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# Influence of the Reclaim Addition on Properties of Moulding Sands with the Geopol Binder

**D. Drożyński<sup>a\*</sup>, A. Bobrowski<sup>b</sup>, M. Holtzer<sup>b</sup>**
<sup>a</sup>Department of Moulding Materials, Mould Technology and Foundry of Non-ferrous Metals

<sup>b</sup>Department of Foundry Process Engineering

AGH University of Science and Technology, Faculty of Foundry Engineering,

\*Corresponding author. E-mail address: dd@agh.edu.pl

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## Abstract

The investigation results of the influence of the reclaim additions on the properties of moulding sands with the GEOPOL geopolymer binder developed by the SAND TEAM Company were presented. Two brands of hardeners were applied in the tested compositions, the first one was developed by the SAND TEAM Company, marked SA72 and the new hardener offered by the KRATOS Company, marked KR72. The main purpose of investigations was to determine the influence of reclaim fractions and the applied hardener on the basic moulding sands properties, such as: bending and tensile strength, permeability and grindability. The unfavourable influence of the reclaim additions into moulding sands on the tested properties as well as an increased hardening rate, were found. Moulding sands, in which the hardener KR72 of the KRATOS Company was used, were less sensitive to the reclaim additions.

**Keywords:** Inorganic binder, Moulding sand, Geopolymer binder, Mechanical properties, Technological properties

## 1. Introduction

Current technologies using water-glass - hardened by CO<sub>2</sub> - as a binder (applied mainly for the cores production in some aluminium and cast iron foundry plants) and hardened by liquid esters based mainly on glycerine and ethylene glycol (the so-called acetates) are characterised, apart from obvious ecological good points, by certain technological failures such as: bad knocking out ability, low process yield or difficulties in the spent moulding sands reclamation. Investigations on water-glass modifications, aimed at limiting these failures, containing applications of organo-functional polymers and acrylic copolymers, polyvinyl alcohols, are currently performed. Several processes utilising the physical factors, mainly temperature, for

hardening - were worked out in recent years. The first implementations, of new technologies based on water-glass as a binder, were in the cores production for permanent mould castings of brass and light metals. Presently these technologies are successfully used also in the cast iron and cast steel foundries. Among others, these are technologies: INOTEC (ASK Chemicals Company), CORDIS (Hüttenes Albertus Company) and AWB (MINELCO Company). A good point of such binders is their solubility in water and thus the reactivation possibility [1-12].

Another kind of inorganic binders is based on geopolymers and inorganic salts (NaCl, KCl). Geopol is the inorganic binders system based on geopolymers, applied in cores and moulds production of self-hardening moulding sands. This GEOPOL (geopolymer), under an influence of liquid hardeners undergoes polymerisation, due to which polymers of a high binding ability

are formed. Geopolymers are inorganic materials, belonging to alkaline aluminosilicates. These materials contain silicon and aluminium as well as - stabilising them - alkaline elements such as sodium or potassium. Geopolymers are obtained by means of a synthesis. The binder, which already in its initial state is a geopolymer (however of a low polymerisation degree), is produced for the needs of foundry engineering. It means this geopolymer is not formed only during hardening (as it occurs in case of geopolymers produced for building industry, where the hardening process is long and equals e.g. 28 days). This warrants the proper polymerisation and hardening rates. The applied hardeners (of the SA 70 series) provide the proper hardening times (from 15 to 150 minutes) allowing the instrumentation removal. The GEOPOL binder can be used for making moulds and cores for castings of cast iron, cast steel and non-ferrous metals. The GEOPOL system is suitable for high-silica, olivine, chromite and zirconium sands. The GEOPOL binder is a colourless liquid of an alkaline character (pH = 11 – 13) and of an amorphous structure, well water soluble [13-18].

According to the producer (the SAND TEAM Company) moulding sands with the GEOPOL binder are characterised by a good knocking out ability and are easy for the mechanical reclamation. The formed geopolymer has a high strength, which causes the binder detachment from grains (it means that the destruction is of an adhesive character). The moulding sand with the GEOPOL binder can be also prepared with the reclaim addition as the matrix.

Investigations of mechanical and technological properties of moulding sands with the GEOPOL binder and SA72 and KR72 hardeners, prepared on the fresh sand matrices were performed first [19, 20]. In order to determine the influence of the reclaim fraction (from moulding sand with the GEOPOL binder) and the new hardener of the KRATOS Company on the basic properties of moulding sands with the GEOPOL binder, the investigations described in the hereby paper were carried out.

The elution [22] and gas evolution tendency of these moulding sands was also tested in order to determine their influence on the environment during individual operations (mainly of pouring and knocking out of castings) [21].

## 2. Applied materials and investigation methodology

Moulding sands of the composition: matrix – 100 parts by mass, GEOPOL binder - 2.0 parts by mass, hardener: SA72 (SAND TEAM) or KR72 (KRATOS) in amounts being 14% in relation to the binder amount. The pure high-silica sand 'Biała Góra', the reclaim (obtained in the mechanical reclaimer) of moulding sands with the GEOPOL binder and the hardener, as well as their mixtures were applied as the matrices. Moulding sands with the reclaim fractions being: 0, 60, 80 and 100%, were tested.

Moulding sands were prepared in the laboratory roller mixer, LM-1 type, applying the following order of adding substances and mixing times: matrix + hardener – 1.5 min, then binder was added and mixed again for 1.5 min.

The moulding sands properties were determined for shaped elements compacted by vibrations in the device LUZ-1 for 20 seconds at the amplitude of 2 mm.

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,  $P_u^u$ , acc. to standard: PN-80/H-11072,
- Grindability, S, acc. to standard: BN-77/4024-02.

## 3. The obtained results and their discussion

The results of the basic properties of moulding sands are presented in Figures 1 - 4: Fig. 1 – Tensile strength  $R_m^u$ , Fig. 2 – Bending strength  $R_g^u$ , Fig. 3 – Permeability  $P_u^u$  and Fig. 4 – Grindability S.

Analyses of the investigation results of the influence of the hardening time on the tensile strength (Fig. 1a and 1b) and bending strength (Fig. 2a and 2b) allowed to find out a significant increase of the obtained values with the hardening time prolongation. Moulding sands prepared on the pure high-silica sand, in which the SA72 hardener was used, obtained higher strength values (after 24 hours of hardening) than the sands with the KR72 hardener by app. 38% for  $R_m^u$  and app. 30% for  $R_g^u$ .

An application of the reclaim in the matrix causes the moulding sand hardening acceleration, which can be noticed due to higher strength values in shorter hardening times (1 – 4 h), especially in case of moulding sands with the SA72 hardener. However, after 24 hours of hardening an unfavourable influence of the reclaim addition can be noticed. Moulding sands with the KR72 hardener are less sensitive for an increase of the reclaim fraction in the matrix. Their strength decrease at the reclaim fraction being 60% equals app. 20% for  $R_m^u$  and  $R_g^u$ , while in case of moulding sands with the SA72 hardener this decrease equals app. 50%. Moulding sands with the KR72 hardener, after 24 hours of hardening, obtained higher strength values for every composition containing the reclaim, than sands with the SA72 hardener.

The results of the permeability tests are presented in Figure 3a (moulding sands with the SA72 hardener) and 3b (moulding sands with the KR72 hardener). Moulding sands with the SA72 hardener obtained higher permeability values for nearly every tested composition, since only in case of moulding sands prepared totally on the reclaim the permeability was the same as for the sand with the KR72 hardener. The largest difference in the obtained values occurred for moulding sands prepared on the pure high-silica sand, where the moulding sand permeability with the SA72 hardener was app. 30% higher than the one with the KR72 hardener. In case of the sand with the KR72 hardener an increased reclaim content causes increasing of its permeability.

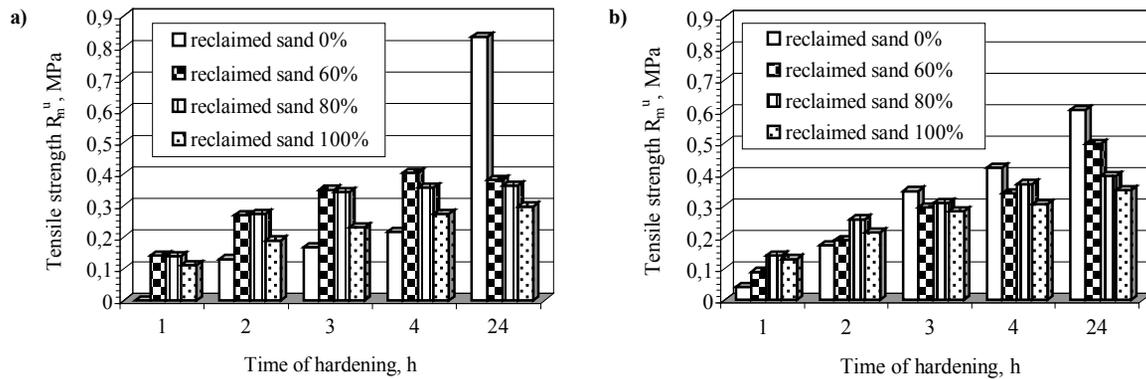


Fig. 1. Influence of the hardening time on the tensile strength,  $R_m^u$  of the moulding sand of the composition: high-silica sand 0 – 100 parts by mass, reclaim 0 – 100 parts by mass, GEOPOL binder 2.0 parts by mass, hardener – 14% of the binder amount: a) SA72, b) KR72

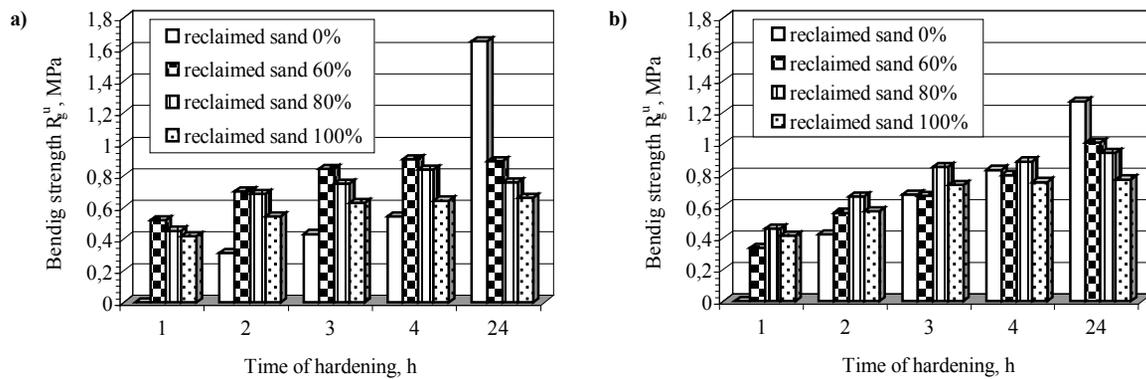


Fig. 2. Influence of the hardening time on the bending strength,  $R_g^u$  of the moulding sand of the composition: high-silica sand 0 – 100 parts by mass, reclaim 0 – 100 parts by mass, GEOPOL binder 2.0 parts by mass, hardener – 14% of the binder amount: a) SA72, b) KR72

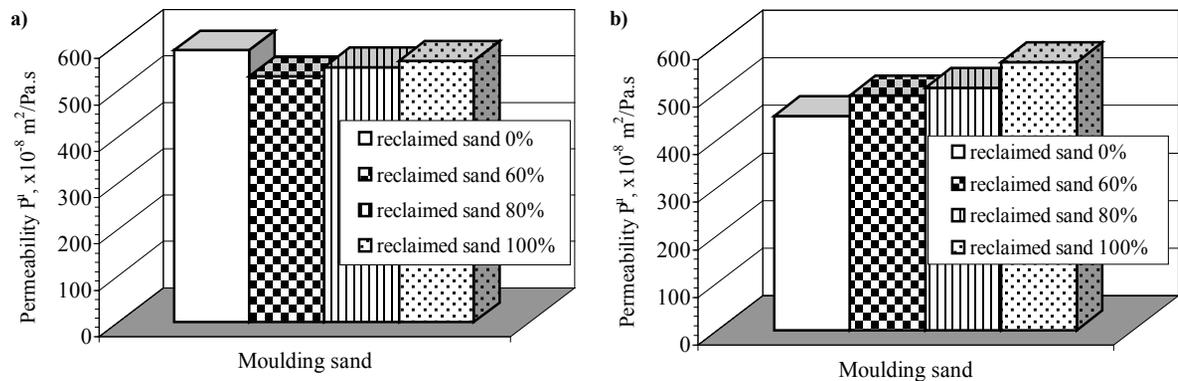


Fig. 3. Influence of the reclaim addition on the permeability,  $P^l$ , of the moulding sand of the following composition: high-silica sand 0 – 100 parts by mass, reclaim 0 – 100 parts by mass, GEOPOL binder 2.0 parts by mass, hardener – 14% of the binder amount: a) SA72, b) KR72

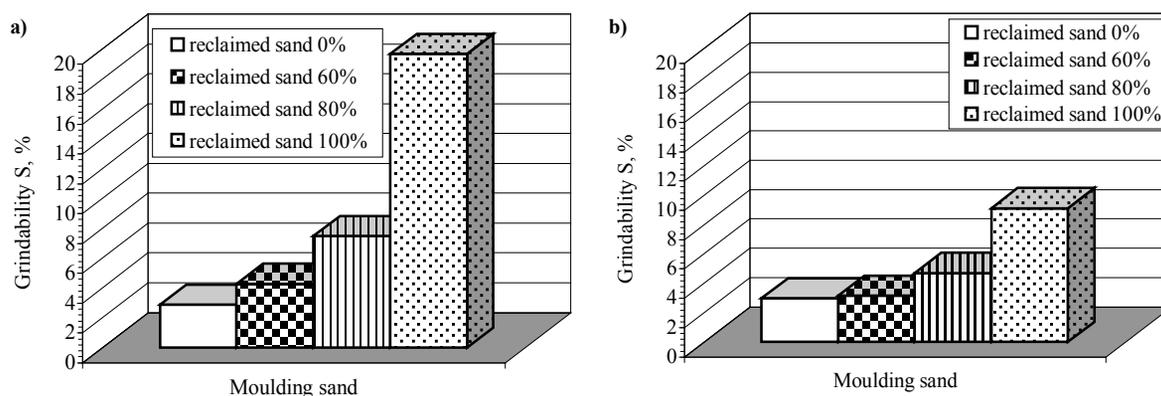


Fig. 4. Influence of the reclaim addition on the grindability, S of the moulding sands of the following composition: high-silica sand 0 – 100 parts by mass, reclaim 0 – 100 parts by mass, GEOPOL binder 2.0 parts by mass, hardener – 14% of the binder amount: a) SA72, b) KR72

The grindability results of the tested moulding sands compositions are presented in Figure 4a (sands with the SA72 hardener) and 4b (sands with the KR72 hardener). The obtained results allow to state that the reclaim addition unfavourably influences the moulding sand grindability. In case of moulding sands prepared on the pure high-silica sand the grindability (for the tested hardeners) is practically the same, app. 3%. When the reclaim was added the moulding sands with the SA72 hardener had higher grindability values than the sands with the KR72 hardener – at 60% of the reclaim fraction by 36%, at 80% of the reclaim fraction by 60%, and when the reclaim fraction was 100% by 116%.

## 4. Conclusions

Investigations of the properties of moulding sands with the GEOPOL binder hardened by the hardener of the SAND TEAM Company (SA72) and by the one developed by the KRATOS Company (KR72) revealed that:

1. The reclaim addition to the moulding sand accelerates the hardening process and unfavourable influences the obtained strength values. Moulding sands with the KR72 hardener are less sensitive to the reclaim presence and after 24 hours of hardening obtained higher strength values (for each mixture containing the reclaim) than sands with the SA72 hardener.
2. Moulding sands with the SA72 hardener obtain up to app. 30% higher permeability values as compared with the sands with the KR72 hardener. A reclaim addition in case of applying the SA72 hardener is unfavourable, while for moulding sands with the KR72 hardener an increased reclaim fraction causes a permeability increase. Moulding sands prepared on matrices with reclaim fractions have the same permeability for both applied hardeners.
3. The reclaim introduction into moulding sands worsens their grindability. The moulding sand with the SA72 hardener shows a significantly increased grindability with an increased reclaim fraction than the sand with the KR72

hardener. This difference exceeds 100% for moulding sands prepared fully on the reclaim as the matrix.

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