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Effect of particle size in the reaction rate of sodium silicate used in the geopolymer production

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Silica is one of the most abundant oxide materials in the earth's crust (12%) and occurs commonly in nature as sandstone, silica sand or quartzite [1]. Aqueous silicate solutions are important in biology, geology and numerous technical processes including for example the manufacturing of sols, gels and zeolites [2]. Sodium silicate is also used as an activator for geopolymer cement synthesis [3-5].

Geopolymers seems like a promising application in the cement industry as an alternative binder to Portland cement. The cement production worldwide is responsible for 5-7% of anthropogenic CO_2 emissions; the geopolymer technology could reduce such emissions from 25 to 45% [3].

In a reaction, particle size plays an important role, being the most significant factor determining the reaction rate. Surface area increases very rapidly as the particle diameter decreases. The efficiency of the activator is also increased with finer particle size, because activation involves chemical reaction between the activator and the particle surface [6].

In this work, sodium silicate (Na_2SiO_3) was obtained by chemically reacting soda with silicon dioxide (SiO_2) having different particle size. Before the reaction, the as-received silicon dioxide was sieved in order to determine its initial size; subsequently it was reduced using a SPEX 8000M mixer/mill under an air atmosphere for different milling times. A CILAS1180 equipment was used to determine the particle size of the milled powders. The as-received sample as well as the milled powders were made to react with sodium hydroxide 57% w/w; the resulting products were made to dry in oven for further analysis.

The optical micrograph in figure 1 shows silicon dioxide before milling. Its mesh distribution is presented in figure 2; as can be seen, the 70% is retained in mesh 60 (250 µm). Table 1 displays the study of particle size distribution after the mechanical milling process; the best size/time rate was at 5 minutes. In figure 3 the average size of the milled powders is shown, in which this milling time corresponds approximately to 10 µm. A high variation in particle size and morphology of 5-minute sample is shown in figure 4; it is worth mentioning that particles measured with the CILAS equipment correspond to a sub-micrometric particle clusters. Figures 5 presents infra-red spectra of the products obtained from as-received SiO_2 (A), milled SiO_2 (B), and a commercial sodium silicate (C). The presence of sodium carbonate (Na_2CO_3) was detected in all samples. However, sample A presents a higher Na_2CO_3/Na_2SiO_3 absorbance band rate compared with sample B, which can suggest a higher reaction rate in the last one due to the higher particle surface area. XRD patterns of samples A and B are displayed in figure 6, where both phases were detected; furthermore, the reflection intensities evidence that sample A contains a higher quantity of Na_2CO_3.

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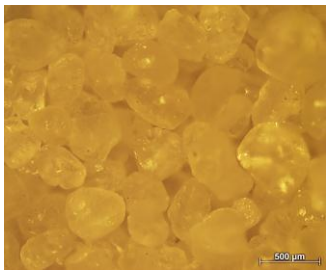

Figure 1. As-received silicon dioxide.

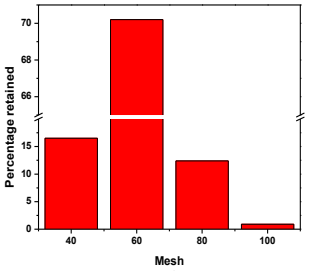

Figure 2. Mesh distribution of silicon dioxide.

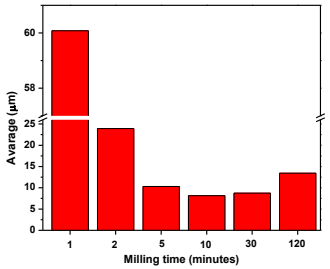

Figure 3. Average silicon dioxide particle size versus milling time.

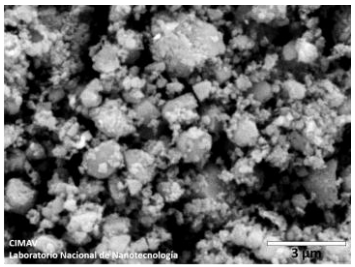

Figure 4. SEM micrograph of silicon dioxide after 5 minutes of milling.

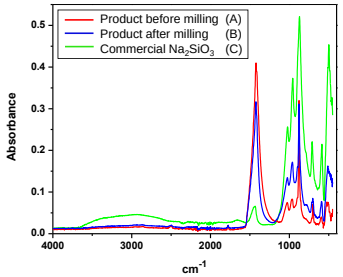

Figure 5. FTIR spectrum of sodium silicate.

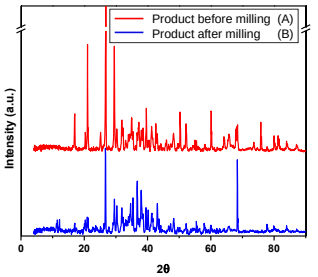

Figure 6. X-ray diffraction of the products.

Table 1. Diameter dispersion at different milling times.

Milling time (minutes)	Diameter (µm) at 10%	Diameter (µm) at 50%	Diameter (µm) at 90%
1	3.52 ± 0.10	35.53 ± 0.46	157.32 ± 1.30
2	2.21 ± 0.01	15.54 ± 0.05	59.41 ± 0.25
5	1.06 ± 0.09	5.53 ± 0.24	27.68 ± 0.96
10	0.98 ± 0.01	4.35 ± 0.13	21.52 ± 0.74
30	0.99 ± 0.01	4.84 ± 0.18	23.00 ± 0.70
120	1.05 ± 0.21	6.96 ± 0.41	31.71 ± 2.15