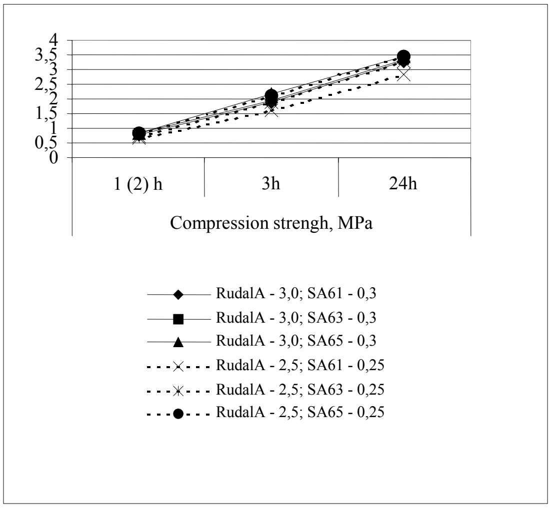

Fig. 4. Kinetics of changes in the compression strength of Rudal binder

It is easy to note that in the modified sodium silicates the sand strength during the first few hours increases very slowly, which is best seen in the case of 150 MC sodium silicate, while in the case of Rudal the increase in strength occurs much more quickly (the curve assumes an almost linear shape), achieving relatively high values as early as after the lapse of three hours.

Although final values of the strength are comparable for all the three types of binder, the kinetics of the strength growth may determine the choice of a given binder to make it best fitted to the currently applied production cycle (e.g. the time of core box dismantling demanded by the technological process) or to the size of moulds.

The technological parameters of the sands were determined also in respect of different ambient conditions. The changes covered both temperature and relative humidity. The investigations were carried out in an air-conditioned chamber, which enabled maintaining the conditions stable throughout the entire cycle of investigations.

The investigations were conducted for three different values of temperature and for three different values of the relative humidity.

The graphs below compare the bench life and the strength parameters examined after 3 and 24 hours at changing humidity and ambient temperature.

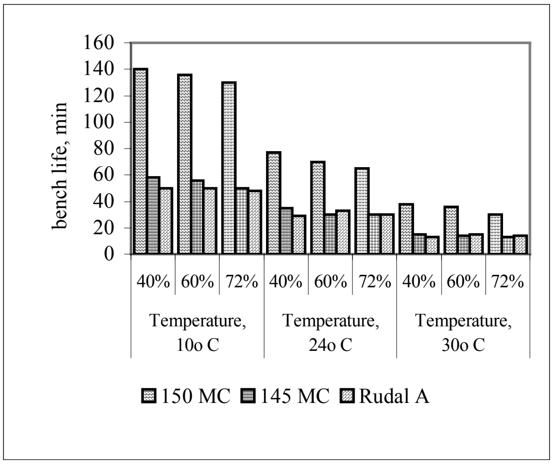

Fig. 5. The bench life in function of temperature and humidity

An analysis of the results of the investigations plotted in the form of diagrams shows that the self-setting sands prepared with modified binders are sensitive to ambient temperature but not to the effect of humidity. The bench life of these sands, longer or shorter, depends on the temperature.

The longest bench life offer the sands prepared with modified 150 MC sodium silicate.

Irrespective of ambient temperature, the addition of hardeners characterised by different level of activity reduces the sand bench life by approximately one half. Similar behaviour reveal the sands prepared with modified 145 MC sodium silicate and sands prepared with Rudal A.

The character of changes in compression and bending strengths is similar in all the sands examined after 1h, 3 h and 24 h.

From an analysis of the results of the investigations it has been concluded that with the hardening process parameters preset and maintained during the studies, the greatest effect on the strength characteristics has the temperature. Changes in strength under the effect of the changing ambient humidity but with the temperature kept constant are only insignificant.

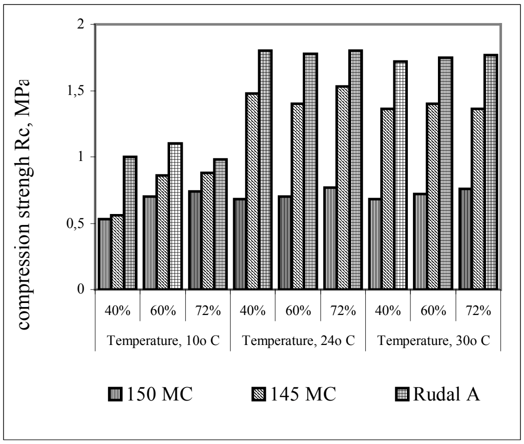

Fig. 6. Changes of compression strength in function of temperature and humidity after 3 h since the sand preparation

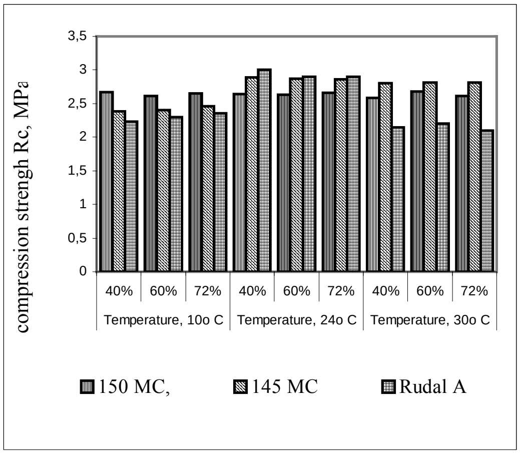

Fig. 7. Compression strength in function of temperature and humidity after 24 h since the sand preparation

In the case of sands with 150 MC sodium silicate, the most stable strength parameters were obtained in as-hardened state, irrespective of the ambient conditions. The differences are quite serious after the time of 3h since the sand preparation but this is due to a significant effect of temperature on the bench life of these sands, and hence on the time of hardening.

Sands with the 145MC sodium silicate and with Rudal achieve higher strength parameters after 3 h, which is related to their shorter bench life and lower stability in as-hardened condition (after 24h). Temperature and humidity were observed to be of major importance in the case of sands with Rudal binder.

3.2. CO_2-hardened sands

The composition of the CO_2 hardened sands was established as a result of preliminary investigations using modified sodium silicate in grades 145 MC and 150 MC as well as a geopolymer Rudal A binder with and without the addition of a Geotek catalyst. As ambient conditions the temperature of 22^0C and humidity of 42% were selected.

The following parameters were determined in the ready sand mixtures: permeability P, compression strength Rc, bending strength Rg and friability. The typical parameters were determined immediately after the sand hardening and after the time of 3 and 24 h. For the sake of comparison, basic technological parameters were also determined for sands with the non-modified binders.

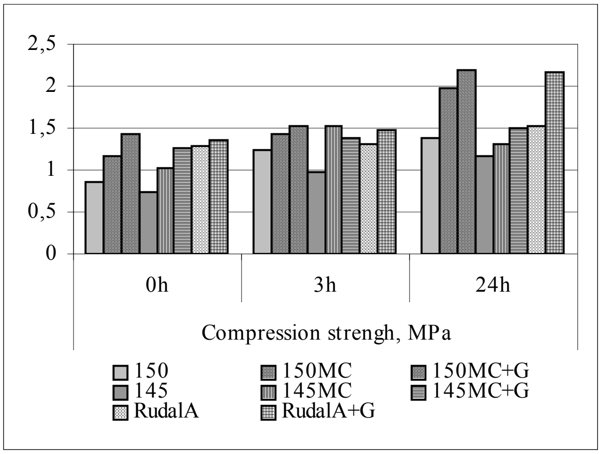

Fig. 8. Kinetics of changes in the compression strength of CO_2 hardened sands with various types of inorganic binders

Basing on the results of the investigations it has been stated that under the assumed and maintained hardening parameters, the best strength characteristics offer the sands prepared with a modified 150MC binder. Sands with the geopolymer binder reach similar values but only when Geotek catalyst is added.

Compared with the sands prepared with non-modified sodium silicates of grades 145 and 150, the sands with the modified binders are characterised by higher strength properties.

To reach comparable strength properties, the CO_2 hardened sands prepared with the modified inorganic binders need twice less of the binder addition than the same sands prepared with non-modified binder grades. Obviously, this fact being of great practical, economical and ecological impact, stresses the need of a wide-scale application of the new binders in foundry industry.

Sands prepared with geopolymer binder are characterised by higher friability than the sands prepared with modified grades of sodium silicate. The friability of sands with this binder rapidly increases with the elapsing time.

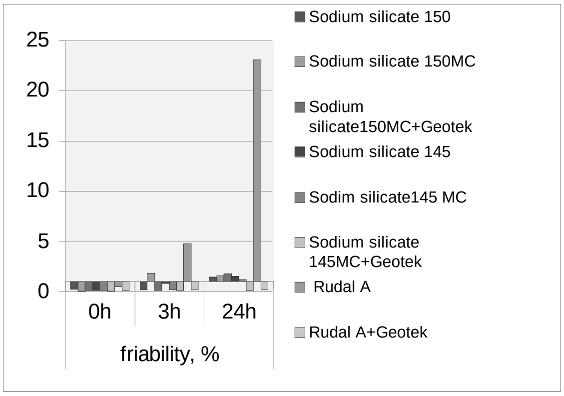

Fig. 9. The friability of CO_2 hardened sands in function of the binder type and catalyst addition

The addition of Geotek catalyst to sands prepared with modified binders improves their strength properties, accelerates the hardening process and reduces friability, especially in the case of geopolymer Rudal A binder. An addition of the Geotek definitely improves the sand quality, which is now comparable to the quality of sands prepared with modified sodium silicate of grade 150MC, as shown in the diagram above.

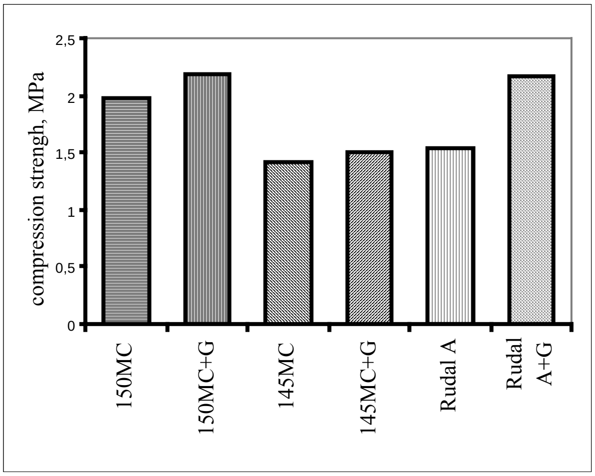

Fig. 10. Compression strength of the sand with and without an addition of the Geotek catalyst after 24h since the sand preparation

The preliminary studies on the effect of ambient conditions on the quality of CO_2 hardened sands with modified binders indicate a higher (contrary to self-setting sands) sensitivity of these sands to ambient humidity. Temperature is much lesss critical in this case. The investigations will be continued at further stages of the research programme.

4. Conclusions

The above presented results of the investigations of the kinetics of the binding process in sands with new modified inorganic binders enable us to better assess the applicability of a given binder in respect of the conditions and requirements imposed by potential users, i.e., the foundries.

In the case of self-setting sands, with comparable final strength parameters obtained for all the three types of binders, the choice of binder may depend on production cycle (e.g. the time of core dismantling dictated by the currently applied technological process) or on the size of moulds produced.

Analysing the results of the investigations carried out on the self-hardening sands it should be stated that an important external factor influencing the strength parameters of the sand is temperature.

The effect of temperature and humidity is most visible in sands with Rudal binder.

The application of modified inorganic binders in CO_2 hardened sands enables an almost double reduction of the binder content in sand, which is very important in terms of both economy and ecology, speaking in favour of a wide-spread use of the new binders by foundries.

The geopolymer binder used in CO_2 hardened sands without any special additions improving the surface quality and technological parameters must obviously „lose the game" compared with modified 150MC sodium silicate.

Basing on the preliminary investigations it seems that studies on the effect of ambient conditions on the quality of CO_2 hardened sands with modified binders should be continued.

An important factor to be taken into consideration at further stages of the studies will be the effect of reclaim on the kinetics of the sand binding process and parameters of the moulding mixtures prepared with this reclaim. The experience acquired so far indicates a beneficial effect of the reclaim on the strength properties of sands hardened with CO_2.

References

[1] K.Löchte, R.Boehm, Cordis, The inorganic binder system-properties and experience, Casting Plant and Technology International 2005 Vol.21, No. 3, p.6.

[2] K.Löchte, R.Boehm, Properties and expierence of an inogranic binder. Foundry Trade Journal, January 2006 Vol. 180, p. 28.

[3] J.Novotny, Self-setting sands with geopolymer binding system, Conference Proceedings, VIII Foundry Conference Technical 2005 (in Polish).

[4] St. M. Dobosz, K. Major-Gabryś, A new additive for moulding sands with water glass, DOKSEM 2003, Slovakia, Rajecke Teplice 2003, p. 38-41 (in Polish).

[5] St. M. Dobosz, K. Major-Gabryś, Glassex- a new additive improving the knock-out properties of moulding sands with water glass, Archives of Foundry, Katowice 2004, Vol. 4, No. 13, p. 63-68, (in Polish).

[6] A. Baliński, Chemical modification of sodium silicate to reduce the residual strength of moulding sands, A research

work of Foundry Research Institute, Kraków 2002, p. 9, No. 1013/00 (in Polish).
[7] A. Baliński et al., Influence of modification of the sodium silicate with morphoactive agents on the mechanical properties of the moulding sands in temperatures to 9000C, Materials Enginering, 2003, Vol. 10, No. 3, p. 271.
[8] I. Vaskova, L. Bobok, M. Sevcova, Relationships between the physical characteristics of water glass and the technological characteristics of water glass-based moulding and core sands, Materials Enginering 2003, Vol.X, No. 3, p. 249 (in Czech).
[9] P. Jelinek et al., Modified alkaline silicates – inorganic binders of the new generation, Slevarenstvi 2002, No. 1, p.16 (in Czech).
[10] P. Jelinek., R. Skuta, Modified sodium silicates – a new alternative for inorganic foundry binders, Materials Enginering, 2003, Vol. 10, No. 3, p. 283 (in Czech).
[11] A. Baliński., I. Izdebska-Szanda, Effect of morphoactive modifiers of hydrated sodium silicate on temperature transformations taking place in moulding sands prepared with this binder, Archiwum Technologii Maszyn i Automatyzacji, Vol. 24, p.19-29, Poznań, June 2004 (in Polish).
[12] I. Izdebska-Szanda, A. Baliński, Cohesive-adhesive properties of the chemically modified hydrated sodium silicate, A publication of the Faculty of Process and Materials Engineering and Applied Physics, The Częstochowa University of Technology, Czestochowa, 2005 (in Polish).
[13] A.Baliński, I.Izdebska-Szanda, The economical and ecological aspects of using the modified water-glass and fly ash as an additive to green sands, Conference Proceedings, 46 Foundry Conference, Portorož, 2006, p. 39 (CD).
[14] F.Pezarski et al., An improvement in the technology of moulding sands with inorganic binders and in their reclamation process to increase the economy and quality of castings manufactured from alloys of ferrous and non-ferrous metals, A statutory work no. 6005/00, stage 2007 (in Polish).