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SOIL SILICIFICATION

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by

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SOIL SILICIFICATION
(A translation)

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The silicification treatment for waterproofing and hardening soils has been found to be of great use to civil engineers. The method consists of injecting, under pressure, a sodium-silicate solution (water glass) and an insolubilizing solution.

The problem of soil stabilization is certainly one with which the specialists in civil engineering are most concerned. Several processes have been applied among which silicification will particularly be mentioned.

For some years, sodium-silicate has been used in soil waterproofing. Among others, the following specialists have studied this process in Europe: Hugo Joosten, Director of the "Beton- und Tiefbau- und Kälte-Industrie", A. G., of Berlin; Gayard, engineer T.P.E., and the Belgian engineering contractor A. François.

Engineers and contractors are frequently called to erect large structures in loose, water-bearing, fissured, or incoherent ground. Shaft-sinking in such soils requires previous stabilization, either by temporary freezing, by permanent cementation, or by silicification. Soil silicification for shaft-sinking has been applied in several instances. It is also used to waterproof foundation grounds, for instance anchorages, dams and similar structures.

Joosten method - The author of this method was called to study the injection of silicate in fissures and underground cavities in salt mines because these cavities get filled with salt water, impede mining and may cause serious accidents. In contact with a salt solution, sodium silicate forms a silica gel which gradually swells and hardens, thus producing impermeability.

In some cases, after the injection of silicate, another injection of a second liquid is made, which reacts with the silicate (acid solution, solution of salt with acid reaction). Solidification takes place immediately after this second injection. The injection of both solutions is made under high pressure (approx. 100 atm.) by means of 1 inch steel pipes which are driven by sections into the ground. The first pipe is perforated with 50 to 70 holes through which the solutions disperse. Several pipes may be set side by side and thus form waterproofing curtains.

The results obtained with the Joosten method are very interesting; however it will be noted that the compression strength of the treated soils will depend upon their nature: in fine sand, it varies between 10 and 40 kg/cm^2; in gravel, between 40 and 100 kg/cm^2, and in quick sand from 100 to 190 kg/cm^2. This compression strength increases with time: samples that were tested 28 days after solidification have shown a strength of 22.5 to 24 kg/cm^2 and this strength reached 40.5 kg/cm^2 after six months.

The Joosten method was successfully applied to stop inflow of water in mines and to render masonry structures waterproof even under great depths (up to 75 meters). The masonry elements remain unimpaired and are not at all corroded by the solutions.

Gayard method - This method is based on the same principle but it calls for the use of some salts, such as sodium or potassium bicarbonate in the proportion of 5 to 30 percent of the weight of the silicate.

One may use simultaneously:

Sodium or potassium carbonate	3 to 15 percent	of the weight of sodium silicate used
Sodium chloride	3 to 15 percent	
Sodium or potassium hypochlorites	0.3 to 1 percent	

François method - Silicate solutions and a solution of salt with acid reaction are forced into the ground through two boreholes next to each other, under a pressure of 35 to 150 atm. The solution concentration is of 3 to 40 percent of dry materials. The salt commonly used is aluminum sulphate. By increasing the concentration of the solutions cracks several centimeters wide can be filled. The consolidation is achieved by injections of cement grout at the rate of 80 to 200 kg per cubic meter.

Applications - As early as 1936, the attention of the American engineers was drawn to soil silicification. Taking Hugo Joosten's works as a basis, C. Martin Riedel started a series of tests on soil stabilization and internal waterproofing of cracked or porous concretes or concretes that showed cavities in the mass. The American engineers also used a commercial water glass solution ($R = Sio_2/Na_2O = 3$ to 3.3) at 37-40° Baumé. As a reactive salt they chose calcium chloride in concentrated solution. The gel resulting from this reaction fills the voids in the soil, and cements together the grains of the rock to form a mass insoluble in water, with the appearance of sandstone and hardening in time.

The tests made in the laboratory by Mr. C. M. Riedel on samples of Chicago sand, Atlantic and Pacific Coasts sand, Mississippi sand, South Florida sand, have shown that the compression strength of solidified samples varied from 37 to 65 kg/cm^2.

The first large underground stabilization work by silicification was carried out in Florida, at the U. S. Sugar Corporation at Clewiston. It was a question of stabilizing the moving foundation under an extremely heavy engine which caused very strong vibrations: This foundation measured 80 feet by 10 feet. Approximately 600 cubic yards of siliceous sand located under the groundwater level was transformed into a mass of synthetic sandstone having originally a compression strength of 40 tons per square foot.

Seventeen months after the completion of the work, the technical services of the factory published a report stating that no other movement of the foundation had taken place.

Conclusion

Soil silicification will be very useful to civil engineers. Among other applications are: construction of tunnels (protection of tunnels under construction, where sand layers need to be solidified at the cap of the headings), construction of dams, retaining walls, protection of existing foundations, road stabilization, underground canalizations, stabilization of runways, etc.