Reports of the Academy of Sciences of the USSR

V. F. ABROSENKOVA, G. I. LOGINOV, and Academician P. A. REBINDER

1957-01-01T00:00:00+00:00

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Abstract

Full Text

Reports of the Academy of Sciences of the USSR

1957. Vol. 115, No. 3

CHEMISTRY

V. F. ABROSENKOVA, G. I. LOGINOV, and Academician P. A. REBINDER

BINDING OF LIME INTO CALCIUM HYDROSILICATE UNDER NORMAL CONDITIONS

It is generally accepted that the formation of calcium hydrosilicate during the interaction of lime with silica in an aqueous medium can occur, in the hardening of lime-silica binding building materials, only under conditions of hydrothermal treatment in autoclaves at temperatures on the order of 170°. It was believed that this process does not take place at ordinary temperatures, i.e., is not manifested in any appreciable increase in the strength of the formed product.

The study of these processes has been the subject of quite a number of works substantiating technological schemes for the production of silicate brick, roofing tile, and a number of building products ([1]). However, some building products, such as wall blocks, which are finding ever broader application in low-rise construction, do not require the high strength that can be achieved by autoclave treatment.

On the other hand, our work on developing the physicochemical foundations of the technology for producing wall blocks ([2]) gives grounds to suppose that, along with the hydration hardening ([3], [4]) of the lime-sand binder, the binding of calcium hydroxide gradually develops in the surface layers of the sand grains. The more developed the surface of the sand grains proved to be, and the more strongly it was activated in the process of joint grinding with lime, the greater the amount of lime that was bound into calcium hydrosilicate.

Fig. 2. Kinetics of binding calcium oxide by finely ground sand with specific surfaces: 1 –0.7 m^2/g, 2 –2.9 m^2/g

Figure 2: Fig. 2. Kinetics of binding calcium oxide by finely ground sand with specific surfaces: 1 –0.7 m^2/g, 2 –2.9 m^2/g

Fig. 1. Kinetics of binding of calcium oxide by sand: **1**—unground, with a specific surface of 150 cm^2/g; **2**—ground, with a specific surface of 500 cm^2/g.

Using the radioactive isotope Ca^{45}, applied in the form of calcium hydroxide $Ca^{45}(OH)_2$, it was established, for coarse-dispersed sands, that the amount of bound calcium is proportional to the specific surface area of the sand ([5]). In the first stage, calcium binding has the character of irreversible adsorption, passing into a surface chemical reaction.

In the present work, the same method was used to study the kinetics of prolonged calcium binding by sand with more developed specific surface areas (up to 2.9 m^2/g) from a saturated solution. For this purpose, a method was developed for determining bound calcium that excludes the influence of carbon dioxide from water or from air. The amount of bound calcium was determined from the difference between the activities of the initial calcium hydroxide solution and of the same solution after the interaction of lime with sand over a specified period of time.

In accordance with the character of the kinetic curves in Fig. 1, the process of binding lime into calcium hydrosilicate at room temperature consists of two stages: irreversible binding in the surface layer of the sand grains during the first day, and a subsequent diffusion process proceeding at a constant rate.

Indeed, if one calculates the area corresponding to a monomolecular coating of calcium hydrosilicate for the transition to a constant binding rate, then the amount of lime bound by 1 m^2 of the surface of sand grains in such a coating proves to be constant (Table 1). This calculation gives (S_0 = 6 Å^2/ion Ca). The subsequent stage of the interaction of lime with sand has the character of a diffusion process.

Table 1

Specific surface (S), m^2/g	Amount of CaO bound at full coverage (a), mg/g	Adsorption (a/S =), mg/m^2
0.015	0.025	1.6
0.05	0.07	1.4
0.15	0.25	1.6
0.7	1.0	1.4
2.9	4.5	1.5

Fig. 2. Kinetics of binding calcium oxide by finely ground sand with specific surface:
1 –0.7 m^2/g, 2 –2.9 m^2/g

When finely ground sand, activated in the process of joint grinding of lime with sand, is introduced into the composition of the binder, the strength of products prepared with this binder and with a sandy (unground) filler continuously increases with time. The increase in strength of these products under natural conditions is due to the simultaneously occurring processes of binding lime into calcium hydrosilicate by silica and into calcium carbonate by carbon dioxide. These processes proceed very slowly, since both are based on a diffusion process.

Thus, in hollow (slotted) blocks measuring (390 ×190 ×190) mm^3, prepared with a lime-sand binder composition of 1 : 1 from unslaked lime ground together with sand to an active specific surface of 1.25 m^2/g, the compressive strength continuously increases. In all cases, small amounts (0.2-0.4% relative to lime) of plasticizer-retarder additives for hydration hardening were introduced into the mixing water (Table 2).

Table 2

Lime, %	Sand, %	Unground sand, %	Mixing water, %	7 days	1 month	3 months	6 months	1 year	2 years
12.5	12.5	75 (coarse)	7.5	20	28	–	–	49	–
10	10	80 (medium-grained)	8	12	20	28	36	–	48

For the data in Table 2, average values were taken from many batches of blocks prepared according to a technology developed jointly with the All-Union Scientific Research Institute for New Problems of Fine Grinding of Building Materials on the basis of a vibromill (VNIITISM).

There is sufficient reason to believe that the carbonation of calcium hydroxide proceeds considerably more slowly than its silicification. In particular, this is confirmed by X-ray structural analysis data: under ordinary storage, a line characteristic of calcium monohydrosilicate, corresponding to an interplanar spacing of 3.01 Å (6), appears on the roentgenogram only after 2 years of storage, whereas the lines corresponding to calcium carbonate are absent.

Institute of Physical Chemistry
Academy of Sciences of the USSR

Received
6 IV 1957

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Note: Figure translations are in progress. See original paper for figures.

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