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COMPOSITES THEORY AND PRACTICE

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INFLUENCE OF WATER GLASS MODIFICATION WITH NANOPARTICLES OF MgO ON STRENGTH PROPERTIES OF MOULDING SANDS

An attempt was made to modify water glass with a propanol suspension of magnesium nano-oxide obtained by the thermal method. Foundry binders are usually complex synthetic materials of different chemical nature. Due to their specific chemical composition, they often pose a threat to both humans and the environment. Therefore, the constantly tightening rules on environmental protection have compelled the foundry industry to replace hazardous organic binders with less harmful ones, i.e. inorganic. Considering the above requirements, a foundry binder with a promising future seems to be water glass. It is cheap, easily accessible, and non-toxic. At the same time, the potentials of water glass as a binder for moulding and core sands have not been so far fully explored. The effect of the modifier and its content on the R_m^U tensile strength of loose moulding sands was examined. The content of modifier was determined at which the sand reaches the highest and the lowest values of R_m^U. This content amounts to 3 mass% and 5 mass% giving 1.61 MPa and 0.42 MPa, respectively. It was proved that the maximum value of R_m^U was the effect of the chemical reaction of water glass with magnesium nano-oxide, while the minimum value of R_m^U was due to the excessive binder wettability of the sand grains, hindering the formation of strong binding bridges in the sand mixture. FT-IR studies revealed the presence of chemical reactions taking place between the binder and modifier, the result of which was the presence of Mg^{2+} cations in the of water glass structure.

Keywords: moulding sands with water glass, MgO nanoparticles, modification

WPŁYW MODYFIKACJI SZKŁA WODNEGO NANOCZĄSTKAMI MgO NA WYTRZYMAŁOŚĆ SYPKICH MAS

W pracy podjęto próbę modyfikacji szkła wodnego zawiesiną w propanolu nanotlenku Mg otrzymanego metodą termiczną. Spoiwa odlewnicze są to zwykle złożone materiały syntetyczne, o różnym charakterze chemicznym. Ze względu na skład chemiczny często stanowią one zagrożenie dla człowieka i środowiska. Dlatego też z uwagi na zaostrzające się przepisy dotyczące ochrony środowiska przemysł odlewniczy zmuszony jest zastępować szkodliwe spoiwa organiczne spoiwami mniej szkodliwymi - nieorganicznymi. Mając na uwadze powyższe wymogi, perspektywicznym spoiwem odlewniczym jest szkło wodne. Jest ono tanie, dostępne oraz nietoksyczne. Równocześnie możliwości szkła wodnego jako spoiwa mas formierskich i rdzeniowych nie są w pełni wykorzystane. Dlatego też w niniejszej pracy zbadano wpływ modyfikatora, jego udziału na wytrzymałość na rozciąganie R_m^U sypkich mas. Dla zastosowanego modyfikatora określono udział, przy którym masa osiąga największą i najmniejszą wartość R_m^U wynoszącą odpowiednio: 3% mas. - 1,61 MPa i 5% mas. - 0,42 MPa. Wykazano, że największa wartość R_m^U jest efektem reakcji chemicznej szkła wodnego z nanotlenkami Mg, natomiast najmniejsza wartość R_m^U spowodowana jest zbyt dobrą zwilżalnością osnowy przez spoiwo uniemożliwiającą wytworzenie w masie silnych mostków wiążących. Badania FT-IR ujawniły chemiczną reakcję zachodzącą pomiędzy spoiwem a modyfikatorem, wynikiem której jest obecność kationów Mg^{2+} w strukturze szkła wodnego.

Słowa kluczowe: masy ze szkłem wodnym, nanocząstki MgO, modyfikacja

INTRODUCTION

Foundry binders are usually complex synthetic materials of different chemical nature. Due to their specific chemical composition, they often pose a threat to both humans and the environment. Therefore, the constantly tightening rules on environmental protection have compelled the foundry industry to replace hazardous organic binders with less harmful ones, i.e. inorganic.

Considering the above requirements, a foundry binder with a promising future seems to be water glass. It is cheap, easily accessible, and non-toxic. At the same time, the potentials of water glass as a binder for moulding and core sands have not been so far fully explored.

In the technology of moulding sands it is required to ensure the optimum properties of moulds and cores, combined with a residual strength effectively reduced in a wide range of temperatures (300÷1200°C), to improve the moulding and core sand knocking out properties and reclaimability [1-4].

The conducted research has indicated that the most effective method to improve the quality of sands with water glass is through modification of the binder with e.g. polyphosphate [4]. The method used most recently involves modification with the nanoparticles of metal oxides [5-10].

In the studies described above, a great deal of attention has been devoted to the problem of modifier impact on the binder structure and properties. The relationships between the composition, structure and properties are still poorly understood and will be the subject of further work.

In the described experiment, an attempt was made to modify water glass with a suspension of magnesium oxide (MgO) "nano-flakes" in propanol. The modifier effect on the sand strength was investigated together with its impact on the structure of the binder.

EXPERIMENTAL PROCEDURE

Test materials

Binder modification was carried out on "R 145" sodium water glass with modulus M = 2.5 and density $d^{20} = 1470$ kg/m^3.

For binder modification, magnesium oxide MgO "nano-flakes" produced by the thermal decomposition of basic magnesium carbonate ($4MgCO_3 \cdot Mg(OH)_2 \cdot 4H_2O$) were used. The proposed modifier was a suspension of MgO nanoparticles (nano-flakes) with the following parameters:

- MgO dispersed phase with an average size of about <100÷300 nm>
- propanol as a dispersing phase
- concentration of the suspension $c = 0.3$ M.

Figure 1 shows the obtained "nano-flakes" of MgO; the results of chemical analysis are shown in Figure 2.

a) b)

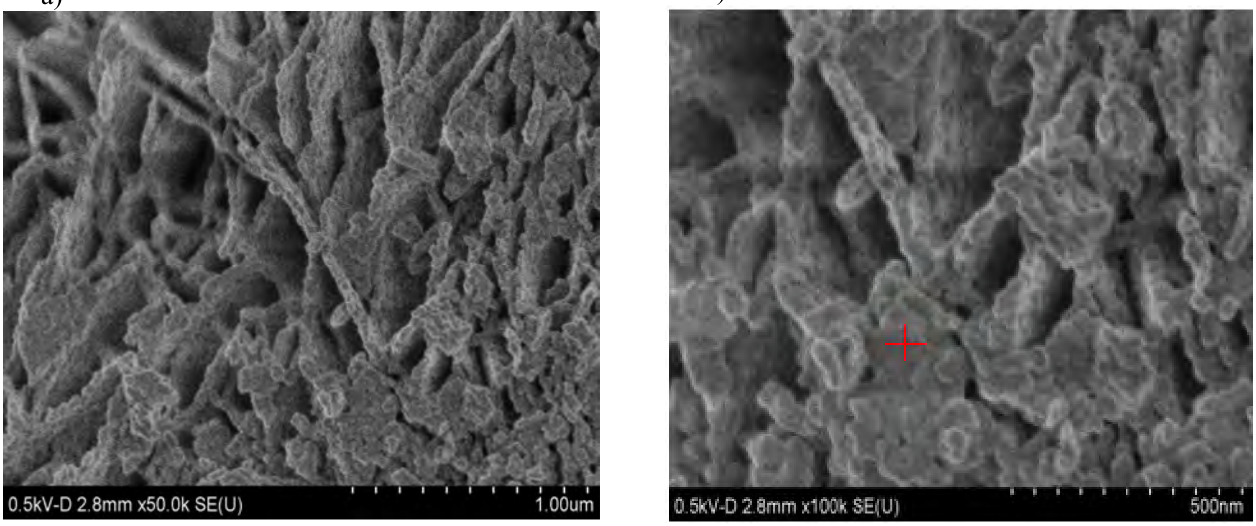

Fig. 1. Magnesium oxide (MgO) formed by thermal decomposition (a, b)

Rys. 1. Tlenek magnezu (MgO) powstały na drodze termicznego rozpadu (a, b)

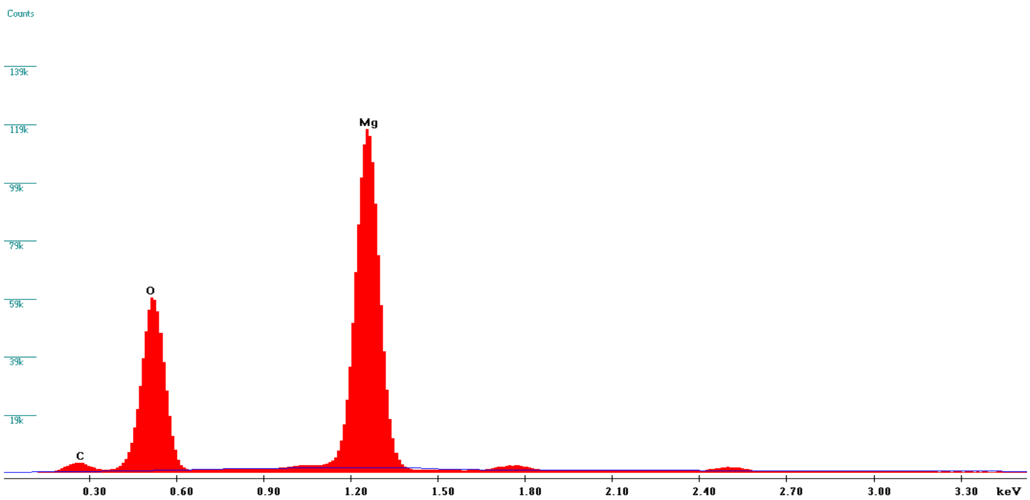

Fig. 2. EDS analysis of chemical composition of powder formed as result of thermal decomposition of basic magnesium carbonate

Rys. 2. Analiza składu chemicznego EDS, proszku otrzymanego z rozpadu termicznego zasadowego węglanu magnezu

Measurement methodology

The modification of water glass was carried out by introducing to the binder 1, 3 and 5 mass% suspension of MgO "nano-flakes" in propanol and homogenisation of the mixture.

To determine the binder-modifier relationships, studies were carried out by infrared spectroscopy (FT-IR).

The effect of the modification was evaluated by testing the R_m^U tensile strength of loose moulding sands with 1, 3 and 5 mass% MgO suspension in propanol after different hardening times. For analysis, the R_m^U after 24 hours of hardening was used.

RESULTS AND DISCUSSION

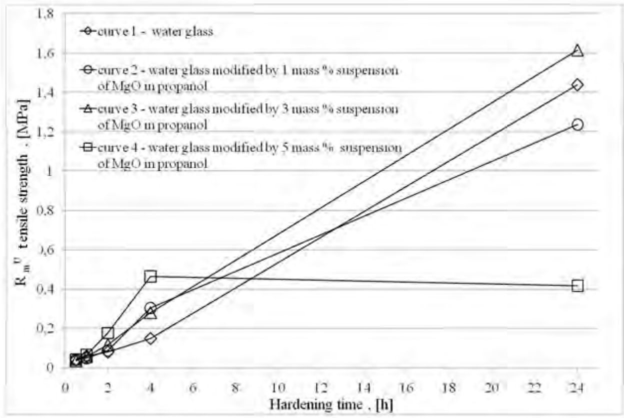

Fig. 3. R_m^U tensile strength of loose moulding sands with water glass, unmodified and modified. Hardening conditions: temperature t_{ot} = 23.5°C, moisture content W_w - 39%

Rys. 3. Wytrzymałość na rozciąganie R_m^U sypkich mas ze szkłem wodnym niemodyfikowanym i modyfikowanym. Warunki utwardzania: temperatura otoczenia t_{ot} = 23,5°C, wilgotność względna W_w - 39%

Figure 3 shows changes in the R_m^U tensile strength in time observed for loose moulding sands with water glass unmodified and modified with a propanol suspension of MgO nano-flakes obtained by the thermal method. The graphs shown in this figure represent different weight fractions of modifier, i.e. 1, 3 and 5 mass%. As follows from the diagrams, the R_m^U tensile strength of the sand containing 1 and 3 mass% modifier has increased, reaching its maximum level after 24 hours of hardening. After 24 hours of hardening, the sand with 3 mass% modifier had an R_m^U tensile strength equal to 1.61 MPa, thus increasing its value by approximately 15% compared to the R_m^U tensile strength of the sand with the unmodified binder (about 1.44 MPa). The addition of 1 and 5 mass % modifier did not give satisfactory results in terms of strength improvement. The time-related course of changes in the tensile strength R_m^U of the sand with the 5 mass% addition of modifier deserves attention. Adding this compound to the binder caused a significant (nearly 71%) drop in the R_m^U tensile strength (Fig. 4).

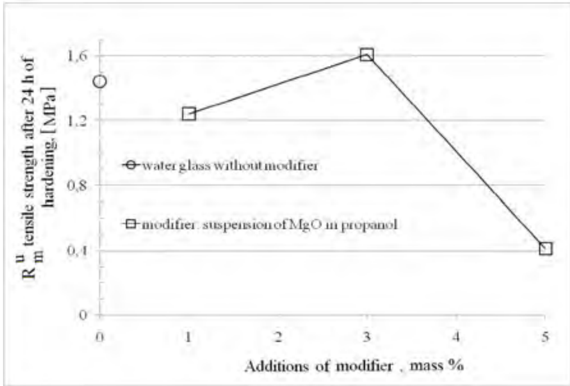

Fig. 4. Effect of modifier content on R_m^U tensile strength of loose moulding sands with modified water glass. Hardening conditions: time - 24 h, temperature t_{ot} = 23.5°C, moisture content W_w - 39%

Rys. 4. Wpływ udziału modyfikatora na wytrzymałość na rozciąganie R_m^U sypkich mas ze szkłem wodnym modyfikowanym. Warunki utwardzania: czas - 24 h, temperatura otoczenia t_{ot} = 23,5°C, wilgotność względna W_w - 39%

Figure 5 shows the effect of the content of the examined modifier on the R_m^U tensile strength of loose moulding sands. The studies have shown that the optimum content of modifier making the sand reach the highest value of R_m^U is the 3 mass%.

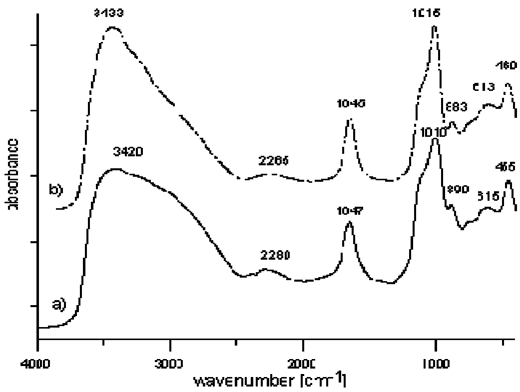

Fig. 5. Absorption spectra of: a) unmodified water glass, and b) water glass modified immediately after modification process

Rys. 5. Widma absorpcyjne: a) niemodyfikowanego szkła wodnego oraz b) modyfikowanego szkła wodnego bezpośrednio po procesie modyfikacji

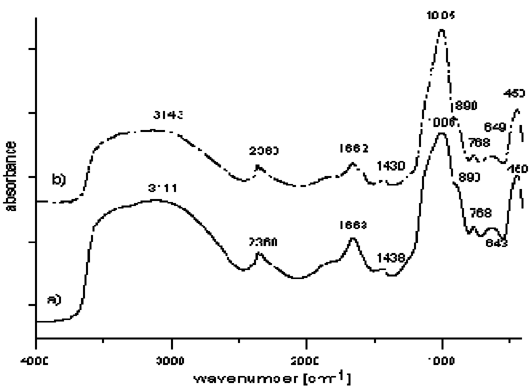

Fig. 6. Absorption spectra of: a) unmodified water glass, and b) water glass modified after 24 hours of hardening

Rys. 6. Widma absorpcyjne: a) niemodyfikowanego szkła wodnego oraz b) modyfikowanego szkła wodnego po 24 h utwardzania

Figures 5 and 6 illustrate the FT-IR spectroscopic studies of a binder modified with 3 mass% MgO suspension in propanol. The presented spectra refer to the binder immediately after the modification process (Fig. 6) and after 24 hours of hardening (Fig. 6). The analysis of water glass in the examined spectra revealed in the spectrum of the unmodified binder the presence of characteristic areas (Figs. 5 and 6, curve a) in the range of wave numbers 3500÷2500 cm^{-1}. This band corresponds to the vibrations of the OH and H_2O groups. The next characteristic area is the absorption band appearing in the range of 2500÷2000 cm^{-1}, originating from vibrations between the silicate lattice and Si $(OH)_4$ [11]. The bands appearing at 1647 cm^{-1} and 1010 cm^{-1} correspond to the deformation vibrations of molecular water [12] and asymmetric vibrations derived from the bonds between Si-O-Si [13]. On the other hand, the bending vibrations originating from the O-Si-O bonds in a pseudo-crystalline lattice correspond to the absorption bands in the range of wave numbers 800÷400 cm^{-1} [13].

The spectrum of water glass modified with a 3 mass% addition of suspension of MgO nanoparticles in propanol (Figs. 5 and 6, curve b) shows shifting of the maxima of absorption bands in all the characteristic areas. The most visible effect of the addition of modifier is shifting of the band from position 3420 to 3433 cm^{-1} (Fig. 5) and from position 3111 to 3143 cm^{-1} (Fig. 6), combined with a change in both the intensity and height. Distinctly visible is also shifting of the absorption band corresponding to the asymmetric vibrations of Si-O-Si from position1010 to 1015 cm^{-1} (Fig. 5). Particularly noteworthy is shifting of the absorption bands appearing at the wave numbers of 890 cm^{-1} (shifting to 883 cm^{-1}) and 615 cm^{-1} (shifting to 613 cm^{-1}, Fig. 5). The observed changes in the position of wave numbers (Fig. 5, curve b) shifting towards the lower values prove the presence of Mg^{+2} cations in the structure of the modified water glass [10, 14-16].

Increasing the modifier content in the binder to 5 mass% MgO suspension in propanol [9] confers that this binder has very good, practically complete, wettability. This is not a desirable phenomenon from the technological point of view, because such a binder is deprived of the ability to produce strong binding bridges, which give the necessary strength to the moulding sand. The sand containing a binder modified in this way had the lowest tensile strength after 24 hours of hardening, i.e. amounting to about 0.46 MPa.

SUMMARY

The modification of water glass with the suspension of MgO nano-oxides in propanol has indicated a positive effect on improvement of loose moulding sand strength. This effect is the strongest with an optimum content of modifier, which amounts to 3 mass% and makes the sand reach after 24 hours of hardening an R_m^U tensile strength of about 1.61 MPa. Exceeding the optimum content of modifier causes a significant drop in the R_m^U value, especially when the addition of the modifier is 5 mass%. The FT-IR studies revealed the presence of chemical reactions taking place between the binder and modifier, the result of which was the presence of Mg^{2+} cations in the structure of water glass. A significant decrease in R_m^U, i.e. by about 71%, when the optimum content of modifier was exceeded, is due to the almost complete wettability of the base sand grains that prevents the formation of strong binding bridges in the sand.

Acknowledgements

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