ARCHIVES
of
FOUNDRY ENGINEERING

ISSN (1897-3310)
Volume 14
Issue 1/2014

37 – 40

9/1

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

Influence of Binding Rates on Strength Properties of Moulding Sands with the GEOPOL Binder

M. Holtzer [a,] *, D. Drożyński [a], A. Bobrowski [a], W. Plaza [b]
[a] Faculty of Foundry Engineering, AGH University of Science and Technology, Reymonta 23 Str., 30-059 Cracow, Poland
[b] PPH Kratos S.C., Kolejowa 1 Str., 46-040 Ozimek, Poland
* Corresponding author. E-mail address: holtzer@agh.edu.pl

Received 27.06.2013; accepted in revised form 02.09.2013

Abstract

The results of investigations of moulding sands with an inorganic binder called GEOPOL, developed by the SAND TEAM Company are presented in the paper. Hardeners of various hardening rates are used for moulding sands with this binder. The main aim of investigations was determination of the influence of the hardening rate of moulding sands with the GEOPOL binder on technological properties of these sands (bending strength, tensile strength, permeability and grindability). In addition, the final strength of moulding sands of the selected compositions was determined by two methods: by splitting strength and shear strength measurements. No essential influence of the hardening rate on such parameters as: permeability, grindability and final strength was found. However, the sand in which the slowest hardener (SA 72) were used, after 1 hour of holding, had the tensile and bending strength practically zero. Thus, the time needed for taking to pieces the mould made of such moulding sand will be 1.5 - 2 hours.

Keywords: Mechanical properties, Technological properties, Moulding sands, Geopolymer, Inorganic binder

1. Introduction

Binders with inorganic binding systems are gaining more and more interest in the foundry industry. It is mainly caused by the fact that moulding sands with these binders are only minimally harmful for the environment, at comparable technological properties with moulding sands containing organic binders. A typical example of such binder can be the binding system called GEOPOL [1 - 11].

GEOPOL is the inorganic system of binding on the bases of geopolymers, applied in the production of cores and moulds of self-hardening moulding sands, developed by the SAND TEAM Company (The Czech Republic). A binding agent is an inorganic geopolimer, which under an influence of liquid hardeners undergoes polymerisation, forming polymers of a high binding ability. This geopolymer binder can be also hardened by means of CO_2. Geopolymers are inorganic materials, belonging to alkaline aluminosilicates. These materials contain silicon and aluminium and - stabilising them - alkaline elements such as sodium or potassium. Aluminium is contained in the aluminosilicate [12 - 16].

These materials occur in the nature as zeolites (Fig. 1). Geopolymers are obtained by means of synthesis. The binding material produced for the foundry practice, is a geopolymer already in its initial state, however of a low polymerisation degree. It means, that the geopolymer is not formed only during the hardening process, (as it happens in case of geopolymers produced for building industry, where the hardening process is long-lasting and equals e.g. 28 days). It warrants the proper polymerisation and hardening rates. The applied hardeners assure the proper binder hardening times in a range from 15 to 150 minutes, allowing removal of the equipment.

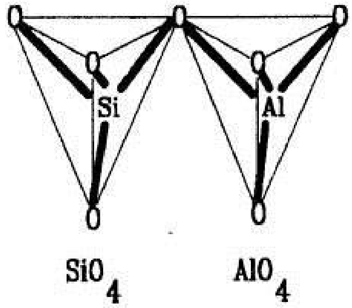

Fig. 1. Structure of a geopolymer. Geopolymers belong to alkaline aluminosilicates

The Geopol binder can be applied for making moulds and cores for castings of iron, cast steel and non-ferrous metals. The Geopol system is suitable for high-silica, olivine, chromite and zirconic sands. The Geopol binder is a colourless liquid of a basic character (pH = 11 – 13) and amorphous structure, well soluble in water. Hardeners from SA 70 group are used for this binder hardening (SA 71 and SA 72 – slow, SA 73 and SA 74 – middle, SA75 and SA 76 - fast). This allows to obtain various times needed for the model removal from the mould (Fig. 2)

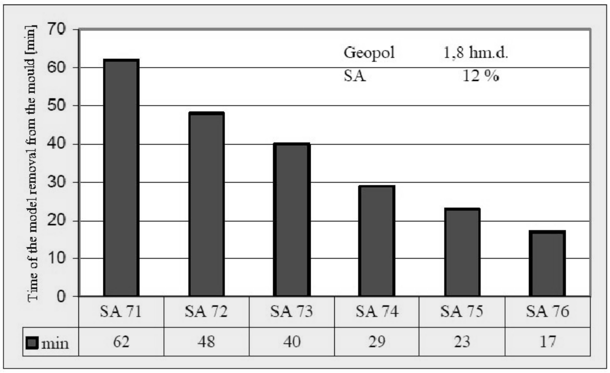

Fig. 2. Allowable times of the model removal from the mould – in dependence of the applied hardener [3]

For cores and moulds with the Geopol binder protective alcoholic coatings should be applied.

According to the producer, the SAND TEAM Company, the moulding sand with the Geopol binder is characterised with good knocking out properties and is easy for the mechanical reclamation. The formed geopolymer has a high strength, which causes that the binder detachment from grains occurs (it means that a destruction is of an adhesive character). The moulding sand with the Geopol binder can be also prepared with an addition of reclaim materials as a matrix. The reclaim addition can be equal 100% for the backing sand, 75% for the facing sand, while up to 60% for the straight core. Complex cores should be prepared in 100% with the fresh sand matrix.

2. Applied materials and investigation methodology

2.1. Materials used in investigations

The following systems were subjected to tests:

- GEOPOL binder + hardener: SA 72, SA 74 or SA 75;

Compositions of the investigated moulding sands (the range suggested by the producer):

- Series I: Geopol binder 1.8 % + hardener 12% (in relation to the binder amount),
- Series II: Geopol binder 1.8% + hardener 14% (in relation to the binder amount),
- Series III: Geopol binder 2.0% + hardener 12% (in relation to the binder amount),
- Series IV: Geopol binder 2.0% + hardener 14% (in relation to the binder amount).

The following properties of moulding sands were tested:

- Tensile strength, R_m^u, acc. to standard: PN-83/H-11073,
- Bending strength, R_g^u, acc. to standard: PN-83/H-11073,
- Permeability, P^w, acc. to standard: PN-80/H-11072,
- Grindability, S, acc. to standard: BN-77/4024-02,
- Compression strength, R_c^w, acc. to standard: PN-83/H-11073,
- Splitting strength, R_p^{tk}, acc. to standard Multiserw Morek.

3. The obtained results and their discussion

3.1. Investigations of moulding sands properties

Changes of the basic properties of moulding sands with the GEOPOL binder in time are presented in Fig. 3 and 4, the tensile strength and bending strength – respectively. When the slowest hardener (SA 72) is used the moulding sand after 1 h has practically zero of bending and tensile strengths. An application of faster hardeners (SA 74 and SA 75) increases the strength after 1 h. to 0.5 – 0.7 MPa, and this value is practically maintained for next 3 - 4 hours. After 24 hours, all investigated moulding sands obtained similar values of the tensile and bending strength. They were within the range:

- Tensile strength: from 0.6 to 0.8 MPa;
- Bending strength: from 1.22 to 1.65 MPa.

A certain regularity was observed: an application of a slower hardener provides slightly higher strength values (after 24 h).

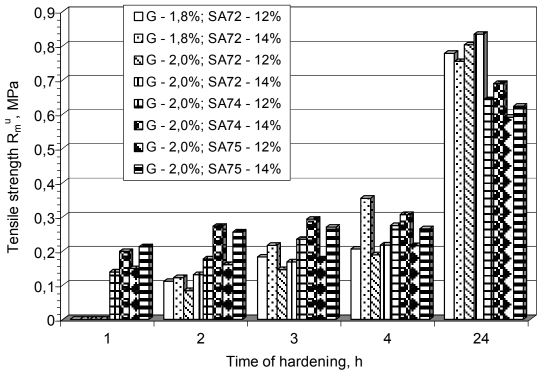

Fig. 3. Dependence of the tensile strength on the hardening time of the moulding sand with the GEOPOL and SA 72, SA 74 and SA 75 hardeners (G - Geopol)

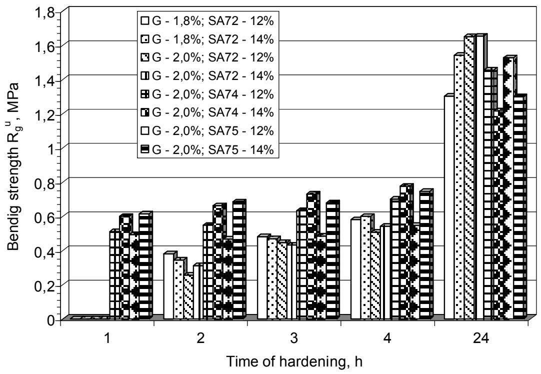

Fig. 4. Dependence of the bending strength on the hardening time of the moulding sand with the GEOPOL and SA 72, SA 74, SA 75 hardeners (G - Geopol)

The results of permeability tests of moulding sands with the GEOPOL binder and hardeners of different binding rates at various fractions of hardeners and binders are presented in Fig. 5.

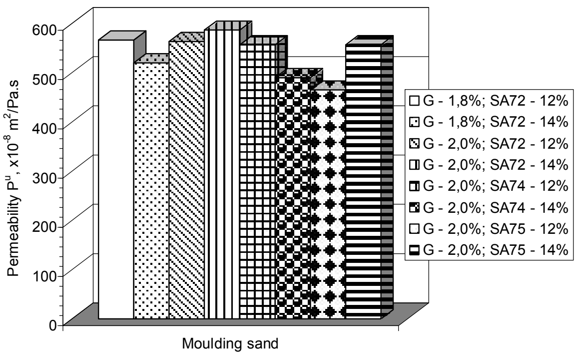

Fig. 5. Dependence of the permeability on the hardening time of the moulding sand with the GEOPOL and SA 72, SA 74 and SA 75 hardeners (G - Geopol)

In practice, none essential differences were found (within the investigated range), since permeability of all sands was within the range: 460 - 590 units.
Also grindability of the tested sands was comparable and within the range: 2.8 –3.9% (Fig. 6).

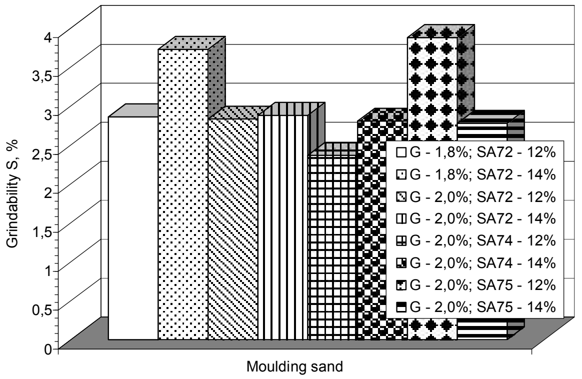

Fig. 6. Dependence of the grindability on the hardening time of the moulding sand with the GEOPOL and SA 72, SA 74 and SA 75 hardeners (G - Geopol)

3.2. Determination of the final strength

The final strength in dependence of the heating temperature was determined for the selected moulding sands systems. As the criterion the compression strength (Fig. 7) and splitting strength (Fig. 8) were assumed. In both cases, the maximum values were obtained for moulding sands heated at temperatures: 800° - 900°C, thereupon at a further temperature increase a weak decrease of these strengths occurred.

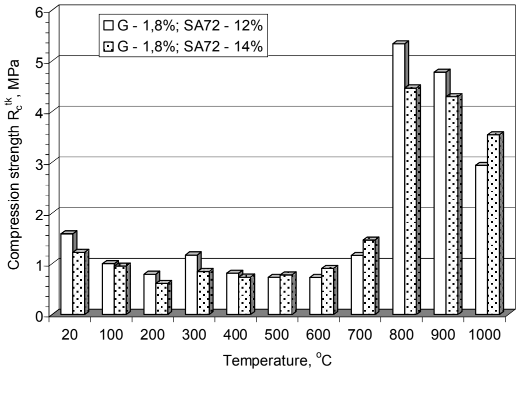

Fig. 7. Dependence of the final compression strength on the heating temperature of the moulding sand with the GEOPOL and SA 72 hardener (G - Geopol)

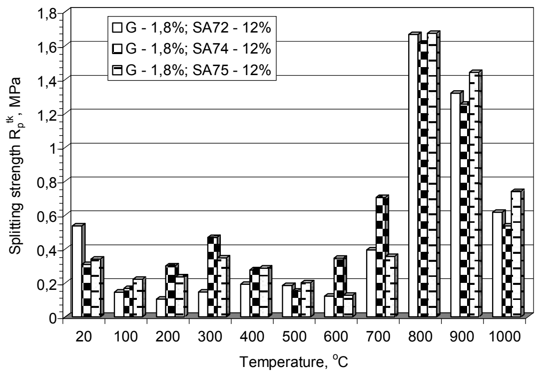

Fig. 8. Dependence of the final splitting strength on the heating temperature of the moulding sand with the GEOPOL and SA 72, SA74, SA75 hardeners (G - Geopol)

4. Conclusions

On the bases of the performed investigations of moulding sands with the GEOPOL binder at applying hardeners of various hardening rates, it can be stated that:

1. An application of a slower hardener (SA72) gives slightly higher moulding sands strength for bending and tensile after 24 hours, than at an application of faster hardeners (SA 74 or SA 75).
2. The moulding sand hardened by the slowest hardener (SA 72), after 1 hour, obtains zero strength for the tensile and bending strength. Only after 3 - 4 hours it obtains strength values comparable with the ones obtained for moulding sands hardened with faster hardeners.
3. A change of the hardener does not cause essential differences in permeability and grindability of moulding sands with the GEOPOL binder, in the tested composition range.
4. The final strength determined by two methods: by measuring the splitting and compression strength indicates that moulding sands with the GEOPOL binder obtain maximum values in both cases at temperatures: 800° - 900°C.

Acknowledgements

The work was realised within the NOT project No. ROW-III-315-2012

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