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Silica Sol Binder for Building Materials

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The use of sodium silicates as gluing binders is limited by the fact that the tensile strength of these bindings is below 50 kg/cm^2, and the fact that the bindings remain water-soluble till the annealing temperature of +250^{0}C. Besides, when heated to +160^{0}C , these gluing binders distend. Gluing binders based on SiO_2 sold or gels exhibit tensile strength above 500 kg/cm^2, are insoluble in water at the annealing temperature of +150^{0}C and do not distend during heating.

The developments are:

1. The preparation of brick on the basis of this binder, with the crush strength an order of magnitude higher than that of a usual brick but annealed at +200^{0}C.
2. The preparation of ecologically safe, water-proof chip board with improved strength characteristics.
3. The preparation of decorative artificial granite and decorative tiles made of broken glass.
4. The preparation of a material similar to lightweight aggregate concrete, with the closed high internal porosity and rather high crushing strength P~500 Kg, density ~0,2 – 1,5; heat conduction ~0,05-0,07 wt/(m grad).

Nowadays the most spread binder in civil engineering is cement – calcium silicates, which, at the addition of water, form crystalline hydrates. They, in their turn, bind large particles of quarry stone and form concrete. Along with a great number of advantages this binder has certain disadvantages. For example, already at 300° C crystalline hydrates begin to decompose resulting in the destruction of articles produced with the use of cement in case of fire accident.

Unlike calcium silicates, hydrosols of silica (silicon dioxide) become water insoluble at 240° C, and if the temperature rises up to 1500° C the strength of articles produced with silica binder just increases.

Silica (silicon dioxide) hydrosol, or colloidal silica, as it comes to be called, is easily moving, opalescent liquid containing water and amorphous silica particles as a disperse phase. The size of sol particles can be in the range of 50 -100 nm and more, and their concentration reaches 50 % by mass and more when the stability of systems is provided. The last means that they are stable to sedimentation and to gel formation. Sometimes the surface of sol particles is modified; antifreezes, antiseptics and other substances are added.

Hydrosol of silicon dioxide is one of the products of silicic acids polycondensation, among which are also hydrogels, "Aerosil" - silica gels (silica xerogels) and so on. Nowadays these disperse materials attract more and more interests of civil engineers in connection with, first, the natural occurrence of silica and, second, increasing possibilities of its use in different industries. In the highly developed countries a variety of colloidal silica articles is produced depending on the end use. The types of product differ in the size of disperse phase particles, their concentration; disperse medium (water, spirits, and acetone), surface modifiers, nature stabilizers, and so on.

Colloidal silica finds use as a binder and filler in different ceramic products, coatings, casting molds and in the production of special glass, cement, paints and coatings. Silica hydrosol is widely used as a raw material to produce adsorbents, carriers for catalysts and photosensitive materials. It is used to treat the surface of floors, walls, fabric, cardboard, paper and metal articles as the means against gliding, for easy dust removal from the surface, for improvement of adhesion and so on.

Besides patent literature, two reviews of Iler P. [1, 2] are devoted to the synthesis and properties of colloidal silica. The problems concerning the mechanism of reactions of silica acids polycondensation and surface properties of silica are discussed in the monographs devoted to the synthesis and silica gel properties [3 – 5].

The first works on the synthesis of silica hydrosols refer to the 1925 – 1930th when stable sols with the concentration of silicon dioxide up to 10% by mass have been produced. At that time it was considered that it is practically impossible to raise the concentration. Only in 1941, due to the works of Berd [6], the considerable concentrating of silica sols became possible. This method that has already become classical includes the neutralization of sodium silicate solutions with the help of highly acid ion-exchange resin, alkali stabilization and concentrating by evaporation. The next serious contribution to increasing the stability of silica sol concentration is the patent of Bechtold and Snaider [7].

The authors of this patent have suggested the method for production of monodisperse sol with the predetermined particle size with the help of replenishment of a part of sol preliminary thermally treated with the solution of silicon acids. Further improvements suggested by other authors have allowed them to produce the silica hydrosol with the above mentioned characteristics. Only after these works there appeared the possibility to use them widely in different fields of industry.

However, it is a rather expensive "pleasure" to produce and stabilize silica hydrosol of high concentration as a binder for building materials. So we have suggested the cheap method for producing hydrosols from sodium silicates with the help of cheap natural ion exchangers or ion exchangers being the industrial wastes [8]. Ion exchanger is added into sodium silicate immediately before manufacturing the product, and then this binder is mixed with the material from which the product is formed. After being formed the product is dried at room temperature during 24 hours and then is heated at the temperature of 150 – 240° C during one hour. In this case all intermediate stages of silica hydrosol synthesis and its stabilization are coupled with the process of product forming, so it is not necessary to spend money for the synthesis and stabilization of binder from silica hydrosol. With the use of this procedure we have developed the methods for manufacturing fire resistant building articles [9], materials from wood waste [10], and from rice husk [11] (Fig. 2).

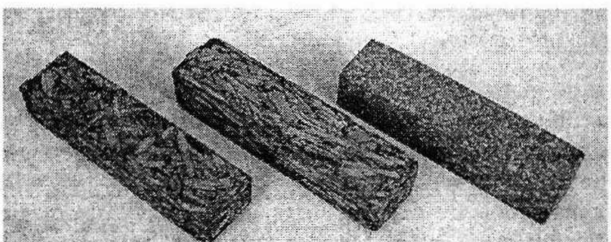

Fig. 1: Products from Wood Waste

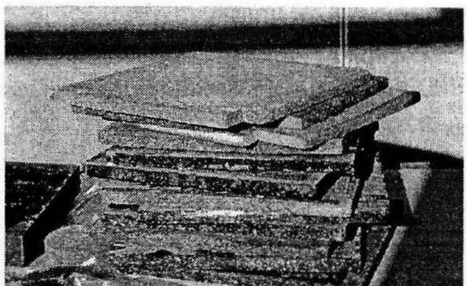

Fig. 2: Products from Rice Husk

To make this binder cheaper, we have developed mechanochemical and other non-autoclave methods for synthesis of sodium silicates from natural minerals and industrial wastes [12].

With the help of such silica sol binder the refractory articles from refractory scrap (chamotte and silica brick) of metallurgical plants were developed and are now being introduced into production (Fig. 3). The compression strength of these articles, already after heat treatment at 240° C, is almost twice higher than initial brick. The melting temperature is 100° higher than that of the initial articles produced with firing at 1200° C. The patent is in preparation now with the use of the data obtained as a result of this development.

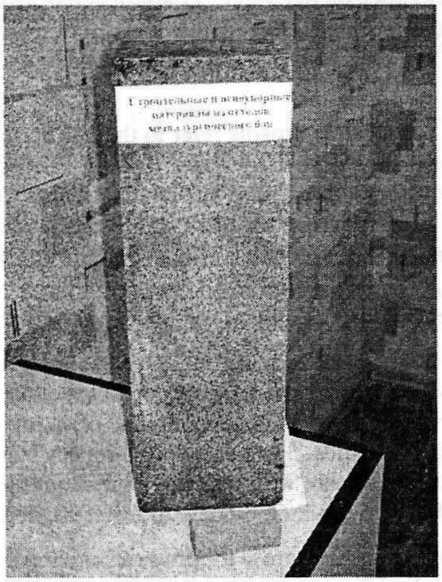

Fig. 3: Silica and Chamotte Brick from Metallurgical Furnaces Waste

The possibility to produce articles at such low temperature results in the reduction of energy consumption by a factor of 25.

Similar development is promoted in China now. Basic material for manufacturing such materials in China is the waste from kimberlite tube near Dalian city. This waste consists almost completely of quartz, so it is an ideal raw material for production of articles according to the invented technology. Two years ago in China there was adopted the law prohibiting the usage of clays for production of building brick, as the clays are a valuable raw material for production of aluminum and ceramic articles. So the production of building brick from another raw material (basalt, sand, industrial waste and so on) is the topical problem.

Production of building brick of sand is the pressing problem in the Siberian region of Russia too, as the reserves of clays in this region are rather limited.

With the help of our technology artificial granite plates with the following polish can be produced (Fig. 4). Nowadays such plates are produced with the help of organic epoxy resins that can result in poisoning and even death of people when fire accident happens. A wide range of decorative ceramic plates, the glaze surface of which is achieved by melting (Fig. 5), can also be produced. The suggested binder can be used to produce abrasive materials which are manufactured with the help of organic resinous binders which result in the formation of toxic poisonous substances at their use. The properties of sodium silicates used for preparation of a binder allow the production of expanded clay aggregate with the density of 0, 3 – 0, 8 g/sm^3, heat conductivity of which is about 0, 07 W/m·K and crashing strength up to 50 MPa. This kind of important materials may be produced of industrial wastes (slag, dust and so on) and any disperse material (sand, basalt, clay, etc.) (Fig. 6).

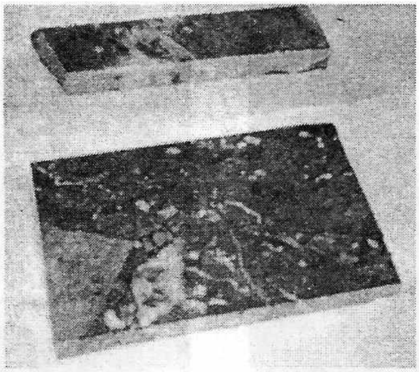

Fig. 4: Artificial Granite

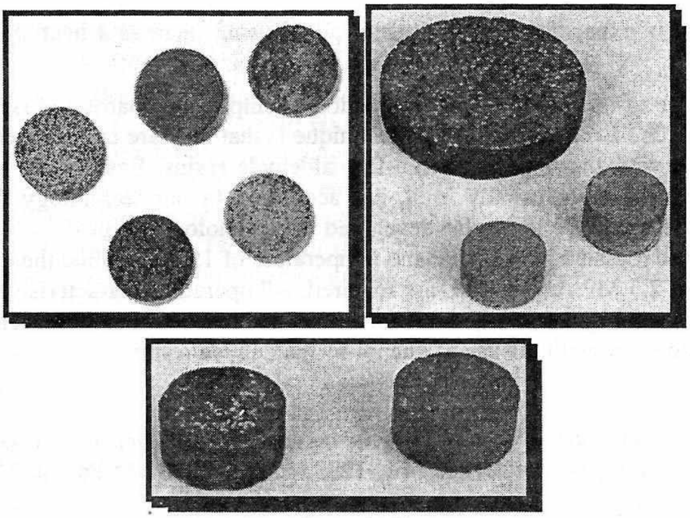

Fig. 5: Ceramic Plates

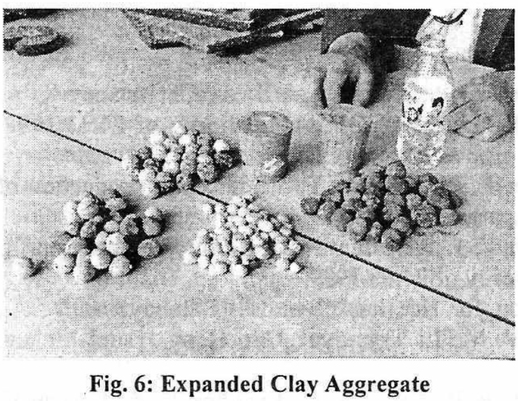

Fig. 6: Expanded Clay Aggregate

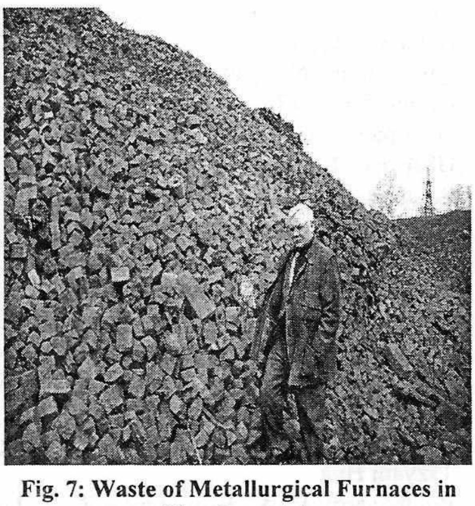

Fig. 7: Waste of Metallurgical Furnaces in Novokuznetsk

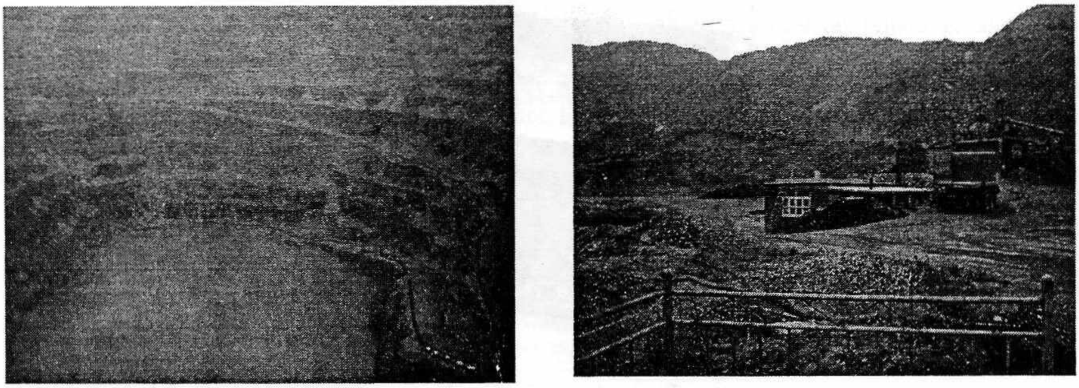

Fig. 8: Waste Kimberlite Tube in Dalyan (China) and its Wastes

The properties of these expanded clay aggregates allow using them as a heat insulating material in civil engineering.

One more possible use of this binder is the production of chip wood boards and rice husk boards. The advantage of the boards manufactured by this technique is that they are environmentally clean, unlike the boards produced with the help of phenol-formaldehyde resins. Besides, to produce chip wood boards, wood sorted chips are usually used, but according to our technology the waste of wood working plants can be used. We have also developed the technology for production of chip wood and rice husk boards at the pressure of 0,1 MPa and temperature of 150° C, unlike the existing technology, where the pressure of 2,5 MPa and 170° C are required. All operating characteristics of chip wood and rice husk boards produced by our method are not worse, and some of them are even better than that of chip wood boards produced with the use of phenol-formaldehyde resins.

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