

# The Influence of Silica Module of the Soluble Sodium Silicate Hardened by Ester on the Residual Strength of Molding Sand

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## Abstract

Describes how to obtain a soluble sodium silicate with a density of 1.40 g/cm<sup>3</sup>, 1.45 g/cm<sup>3</sup>, 1.50 g/cm<sup>3</sup>, and silica module  $M = 2.1$  obtained from the silica- sodium glass with module  $M = 3.3$  and  $M = 2.1$ . Residual (final) strength of molding samples made with these binders, were determined at temperatures corresponding to the characteristic temperatures of phase and temperature transitions of silica gel. Indicated the type of soluble sodium silicate capable of obtain the smallest value of the final strength of molding sand in the specified range of temperatures.

**Keywords:** Soluble sodium silicate, Silica gel, Residual strength

## 1. Introduction

Soluble sodium silicate is an essential inorganic binder used in foundries. Molding sands with soluble sodium silicate has many advantages, most important of which is a good heat resistance of molds and cores and a slight harm in terms of working conditions and environmental protection. An important disadvantage of these moulding sands is their very high strength after the molten metal pouring and cooling to ambient temperature, resulting very difficult knock - out properties.

In all kinds of the molding sands with a binder in the form of soluble sodium silicate, the main factor that gives strength is silica gel. According to previous data, a network of silica gel (large molecule) composed of the chains of non-porous amorphous silica particles, similar to fused quartz. These particles are linked to each other by siloxane bonds  $Si-O-Si$  or hydrogen  $SiOH \dots HOSi$ , and each particle is covered with hydroxyl groups  $Si-OH =$ , and

these groups are at the particle surface during the condensation of the gel [1].

The essential meaning for the strength properties of the moulding sand has a strength of cured gel. Previously conducted studies have shown that silica gel strength depends primarily on the size of the particles and their coordination number. The particle size of the gel in the moulding sands with soluble sodium silicate have diameter 20 - 85 nm [2] and the higher concentration of  $SiO_2$  in solution (in moulding sands is equal to 30 - 35% of the soluble sodium silicate), particles are the smaller, their density are denser and silica gel is high-tensile.

On the particle size of the gel affects the curing kinetics and the  $pH$  of the solution [3-6]. The gel obtained from systems in which the kinetics of gelation process is slower is characterized by higher strength, compared to the faster kinetics of gel formation. The particle size also depends on the  $pH$  of the solution of soluble sodium silicate. At high  $pH$  values, particle size and the speed of formation increases - causing a reduction in

strength. The most strong gels are obtained 800°C - 1100°C [2, 8], which causes a marked reduction in its strength after cooling. The values of temperatures at which occur the changes in the silica gel strength, depends on the characteristics of its structure, chemical composition and the method of curing at low pH values. The strength of the silica gel is also determined by the size of stresses occurring in it. According to [7], they depend on the degree of dehydration of the gel and the presence of a secondary hardening reaction products in the soluble sodium silicate. From the properties of the silica gel resultant in different conditions (thermal or chemical) depends largely strength properties of molding sands, exposed to elevated temperatures and then cooled to ambient temperature. In the result of high temperatures the silica gel present in the mikrohomogeneous system can melt. However, the system “soluble sodium silicate - CO<sub>2</sub>” seems more plausible sintering gel particles, which are increasing at 600°C - 800°C [7], or by other researchers 700°C - 800°C [2], 800°C - 1200°C [8].

The beginning sintering temperature of the formed silica gel depends on the concentration of Na<sup>+</sup> ions in soluble sodium silicate, particle size and degree of compaction (ie, from the same parameters that determine the initial strength of the gel). Further heating of the sintering gel causes loosening of its structure and separation of amorphous silica in the temperature range

## 2. Purpose and methods

Soluble sodium silicate type “m” were obtained from the silica sodium glass with module  $M = 3.3$  subjected to the autoclaving process of chemical modification with NaOH, in order to obtain of the soluble sodium silicate with module  $M = 2.1$  [9-12].

Soluble sodium silicate type “w” were obtained in the process of autoclaving from the molten sodium silica glass with module  $M = 2.1$ . The received soluble sodium silicate type “m” and “w” were concentrated to a density value of 1.40 g/cm<sup>3</sup>, 1.45 g/cm<sup>3</sup> and 1.50 g/cm<sup>3</sup> (notation are presented in table 1.

The characteristic temperature and phase transitions the silica gel of soluble sodium silicate type “m” and “w” is defined by using the hightemperature microscope type PR - 25/1750.

Figures 1 and 2 show the effect of temperature on the value of the maximum increase the high  $\Delta h_{max}$  of silica gel samples formed from the soluble sodium silicate type m and w.

Changes in physico-chemical state of the silicate gel obtained by chemical reaction between the soluble sodium silicate and ethylene glycol diacetate, accompanied a change of the high (volume) of silica gel samples, associated with thermal expansion and the separation of the gas product from the organic components of the binding process and gradually melting the elements of gel the structure.

The maximum volume increase of the silicate gel for all samples followed in temperature from about 630°C to about 750°C. The largest increase of the high (volume) of silica gel samples is observed for soluble sodium silicate type m from about 95% (m-140), about 85% (m-150) and about 75% (m-145). In the case of silica gel formed from soluble sodium silicate type w, this increase is smaller and is about 80% (w-150), about 75% (w-140) and about 65% (w-145).

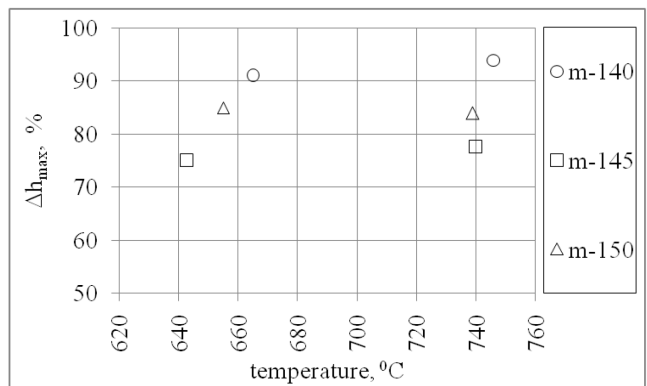


Fig. 1. Influence of temperature on maximum growth of the value  $\Delta h_{max}$  of the silica gel samples formed from the soluble sodium silicate type m

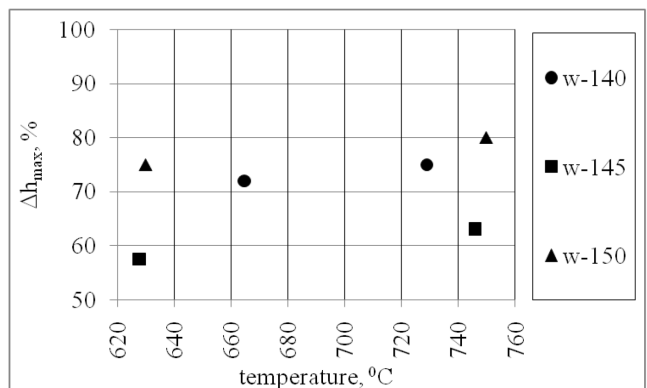


Fig. 2. Influence of temperature on maximum growth of the value  $\Delta h_{max}$  of the silica gel samples formed from the soluble sodium silicate type w

It can therefore be assumed that the smallest final strength will be characterized molding sand with the soluble sodium silicate m-140 and m-150 and heated to the temperature about 650°C.

With the use of the binders like “m” and “w” curing in the ester process (ester of ethylene glycol diacetate) was performed molding sands, in which the binder is not less than 2.5 parts by mass %, and the amount of involved components ( $SiO_2 + Na_2O$ ) was constant (39%). Standardized cylindrical samples with dimensions of  $\phi 50 \times 50$  made of molding sand was subjected to precipitation hardening for 24 hours and then cured for 2 hours at the characteristic temperature and phase transformations occurring in the silica gel, within a temperature range from 300°C to 1000°C.

After cooling the samples to ambient temperature, studied their compressive strength (so-called residual strength  $R_c^{ikm}$ ). Obtained, the minimum values of the residual compressive strength versus temperature of characteristic temperature and phase transformations occurring in the silicate gel is illustrated on figure 3.

Table 1.

Characteristic of the investigated kinds of the materials

Kind of the soluble sodium silicate	Silica modulus $M$ of the silica-sodium glass	Silica modulus $M$ of the soluble sodium silicate	Density of the soluble sodium silicate, $\text{g/cm}^3$
<i>m-140</i>			1,40
<i>m-145</i>			1,45
<i>m-150</i>	3,3	2,1	1,50
<i>w-140</i>			1,40
<i>w-145</i>			1,45
<i>w-150</i>			1,50

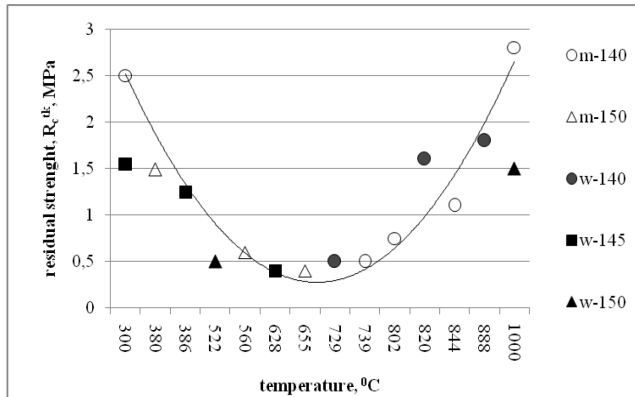


Fig. 3. Minimum values of residual compressive strength  $R_c^{tk}$  of the molding sand samples with the soluble sodium silicate type "m" and "w", depending on the characteristic values of temperature and phase transformation of the silicate gel

### 3. Conclusions

The obtained results indicate that the minimum value of residual compressive strength  $R_c^{tk}$  in the temperature range from about 300°C to about 650°C, is present in the molding sand with the binder *m-150*. Therefore can be concluded that the binder *m-150* is particularly recommended for the manufacture of molds and cores for casting from low melting alloys (eg aluminum alloys). In the higher temperature range (from about 650°C to about 850°C), the smallest value of the residual strength  $R_c^{tk}$  is achieved for molding sand with the binder *m-140*. At the temperatures close to 1000°C the lowest value of the residual strength  $R_c^{tk}$  is achieved for molding sand with the binder *w-150*.

The presented results allow to conclude that process for the preparation of soluble sodium silicate from sodium silicate glass and its density, has an essential influence on the residual strength of the molding sand prepared with the use of such binders.

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