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Effect of bentonite addition on residual strength of microwave-hardened waterglass-containing moulding sands

M. Stachowicz, K. Granat*, D. Nowak
Foundry and Automation Group, Wroclaw University of Technology, ul. Łukasiewicza 5, 50-371 Wrocław, Poland
*Corresponding author. E-mail address: kazimierz.granat@pwr.wroc.pl

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Abstract

The paper presents results of a preliminary research of the effect of bentonite addition on residual strength of microwave-hardened moulding sands, containing sodium waterglass. Strength was determined at ambient temperature, on cylindrical specimens baked in an oven. Moulding sands for examinations were based on high-silica sand with addition of 2.5 % of non-modified, domestic-made waterglass grade 145. The prepared standard cylindrical specimens were hardened using the innovative microwave heating process and next baked for 30 minutes at temperatures between 100 and 1200 °C. Strength parameters of the specimens were determined on the specimens cooled-down to ambient temperature. The obtained results were compared with literature data to evaluate the effect of the applied hardening method and of the special additive on residual strength as a function of baking temperature. A favourable effect was found of both the innovative heating process and the applied bentonite addition.

Keywords: Moulding sand, Sodium waterglass, Bentonite, Residual strength, Microwave hardening

1. Introduction

Innovativeness and new technologies are some of the most important issues of 21st century's foundry industry. They include quality of manufactured products and productivity, as well as environmental protection that becomes more and more important. In comparison to other moulding sands and especially to core sands used in the technologies employing organic binders, hydrated sodium silicate (sodium waterglass) causes most problems at pouring moulds with alloys having high melting points, e.g. cast iron or cast steel. Therefore, in order to make moulding and core sands containing this binder an alternative for those less environment friendly, it should be strived for improving knock-out properties of overheated sandmixes. Unfortunately, the no-bake technologies of waterglass-containing moulding sands still cause inconveniences in spite of long-time experience in their hardening. After the regulations on environmental protection were tightened in mid-90s of the last century, researchers resumed solving the problems of knock-out properties and recovery of waste moulding sands containing this group of inorganic binders. Research works carried-out in this field are currently of preferential importance in many scientific centres in Poland and abroad.

Application of the innovative microwave hardening that employs the phenomenon of dielectric drying can be one of the ways of improving knock-out properties of these moulding sands. The authors of [1-4] indicate very good mechanical properties obtained in the process of dielectric drying of waterglass-containing moulding sands in comparison to traditional, chemical methods of their hardening. High strength R_m^U of moulding sands hardened by microwaves, calculated on 1 % of the binder [5], permitted classifying all the non-modified, commercially available grades of sodium waterglass (137, 140, 145, 149 and 150) to 1st class of the highest-quality binders. Optimum binder content in these sandmixes was decidedly lower than that commonly applied, ranging from 1.5 to 2.5 %.

Examination results presented in [6] for such a reduced binder content and, additionally, compared with those for 3.5 % of binder, indicate that quality of moulding sand after baking at a temperature above 750 °C is significantly dependent on quantity of used waterglass. It was also observed that an important parameter crucial for mechanical parameters of waste moulding sand, determined at ambient temperature, is molar modulus of the binder. For the sandmixes containing ≥ 2.5 % of all binder grades with modules between 2.9 and 2.0, it is advisable to continue research works aimed at improving knock-out properties of moulding sand, related to reduction of its residual strength.

Among special additives like chamotte sand, kaolinite, aloxite and bauxite that can influence strength R_c^{tk}, mentioned is also bentonite clay, like the "Special" bentonite. This is an example of additives to waterglass-containing no-bake sandmixes in order to give them low strength that first of all facilitates moulding works [7]. Moreover, additions of bentonite reduce changes of moulding sand volume, caused mainly by changing volume of high-silica matrix at elevated temperatures. Thanks to use of bentonite, reduced is quantity of casting defects resulted from polymorphic transformations of high-silica sand. For chemically hardened sandmixes, especially in the CO_2 process, small bentonite content reduces their residual strength.

2. Purpose of the work

The performed examinations were aimed at determining strength changes of a waterglass-containing moulding sand in function of temperature, with special consideration of the effect of microwave hardening process on structure of linking bridges coupling sand matrix with silicate binder. From the viewpoint of possible application of the innovative microwave apparatus, of particular interest is reducing residual strength of waste moulding and core sands in the whole temperature range of pouring moulds. Determination of residual strength produces significant information about possible processes of knocking-out the moulding sand and recovering the matrix. Influence of temperature on compressive strength of microwave-hardened sandmixes was determined within 100 to 1200 °C at intervals 100 °C (in some ranges even 50 °C) for the bentonite-containing moulding sands.

3. Preparation of moulding sands

The examined moulding sands were prepared of high-silica sand from the mine Nowogród Bobrzański with main fraction 0.40/0.32/0.20 and non-modified sodium waterglass 145 made by Chemical Plant „Rudniki” S.A. with properties (acc. to the certificate) given in Table 1. The selected water-glass is the most popular binder used for preparing casting moulds and cores.

Components were mixed in a laboratory muller mixer [10,11]. The components were dosed in sequence as follows: 4 kg of high-silica sand (1K), 40 g of bentonite "Special" and after starting rotations – 40 ml (1 %) of water. Adding this amount of water guaranteed uniform mixing and distributing the additive during preliminary mixing. After 60 seconds of mixing, dosed was sodium waterglass grade 145. All the components were next stirred for 180 s. On the grounds of data from [6], content of waterglass was accepted as 2.5 %.

Table 1.
Physico-chemical properties of sodium waterglass 145 used in the examinations compared with other grades

Waterglass grade	137	140	**145**	149	150
Molar modulus SiO_2/Na_2O	3.2÷3.4	2.9÷3.1	**2.4÷2.6**	2.8÷3.0	1.9÷2.1
Oxide content (SiO_2+Na_2O) %	35.0	36.0	**39.0**	42.5	40.0
Density (20 °C) g/cm^3	1.37 ÷1.40	1.40 ÷1.43	**1.45 ÷1.48**	1.49 ÷1.51	1.50 ÷1.53
Fe_2O_3 % max.	0.01	0.01	**0.01**	0.01	0.01
CaO % max.	0.1	0.1	**0.1**	0.1	0.1
Dynamic viscosity min. (P)	1	1	**1**	7	1

Of the so prepared sandmixes, standard cylindrical specimens for compression tests were formed on a standard laboratory rammer. The formed sandmix was compacted according to the recommendations given in [7].

The samples were next dried in quick dielectric process in a microwave oven of power output 900 W and, after cooling-down to ambient temperature, were placed in the chamber of a syllite furnace. After baking for 30 min at a strictly determined temperature, the specimens were taken-out and cooled-down to ambient temperature in free air. The cylindrical specimens were subject to destructive mechanical tests on the apparatus LRuE-2e for mechanical testing of moulding sands. For SEM observations, the material was spray-deposited with carbon.

4. Discussion of examination results

Results of the performed examinations were collected in Figs. 1 and 2. In Fig. 1, exactness of determining the influence of baking temperature on the R_c^{tk} parameter in the characteristic, interesting temperature range from 600 to 1200 °C was increased by condensing the measurement points (every 50 °C). This range is especially important because of occurring there the phenomenon of melting the hardened silicate glaze and its flowing over grains of the high-silica matrix. This phenomenon is of particular importance in foundry industry, among others from the viewpoint of minimizing the risk of surface detects of castings. Changes occurring on matrix grain surfaces are described in the section concerning SEM image analysis.

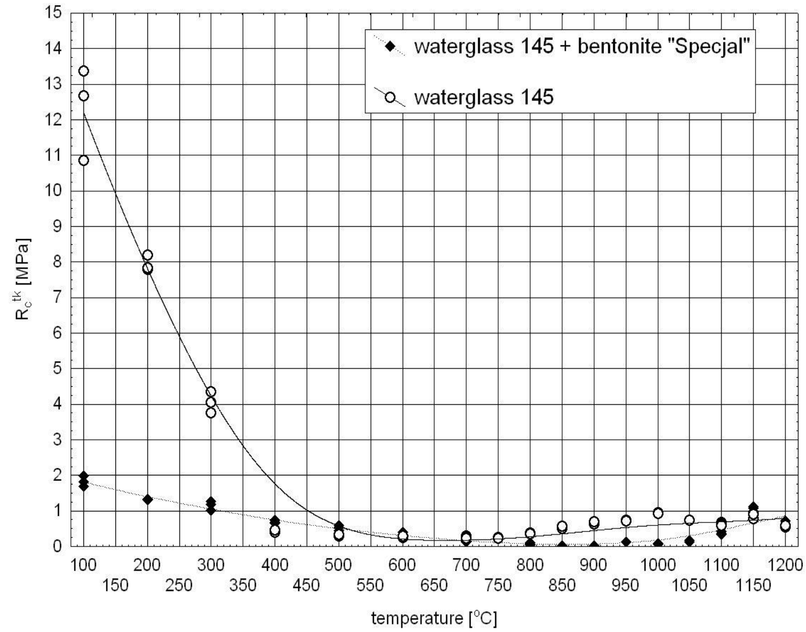

Fig. 1. Effect of baking temperature on residual strength of microwave-hardened moulding sand containing bentonite addition

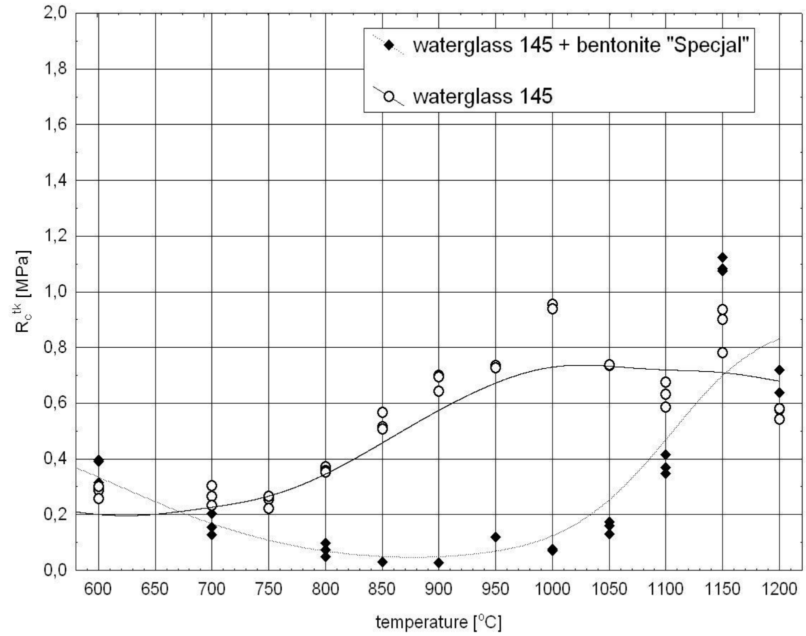

Fig. 2. Effect of baking temperature on residual strength of microwave-hardened moulding sand containing bentonite addition

Introducing 1 % of bentonite to moulding sand reduced its strength R_c^{tk} between 100 and 200 °C. Strength of the sandmix with bentonite "Special", baked at 100 °C, was six times lower than that of the moulding sand without the additive, see Fig. 1. Linking bridges observed after baking the sandmix for 30 min at 100 °C are shown in Figs. 3a and 3b, and those observed after baking at 300 °C are shown in Figs. 4a and 4b. Both examined moulding sands after baking revealed comparable strength R_c^{tk}. However, the special additive influenced other than typical for microwave hardening [8] distribution of silicate glaze on matrix grain surfaces, see Figs. 3 and 4a. The addition increased volume of the mixture of waterglass and solid bentonite particles and thus developed the linking bridges created during microwave hardening, see Fig. 4. In the entire considered range between 100 and 300 °C, the linking bridges revealed features of adhesive destruction occurring on the interface binder-matrix grains, see Fig. 3a. Further thermal action on the bridges, resulting in decreasing their initial mechanical properties to ca. 0.1 MPa, is observed till the baking temperatures between 1000 and 1050 °C, see Fig. 1. In Figure 2, approximated trend lines indicate beneficial effect of bentonite addition within the baking temperature range from 700 to 1100 °C, in that strength of a moulding sand with a special addition is even ten times lower than of the other sands. In the baking temperature range from 300 to 950 °C, observed was mainly adhesive-type destruction of linking bridges, see Figs. 5a, 5b and 6a. At baking temperature 950 °C, the binder partially melted and a characteristic porous structure was observed [8], also in moulding sands without special additions.

a) b)

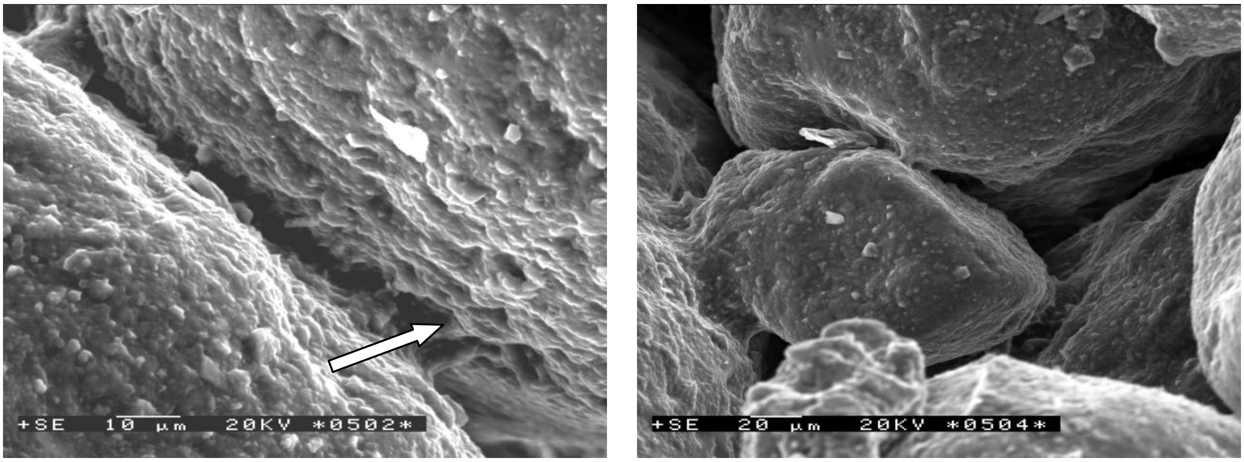

Fig. 3. Linking bridges in moulding sand with waterglass 145 and with bentonite addition,
after baking at 100 °C: a) crack of an adhesive-type bridge, indicated by the arrow, b) complex of bridges

a) b)

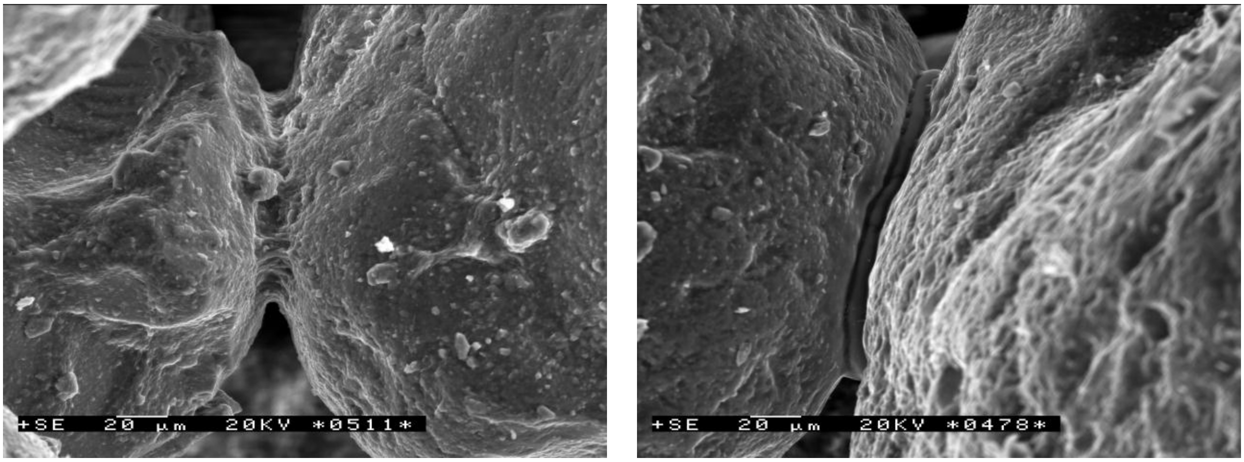

Fig. 4. Linking bridges in moulding sand with waterglass 145 after baking at 300 °C:
a) with "Special" bentonite addition, b) without bentonite addition

a) b)

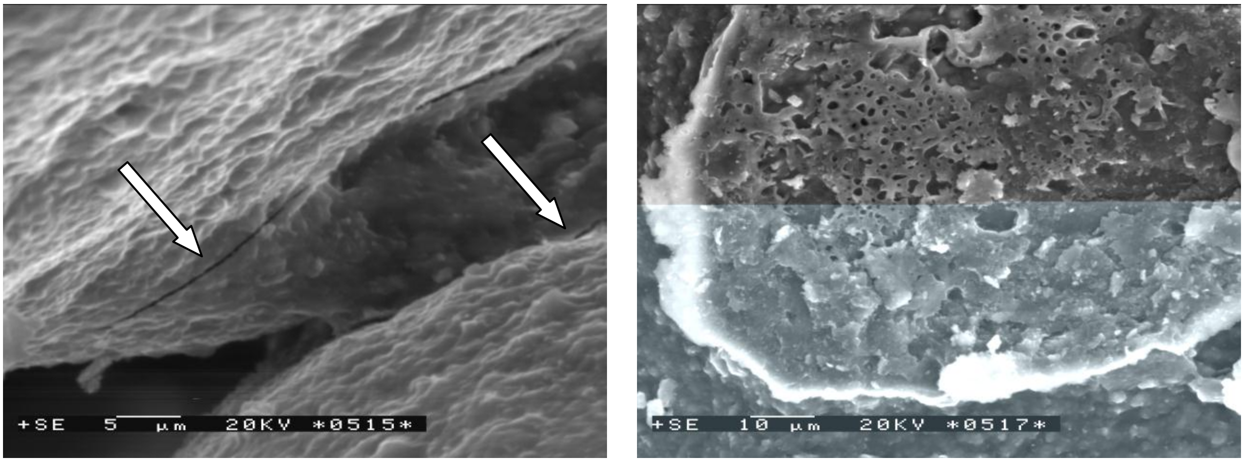

Fig. 5. Linking bridges in moulding sand with waterglass 145 and with bentonite addition, after baking at 700 °C: a) two-sided destruction of adhesive-type bridge, b) base of a linking bridge

In the temperature range between 1050 and 1200 °C, residual strength of moulding sand slightly increased again, marginally exceeding 1 MPa at 1150 °C. At these temperatures, strength R_c^{tk} was equal to that measured for the sandmix without bentonite addition. Observations of fracture surfaces of the specimens shown in Fig. 6, containing special additive and baked at 950 °C and above, indicated the problem of melting a layer of glassy sodium silicate and of the binder flowing over surfaces of high-silica matrix grains. For the waterglass grade 145 used in the presented research, with average molar module of 2.5, the phase transformation begins as early as at ca. 800 °C [9]. This phenomenon is related to the presence of low-melting eutectic mixtures of the system Na_2O–SiO_2, causing creation of "glassy" linking bridges. After baking the moulding sands at temperatures above 950 °C, destruction of the linking bridges was continued mainly as a result of breaking cohesion at the interface grain-binder, see Fig. 6a. As a result of further heating the sandmix, observed were also cracks on high-silica grain surfaces and cases of tearing-off clusters of sand grains at foundations of the linking bridges, as indicated in Fig. 7. The observed phenomenon of breaking matrix grains can be caused e.g. by strong overheating of the matrix and rapid cooling in the air of the specimens taken-out from the oven. One of the results of such behaviour of high-silica matrix can be increase of the matrix shape index W_k. In the case of reusing a moulding sand as a regenerate, a visible effect of increased W_k index is lower surface quality of castings.

a) b)

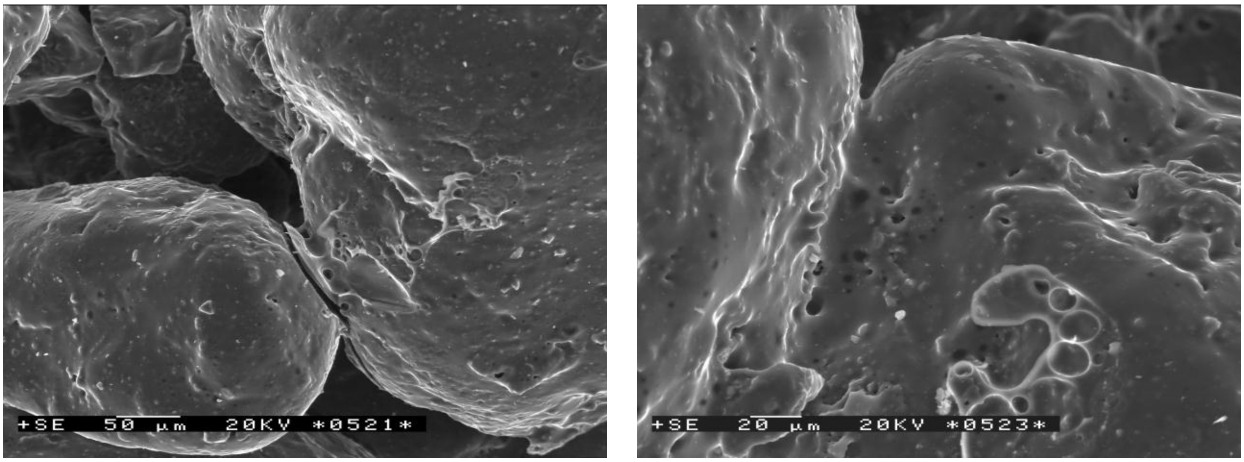

Fig. 6. Linking bridges in moulding sand with waterglass 145 and with bentonite addition after baking at 950 °C: a) adhesive-type destruction of linking bridges, b) surface and internal structure of a linking bridge

a) b)

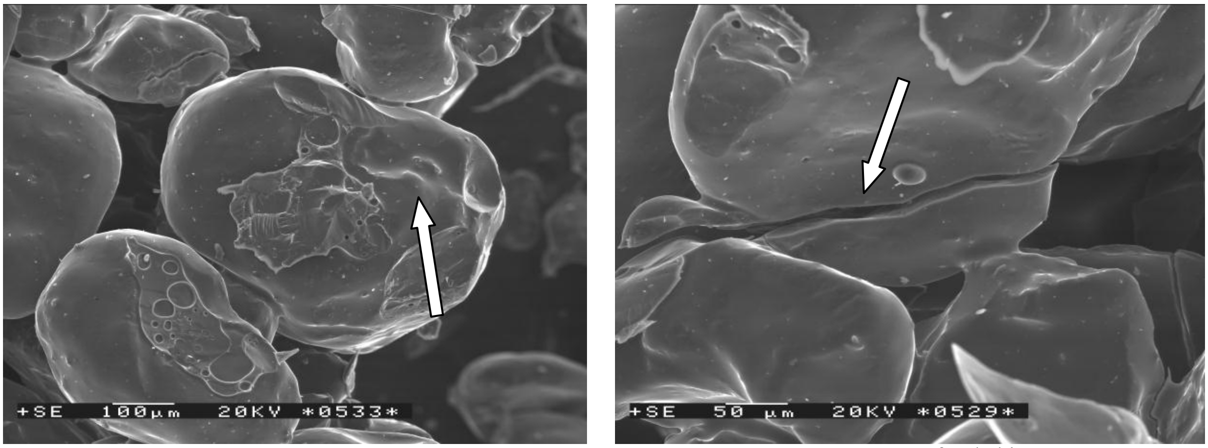

Fig. 7. Linking bridges in moulding sand with waterglass 145 and with bentonite addition after baking at 1200 °C: a) surface smoothed as a result of flowing silica glaze, b) crack in a high-silica grain

The specimens baked within the whole temperature range, of moulding sands with bentonite addition and without it, were characterised by high friability after cooling down to ambient temperature.

5. Summary

Analysis of the examination results indicates that addition of the bentonite "Special" to moulding sands based on high-silica sand from the mine Nowogród Bobrzański and containing waterglass grade 145, subject to microwave hardening, results in the following:

- improved formability of loose quick-hardening sandmix and possible use of traditional foundry tooling to prepare casting moulds and cores,
- clearly different changes of residual strength R_c^{tk} in function of temperature within the entire range between 100 and 1200 °C,
- lower strength R_c^{tk} of moulding sand with bentonite addition at 100 °C in relation to that without bentonite,
- significantly reduced residual strength of moulding sand to the values below 0.2 MPa in wide temperature range from 700 to 1050 °C,
- destruction of adhesive-type linking bridges in the entire examined temperature range,
- phenomenon of partial melting of silica glaze and its spreading on surfaces of matrix grains after baking at a temperature above 900 °C,
- possibility of wider application of waterglass-containing sandmixes to manufacture high-quality casting moulds and cores.

Acknowledgement

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