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Effect of Sand Wetting on Physically Hardened Moulding Sands Containing a Selected Inorganic Binder. Part 1

M. Stachowicz*, K. Granat, L. Palyga

Department of Foundry Engineering, Plastics and Automation, Wrocław University of Technology,
ul. Smoluchowskiego 25, 50-372 Wrocław, Poland

*Corresponding author. E-mail address: mateusz.stachowicz@pwr.edu.pl

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Abstract

In the paper, an attempt was made to evaluate the effect of preliminary wetting of high-silica base during preparation of moulding sands containing a selected grade of sodium water-glass, designed for hardening by traditional drying or by electromagnetic microwaves at 2.45 GHz. In the research, some water was dosed during stirring the sandmix before adding 1.5 wt% of the binder that was unmodified sodium water-glass grade 137, characterised by high molar module within 3.2 to 3.4. Scope of the examinations included determining the effect of wetting the base on mechanical parameters like compression, bending and tensile strength, as well as on technological parameters like permeability, abrasion resistance and apparent density. The research revealed a significant positive effect of adding water to wet surfaces of high-silica base grains on mechanical properties and quality of moulding sands hardened by physical methods, in particular by microwave heating.

Keywords: Foundry engineering, Microwaves, Water-glass, Wetting, Strength

1. Introduction

Results of previous researches on high-silica based sandmixes containing water-glass showed that it is possible to activate reacted binders, in order to restore their bonding properties, by applying suitable methods of their repeated processing [1,2]. Recovery of bonding properties by a sandmix is conditioned by using selected methods of hardening, like traditional drying or heating with electromagnetic waves at frequency 2.45 GHz [3-5]. It was noticed in the elaborates related to effective methods of activating used sandmixes containing water-glass [1,2], that of particular importance for that process is a small portion of water introduced at the stage of activating surfaces of base grains covered with thermally reacted binder. The wetting additive

enables partial recovery of bonding properties to the water-glass binder. So far, in the researches on influence of physical hardening methods and composition of water-glass containing sandmixes [6] on their properties after hardening, a small addition of 0.5 wt% of water was intuitively introduced during preparation of sandmixes. That addition was introduced in order to reduce dusting at the initial stirring stage and to improve absorption of electromagnetic waves during microwave heating [6]. It was believed that an addition of water extends also reusability of the sandmix, especially in the case of water-glass grades with high molar module >2.5 , very susceptible to action of atmospheric CO_2 .

In each sandmix containing water-glass, a condition to reach good mechanical properties after hardening, uniform in the entire volume, is proper spreading the binder over the base grain

surfaces, to enable most favourable conditions for its spreading [7] to the places where linking bridges are created. It was observed in [7] that, in spite of high chemical affinity of water-glass to quartz, there is a problem of supremacy of viscous interaction over interactions of quartz with binder particles in the form of micelles. In relation to this hypothesis, proper preparation of grains of high-silica base becomes especially important in the case of using very low contents of water-glass [5], typical for physical methods of hardening sandmixes. Apart from viscosity, spreading of the binder depends on many other factors, like temperature of binder, temperature of base [8], morphology of base grain surfaces [9], way of stirring and sequence of introducing liquid components of the sandmix [9], and grade of water-glass [7,10]. Moreover, it was shown in [11,12] that modification of water-glass influences wettability and viscosity of the binder. Of particular importance for quality of the manufactured sandmixes containing water-glass are also special additives [13 - 16] intentionally introduced at the stirring stage in order to improve their knocking-out properties. As results from other observations [6, 17, 18], the method of binder hardening is also important for strength of linking bridges. The best results are obtained by physical methods of hardening: traditional drying and microwave heating, where forming of linking bridges is accompanied by removal of water being a component of inorganic binders as a result of increasing temperature of the sandmix.

As opposed to chemical methods, the two physical hardening methods enable refreshing the sandmixes containing water-glass [1,2]. These reclamation processes are nowadays the object of intensive examinations. However, wide practical application of these eco-friendly and economically grounded hardening technologies requires more detailed knowledge of the process of creating linking bridges from the binder spread on high-silica grain surfaces during the sandmix preparation, including influence of water added during the base preparation stage. Complete knowledge of the factors and phenomena deciding mechanical and technological parameters of the sandmix, obtained by hardening, will facilitate understanding and implementing innovative ways of hardening the sandmixes containing water-glass, well-known from many decades.

2. Purpose of the research

It results from literature data that water present on surface-active crystalline structure of high-silica base [16] can penetrate micropores of sand grains and, moreover, it can create superficial layers: adsorptive and absorptive ones, where water will be bonded with the grain material by hydroxyl groups (OH). Good wettability of base and low viscosity of binder increase probability of creating non-enveloped links [8] between the base and the bonding material, which give the sandmix higher strength in comparison to that containing enveloped links. However, the effect of introducing additional water to the sand-binder system subject to physical hardening methods (slow traditional drying and much faster microwave heating) is unknown. An expected result of introducing an additional amount of water at the stirring stage before adding the binder, can be improvement of mechanical parameters of the sandmix as a consequence of enlarging the adhesive surface area of the binder thanks to its

easier flowing towards the places of increased concentration at contact points of high-silica base grains.

3. Methodology of the research

To prepare the moulding sands used in the research, applied was dried and cooled-down standard high-silica medium sand 1K with main fraction 0.20/0.16/0.315 from the mine Grudzeń Las and unmodified sodium water-glass grade 137, made by Chemical Plant „Rudniki” S.A. (Table 1). In a ribbon laboratory mixer, 6 kg of moulding sand was prepared, as follows:

- variant 0%: 1.5 wt% of binder was dosed to the sand base after starting the mixer and stirred for 4 minutes;
- variant 0.5%: 0.5 wt% of water was dosed to the sand base after starting the mixer, then, after stirring for 60 s, 1.5 wt% of binder was dosed and stirring was continued for 4 min;
- variant 1%: 1 wt% of water was dosed to the sand base after starting the mixer, then, after stirring for 60 s, 1.5 wt% of binder was dosed and stirring was continued for 4 min.

It was observed during preparation of the sandmix that introducing water to dry high-silica sand at the beginning of stirring (variants 0.5% and 1%) guaranteed effective reduction of dusting observed during initial stirring the sandmix in the variant 0%.

Next, cylindrical, longitudinal and octal specimens, formed by vibration compacting on a LUZ-2e stand, were hardened:

- by traditional drying – for 30 min in 56-l chamber of a laboratory drier SL 53 TOP+ equipped with a recirculation fan at 100 ± 0.1 °C, with the ventilation stack unsealed to remove moisture from the drying chamber;
- by microwave heating – for 4 min in 32-l chamber of a 1000 W microwave furnace.

Mechanical tests were performed on a laboratory stand LRuE-2e for sandmix testing, and permeability was measured on an apparatus LPiR. Abrasion resistance was determined on a device built according to E. Janicki's design [9], treating the specimens with 1.77 kg of steel shot.

Table 1.

Physico-chemical properties of water-glass used for the examined moulding sands

Water-glass grade	Molar module $\text{SiO}_2/\text{Na}_2\text{O}$	Content of oxides ($\text{SiO}_2+\text{Na}_2\text{O}$) %	Density (20 °C) g/cm ³	Fe ₂ O ₃ % max.	CaO % max.	Dynamic viscosity min. (P)
137	3.2÷3.4	35.0	1.37 ± 1.4 0	0.01	0.1	1

During the tests, temperature of the binder and the sand base was stabilized at 20 °C. In the room at the height of 1.5 m, there was constant temperature of 23 °C and humidity of 60%.

The vibration compacting process was performed for 120 s with constant amplitude setting at 60.

4. Results

Results of the examinations of influence of hardening method and water addition on properties of the moulding sands are shown in Figs. 1 to 5. The first analysed quantity was average apparent density of the specimens, shown in Fig. 1. It can be seen that increased addition of water to the sandmix during stirring results in decreasing apparent density of the sandmix after compacting and hardening. The differences between densities in the 0% and 1% variants amounted to 6% for microwave heating and 7% for traditional drying.

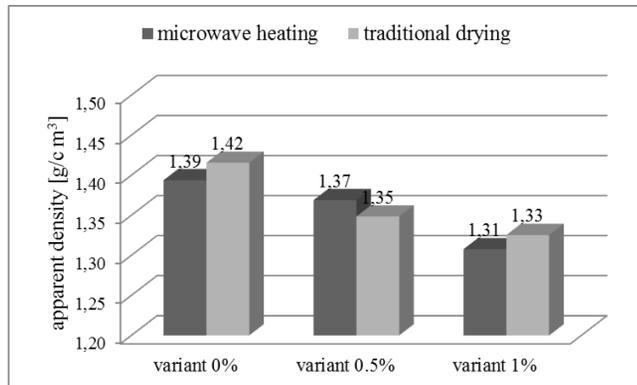


Fig. 1. Effect of water addition and hardening method on apparent density of cylindrical specimens

As was observed in [9], low apparent density of the sandmixes containing binders is not so important for their reached strength values, as in the case of traditional sandmixes. However, lower apparent density with maintained mechanical parameters after hardening will result in reduced consumption of components: natural raw materials and binders.

The next quality indices of linking bridges created in sandmixes containing water-glass grade 137, hardened by two physical methods, were mechanical parameters: tensile strength R_m^U (Fig. 2), bending strength R_g^U (Fig. 3) and compression strength R_c^U (Fig. 4). The data in these figures are arithmetic averages of three measurements for cylindrical and longitudinal specimens, and arithmetic averages of six measurements for octal specimens.

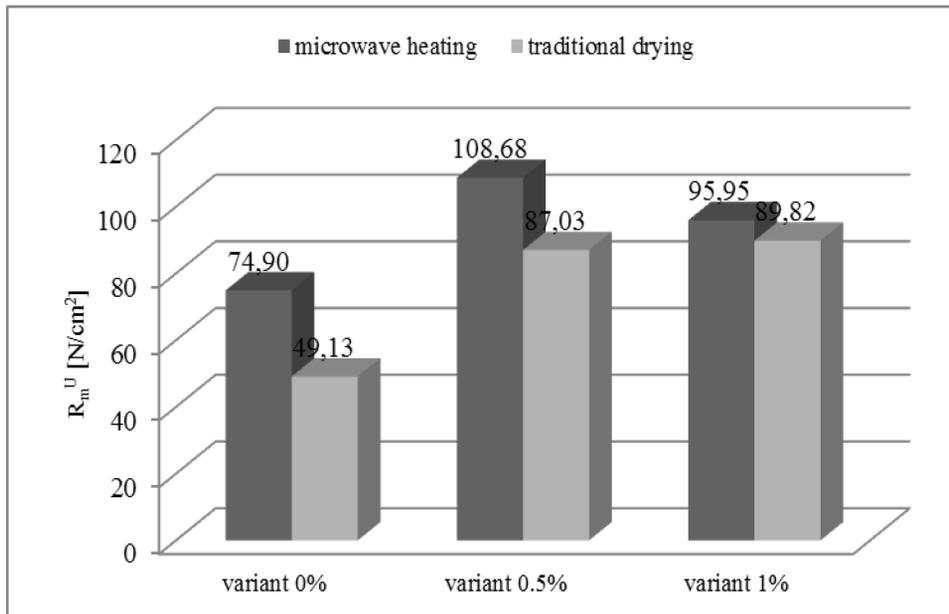


Fig. 2. Effect of water addition and hardening method on tensile strength R_m^U

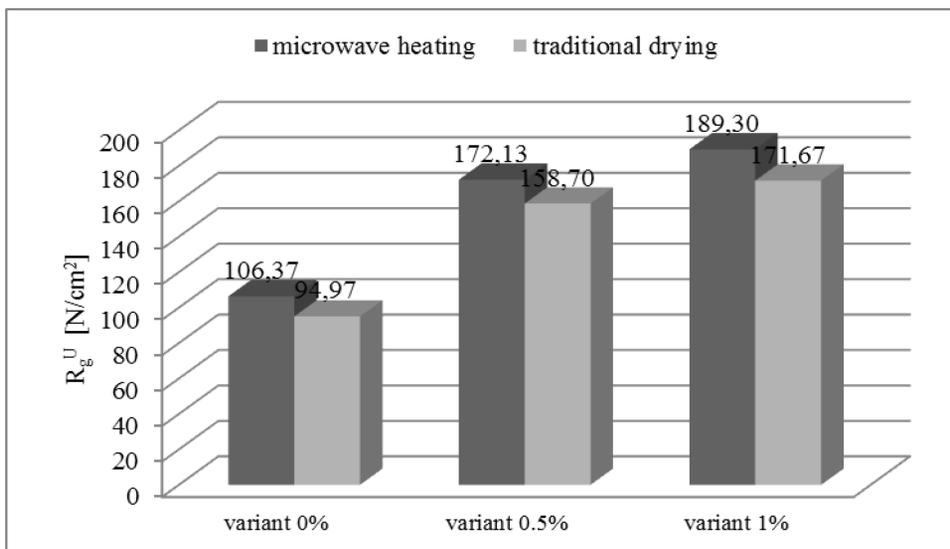


Fig. 3. Effect of water addition and hardening method on bending strength R_g^U

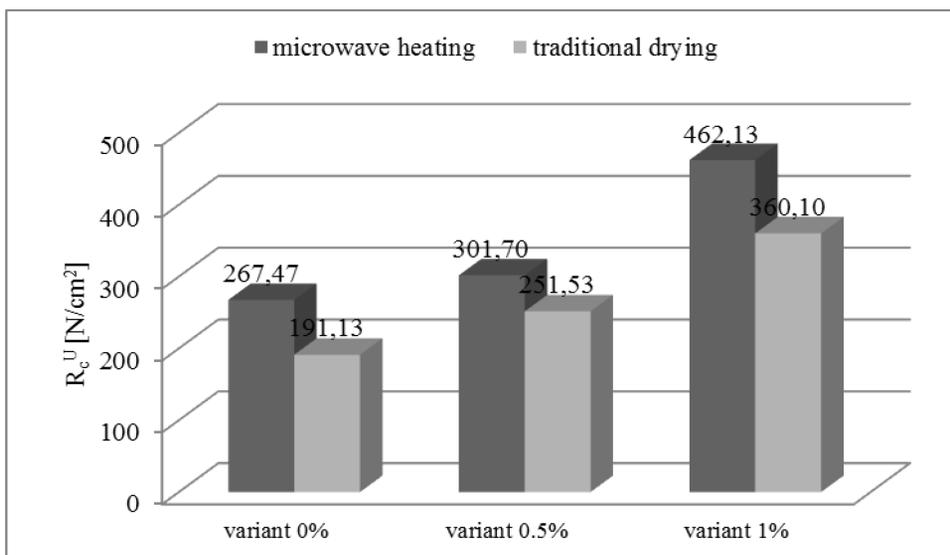


Fig. 4. Effect of water addition and hardening method on compression strength R_c^U

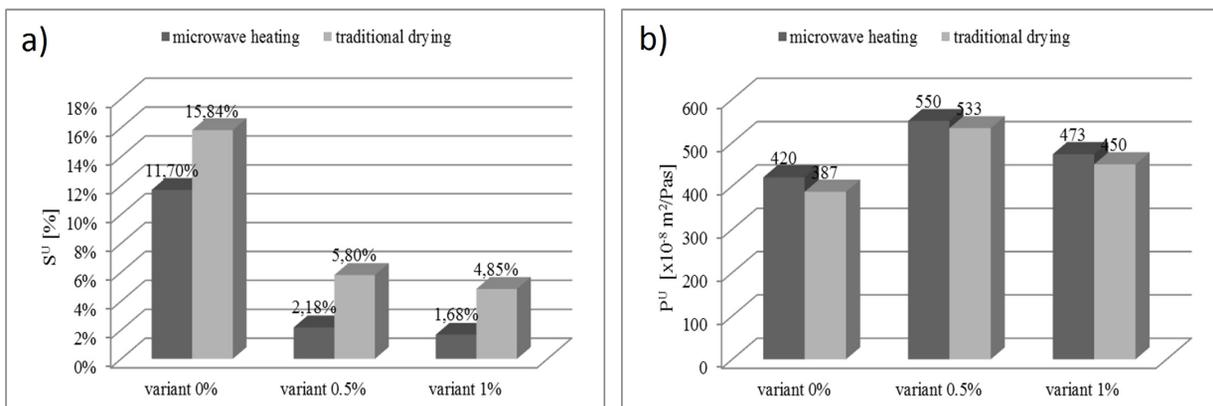


Fig. 5. Effect of water addition and hardening method on abrasion resistance (a) and permeability (b)

Analysis of the results shows clear effect of wetting the sand during stirring, before adding the binder, on mechanical parameters of hardened sandmix. Introducing water to the sand-binder system (variants 0.5% and 1%) resulted in increasing mechanical parameters of the sandmixes, in all analysed cases. An impact has also the applied hardening method. The results in Figs. 2 to 4 show favourable effect of microwave heating in comparison to traditional drying.

In the case of tensile strength (Fig. 2), its maximum value was obtained after hardening the sandmix with electromagnetic waves in the variant 0.5%. In this case, increased amount of wetting water did not significantly improve this parameter for both hardening methods.

In the case of bending strength (Fig. 3), its value in the variant 1% was significantly higher than that in the variant 0%: by 78% for microwave heating and by 81% for traditional drying. A similarly significant increase of compression strength between the variants 0% and 1% was observed for cylindrical specimens: by 73% for microwave heating and by 88% for traditional drying.

In each of the analysed cases, wetting the base improved mechanical parameters of the sandmix to a higher degree for traditional drying than for more effective microwave heating. This effect may be caused by slower action of CO₂ during convection drying of the sandmix containing larger water content.

The subsequent examined quality indices of sandmixes were technological parameters: abrasion resistance (Fig. 5a) and permeability (Fig. 5b).

As can be seen in Fig. 5a, the sandmixes prepared with no addition of water were characterised by very low resistance to action of steel shot falling-down on the specimen surfaces, see Fig. 6a. The specimens traditionally dried were characterised by especially low abrasion resistance, their average mass loss being almost 16%. After microwave heating, the non-wetted specimens showed mass reduction by ca. 12%.

The cylindrical specimens after abrasion resistance test (Fig. 6) show on their surfaces places with higher concentration of binder, where resistance to action of the abrasive material is higher. This proves worse distribution of the binder in the sandmix volume and its impeded uniform dripping. In all the examined sandmixes, the wetting water addition resulted in clear increase of abrasion resistance.

The observed increase of adhesion forces caused by introducing additional wetting agent to the sand-binder system resulted in smaller mass loss after the abrasion resistance test to the level of 5 to 6% for traditional drying (Fig. 6b) and ca. 2% for microwave heating.

Introducing water to the sand-binder system improved also permeability of the sandmixes, while the most favourable at both microwave heating and traditional drying was the variant 0.5%, where permeability reached its maximum value, see Fig. 5b. This effect should be analysed considering observations of linking bridges present after hardening.



Fig. 6. Traditionally dried specimens after abrasion wear test, prepared in variant 0% (a) and in variant 1% (b)

5. Conclusions

The results of the research on the effect of wetting high-silica base grains with water dosed during stirring, before introducing water-glass, and of the applied physical method of hardening lead to the following conclusions:

- The applied unmodified binder grade 137 with average molar module 3.3 can be used as a foundry binder that, after physical hardening, is characterised by good mechanical and technological parameters at its concentration in the sandmix as low as 1.5 wt%.
- The obtained mechanical parameters are influenced by quantity of water added in order to prepare surfaces of high-silica base grains for the binder with high molar module.
- Abrasion resistance of physically hardened sandmixes increases along with increasing quantity of water introduced during stirring the components.
- All the examined parameters show more intensive effect of wetting high-silica grain surfaces in the case of hardening by microwave heating than by traditional drying. This effect can be explained by direct action of faster microwave heating on water molecules, which results in increased binder temperature and facilitates its dripping to the places where high-quality linking bridges are created.
- Sandmixes with low content of the binder characterised by high molar module and viscosity not below 1, designed for physical hardening, should be always prepared with an addition of water wetting high-silica sand grains. Considering the criteria of permeability and tensile strength, recommended is introducing 0.5 wt% of the wetting additive.

- Complementing this research with observations of the created linking bridges in order to relate their structure to the found favourable qualitative parameters of sandmixes, should confirm the presented explanation of the effect of water addition and deliver additional information about the processes conducive to building strong linking bridges.
- In order to determine favourable effect of wetting high-silica base during stirring, before adding the binder, the research should be complemented with further grades of sodium water-glass, including those with medium and low molar module, and an attempt should be made to determine the most favourable addition of water for a specific binder grade and base type.

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