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ALTERNATIVE EVALUATION OF THE PROPERTIES OF THE SILICA SANDS

ALTERNATYWNA OCENA JAKOŚCI PIASKÓW KWARCOWYCH

For the evaluation of silica sands, which belongs to the most employed sands of foundry molding mixtures, there are a number of methods and techniques to characterize their quality. This implies good knowledge of their strengths and weaknesses. However, a small proportion of published results are dedicated to the impact of transport on transport routes in the foundry and the processes of dry reclamation on the properties of the silica sands, in particular on changes to the granulometry and the formation of undesirable dust sands shares, which significantly affect the properties of the sand mixture.

The aim of this contribution is the evaluation of inclination of the silica sand to crush (the formation of dust, change the granulometry) according to the newly developed methodology with regard to its nature of sand (genesis, the shape of the grains, the character of the surface).

Keywords: silica sand, log W, granulometry analysis

Piaski kwarcowe stanowią podstawowe tworzywo na osnowę mas formierskich i rdzeniowych. Stąd istnieje bardzo wiele metod charakteryzujących ich jakość, co umożliwia poznanie ich zalet i wad. Mało jest jednak prac opisujących wpływ systemów transportowych odlewni oraz systemów suchej regeneracji mas na zmianę ich składu granulometrycznego oraz zawartości frakcji pylastych na właściwości mas. Celem niniejszej pracy jest ocena skłonności piasku kwarcowego do rozkruszania, (tworzenia frakcji pyłowych i zmianie granulometrii) według nowo opracowanej metodyki uwzględniającej charakterystyczne cechy piasku wynikające z jego pochodzenia, kształty ziaren i charakteru powierzchni.

1. Introduction

Basic matrix (sand material) for the production of molds and cores is several of miscellaneous materials, natural or synthetic character. As sand it is mean a grainy, refractory material representing the majority, non – plastic component of molding mixture (80-98% depending on the type of binder) with the size of grains bigger than of 0.02 mm. Sand properties are defined by its chemical and mineralogical composition, granulometry and shape of grain. [1-4]. Silica sands belong to the most used sands of foundry sand mixtures. Their advantages and disadvantages are well and widely known [3]. But the efforts of their limitation are stronger nowadays, mainly for environmental reasons [5, 6].

For the evaluation of the quality of the silica sands there are a number of methods, however, little attention is paid to changes of the granulometry and the formation of undesirable dust fraction arising from abrasion as a result of transport on transport routes in the foundry and the marches of dry reclamation.

Sources of dust fractions of SiO_2 are based on the strain of the pressure between two surfaces, either between the particles with each other or between particle and surface of transport equipment. The necessary energy to mill (degradation) increases with decreasing grain size, therefore, the coarser sand grains are more prone.

The mutual abrasion of grains leads to form changes (grinding, sphericity). The dust fraction is also formed due to abrasion of heavily eliminable particles from the surface of the grains even of washed sands (Fig. 1).

An important role is also played by the character of the grain contained in the sands of the various localities. The grains are known:

- Monocrystalline, often transparent.
- Grain conglomerates consist of more or less fused crystals (conglomerate has a porous structure and it is easy to crushed).
- Grain of feldspars, Ca^{2+}, or K^{+}-aluminosilicates, reducing the heat resistance of sand. Opaque grains assign different index of refraction than the SiO_2 (Fig. 2).
- Fragments of rocks, opaque particles also reduce heat resistance.

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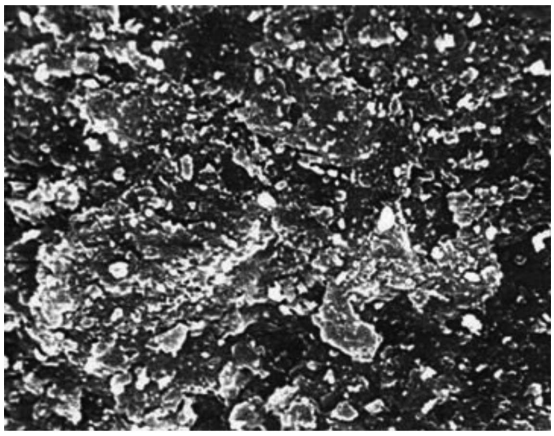

Fig. 1. Un-washed particles on the surface of the grains of Svitavy (2200x)

Fig. 2. Sand of the locality Šajdíkovy Humence, containing feldspars

2. Materials and methods

The possibility of the destruction of sand grains under load is significantly influenced by the size of the sand grains. From this point of view, six various samples of silica sands were selected for the experiment, which can be divided into several groups: i) the sands of the Czecho-Slovak provenance: sand Provodín (assigned as PR), Střeleč (assigned as ST), Šajdíkovy Humence (assigned as ŠH); ii) the sands of Polish provenance: sample Grudzeń Las (assigned as GL), Badger Minig (assigned as SP); iii) standard sand, Haltern (TESTSAND; assigned as H).

Granulometry analysis of samples was selected for the evaluation of sand properties, which was carried out according to VDG MERKBLATT STANDARDS, P34 (Tab. 1). For each of the samples of studied silica sand value of median grain (d_{50}) and a degree of uniformity (S) were determined. On the basis of granulometry analysis, the sand granulometry composition criterion – log W [3] was calculated. This is a thermodynamic probability function with the help of which the sand is evaluated regardless the cumulative curve shape. Log W achieves values from 0 to real number R according to a number of sieves used for the granulometry analysis (e.g. for 8 sieves, R = 90.31). The more Log W approaches 0, the more the sand has an ideal monofraction character. For our experiments is the maximum value of the border-Log W = 104.14.

A close dependence to the propensity of sand for crushing with its surface complexity can be assumed therefore, specific surface area (SSA) of studied samples of silica sands was established using the BET analysis carried out on the device SORPTOMATIC series 1990, TermoFinnigan, using nitrogen as sorption media.

Surface shape and complexity was further studied by scanning electron microscopy (SEM) with EDAX analysis, which served to establish indicative chemical composition of selected sand samples. Laboratory simulation of crushing of samples was carried out according to the methodology [8]. Experiments of the sand crushing were carried out in two variations of the force action on grain, in order to verify the increase of "dust" fractions:

METHOD 1-the destruction of sand by rolling of the load in the pipe, where the load has a combination of abrasion and pressure,

METHOD 2-sand crushing on the vibrating table under the load, where the experiments consist of pressure stress in this case.

In both cases, the changes were observed primarily in the fine fractions (the rest of the network, 0.06; 0.09; 0.125 mm and undersize mesh fraction) as well as the total change of the sample sand granulometry defined as values of the degree of uniformity (S) and granulometry composition criterion – log W .These values were then compared with the values of original (no-stressed) sand samples (assigned as STANDARD).

3. Results and discussion

The basic parameters of the studied samples of sands determined using the granulometry analysis and values of specific surface area using BET isotherms are summarized in Table 1. The values of median grain (d_{50}) of studied sand samples differs greatly in the interval 0.23 mm (sample) to 0.40 mm (PR) with the mean value of 0.31 mm. Values of the degree of uniformity (S) as well as the thermodynamic functions of the arrangement-log W of samples were evaluated on the basis of granulometry analysis.

Generally, it can be suggested, if the value of the degree of uniformity is closer to 100, the character of the sand approximated to mono-fraction. The opposite dependence valid for values of log W, which was confirmed by the values of S and log W obtained for studied samples of sands.

TABLE 1

General parameters of studied samples

		PR	ST	ŠH	GL	SP	H
d_{50}	[mm]	0.40	0.23	0.26	0.34	0.35	0.27
S	[%]	53.7	58.0	62.5	66.6	65.1	68.7
Log W	[-]	71.07	63.85	63.05	63.05	56.40	56.84
SSA	[m^2/g]	1.80	0.25	0.81	0.52	0.65	0.05

Specific surface area (SSA) of individual samples of sands is significantly different. The obtained values of SSA

of sand samples are low; they range from 0.05 m^2/g (sample H) to 1.80 m^2/g (PR sample). This fact can have a negative effect, both in the consumption of binders in the molds and cores manufacture, as well as it can be assumed the increased susceptibility of the crushing of sand, when the failure of the grain surface can be the beginning of the destruction of the grains.

All sand samples used in the experiment high mineralogical purity. The content of silica (SiO_2) for all samples is higher than 96% SiO_2, in accordance with the supplier and the results of the EDAX analysis. Only for the sand samples ŠH and SP, significant content other accompanying minerals, feldspars, probably, were found.

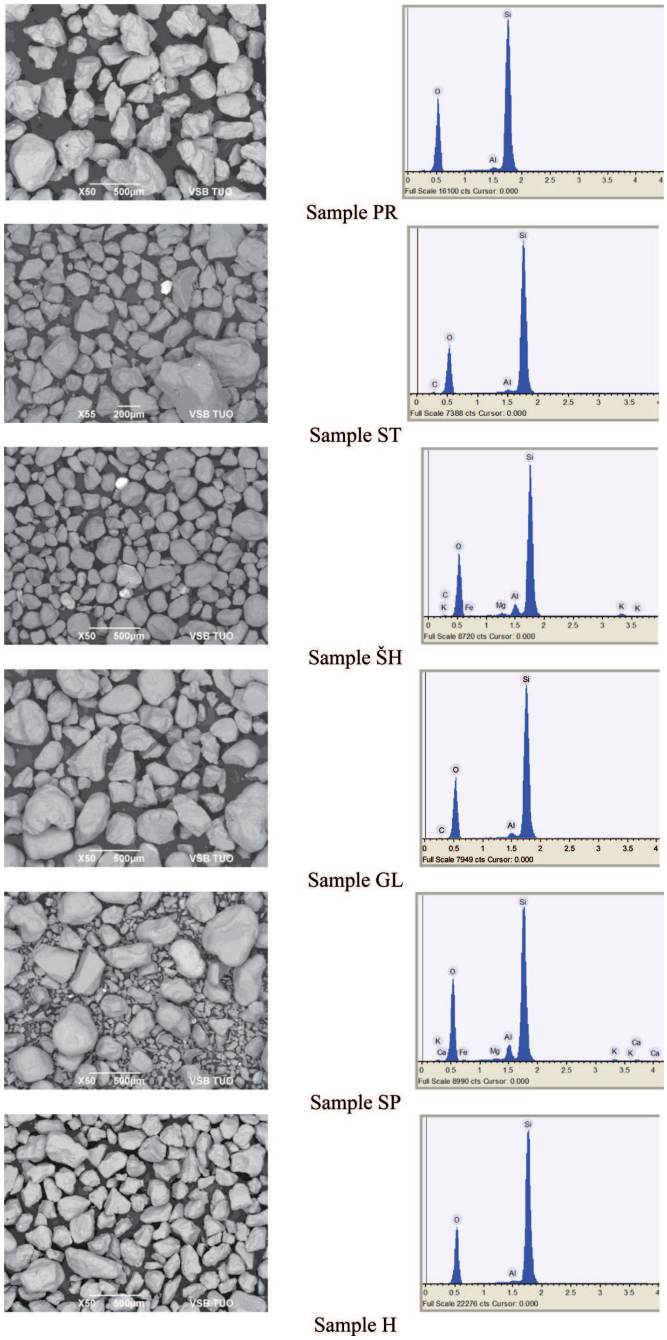

Fig. 3. SEM and EDAX analysis of studied sand samples

The shapes of the individual sand grains are different. Typical shape of grains of studied samples is mostly about the oval shape with rounded edges, with the exception of samples of PR, ST and H angular character of grains. It is probably caused by different genesis of sand samples (Fig. 3).

For the evaluation of the sand sample tendency for crushing, especially the changes of content of fraction of fine size grain were monitored (the rest on mesh, 0.06 0.09 0.125 mm and undersize mesh fraction) as well as the total change in sand granulometry defined by the degree of uniformity (S) and values of the log W. Results of the experiments are summarized in Table 2.

TABLE 2

Changes of fine fraction content of studied samples after crushing

		frakction [%]				d_{50}	S	log W
		0.125	**0.09**	**0.06**	**>0.02**			
PR	STANDARD	1.70	0.30	0.7	0.00	0.40	0.537	71.07
	METHOD 1	2.66	1.00	0.66	0.66	0.37	0.562	109.31
	METHOD 2	1.33	0.33	0.00	0.00	0.40	0.555	69.39
ST	STANDARD	23.30	1.30	0.3	0.00	0.23	0.580	63.85
	METHOD 1	25.66	2.66	1.00	0.66	0.23	0.586	64.96
	METHOD 2	24.00	3.00	0.66	0.66	0.22	0.566	65.52
ŠH	STANDARD	14.00	2.00	0.33	0.00	0.26	0.631	63.05
	METHOD 1	16.33	3.00	1.00	0.66	0.25	0.595	63.70
	METHOD 2	13.33	1.33	0.33	0.00	0.34	0.637	59.48
GL	STANDARD	1.66	0.33	0.33	0.03	0.34	0.666	55.65
	METHOD 1	3.66	0.76	0.66	0.43	0.31	0.710	57.89
	METHOD 2	1.30	0.33	0.00	0.00	0.33	0.666	54.01
SP	STANDARD	2.00	0.33	0.66	0.00	0.35	0.651	56.40
	METHOD 1	4.00	1.00	1.00	0.66	0.36	0.674	54.43
	METHOD 2	1.66	0.66	0.00	0.00	0.33	0.675	71.18
H	STANDARD	9.00	1.30	0.30	0.00	0.27	0.687	56.84
	METHOD 1	12.33	1.33	1.00	0.66	0.26	0.645	58.25
	METHOD 2	8.30	1.00	0.00	0.00	0.28	0.718	26.84

From the obtained results of laboratory simulation of sand grain tendency for crushing follow (table 2) that the samples of silica sands with rounded grains (spherical) and/or with higher content of fine fraction) (lower value of d_{50}) are more resistance for crushing. The changes of values of d50, degree of uniformity S and also log W were found.

Although the highest change of degree of uniformity was found for sample GL (growth about 6%) changes of log W values are more suitable for characterization of the sand sample (this parameter describe sand granulometry more sensitively). For the all studied samples the sand without crushing were taken as a STANDARD and as 100%. Further the changes of values of S and low W were calculated and compared. The most important changes of S and log W parameters are summarized in Table 3.

Maximum change of log W value was detected for the sample PR (54%), which correlates with the obtained results mentioned above.

TABLE 3

Changes of granulometry of sand samples

Change of parameters [%]	PR		GL		SP		H	
	M1	M2	M1	M2	M1	M2	M1	M2
d_{50}	92,5	100,0	91,2	97,1	102,9	94,3	96,3	103,7
S	104,7	103,4	106,6	100,0	103,5	103,7	93,9	104,5
log W	153,8	97,6	104,0	97,1	96,5	126,2	102,5	47,2

M1 – METHOD 1; M2 – METHOD 2

Tendency of the studied sand samples for destruction under the load was further determined by evaluation of the content of fraction 0.125 mm (Fig. 4). The most important changes were calculated (Fig. 4) as the ratio between the original sand without crushing (STANDARD) and sand after crushing (METHOD 1; METHOD 2). Determination of the fine fraction of the studied sand samples (the rest of mesh 0.125 mm) showed that the highest increase of fine particles content of sand samples were obtained for samples H, ST, and ŠH according to applied both laboratory methods of crushing simulation.

In the case of METHOD 1 utilization maximum values of the fine particles increase were detect (the destruction of sand by rolling of the load in the pipe). The maximum values were obtained for sample H (3.33%).

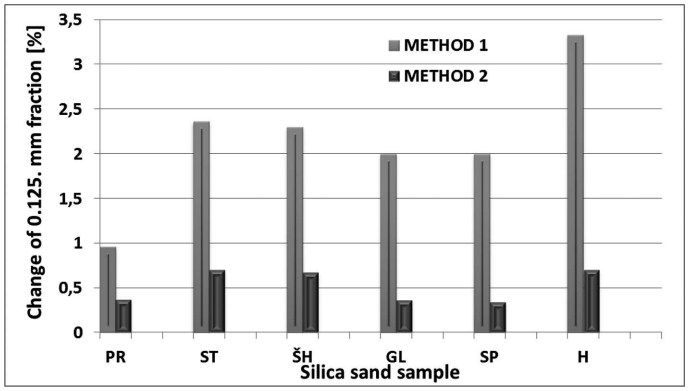

Fig. 4. Changes of fine fraction of studied samples (mesh 0.125 mm; two various methods)

4. Conclusion

For the evaluation of the quality of the silica sands there are a number of methods, however, little attention is paid to changes of the granulometry and the formation of undesirable dust fraction arising from abrasion as a result of transport on transport routes in the foundry and the marches of dry reclamation.

Sources of dust fractions of SiO_2 are based on the strain of the pressure between two surfaces, either between the particles with each other or between particle and surface of transport equipment. The necessary energy to mill (degradation) increases with decreasing grain size, therefore, the coarser sand grains are more prone.

Tendency of sand crushing is closed to grain size. This fact is also confirmed by results of experiments, granulometry analysis of sand samples with different median grain (d_{50}).

With increasing value of median grain, the value of log W also increase (flattening of granulometry curve) and the fine fraction content also increase.

The most important changes of fine fraction content were obtained for the silica sand samples H; ST and ŠH. For the sample H increase of fraction 0.125 mm (3.33%) was found in the case of METHOD 1 utilization.

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