

SEALING AND/OR CONSOLIDATION AGENT
AND METHOD OF USING IT

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The present invention relates to a sealing and/or consolidation agent for ground and construction materials such as mortars, concretes, masonry, as well as a method of using it.

5 More particularly, the sealing and/or consolidation agent is intended for the treatment of alluvial deposits or rocks having cavities.

Ground, whether it is a question of fissured rocks or of alluvial deposits, sometimes has to be consolidated
10 to ensure its stability. This is the case when digging excavations or drilling wells, to prevent the caving-in of the walls.

The setting up of pillars of bridges or buildings on such ground may likewise necessitate a consolidation thereof
15 with a view to preventing their subsidence.

Moreover, sealing of such ground may prove necessary when it supports work such as dams.

Mortars, binders and concretes may display certain variations in volume liable to result in more or less deep
20 and wide fissures which are harmful to the water-tightness, to the protection of the reinforcement and possibly to the stability of the work. Moreover, deterioration may occur in time under the influence of certain external agents liable to lead to a more or less pronounced porosity through
25 the dissolving of hydrated salts.

A subsequent treatment of these materials is therefore necessary with a view to improving the water-tightness

thereof and/or to consolidating them.

The problem posed by the sealing and/or the consolidation of ground and of construction materials is therefore essentially the same, namely to reach the cavities of the fissures and those present in the alluvial deposits by means of an agent capable of penetrating them easily and of filling them in a durable manner.

The sealing and/or consolidation agents used at present essentially belong to two categories, namely, on the one hand solutions of synthetic resins and on the other hand solutions (or liquid fillings) of alkaline silicates, more particularly sodium or potassium silicates.

The resins or products on a resin base which lead to the formation of polymeric compounds may prove useful in certain cases but it is a question of relatively expensive products, the fluidity of which does not always enable the microfissures or micropores to be reached in depth. Moreover, the injection of resins is a relatively recent technique so that the durability of construction works or ground treated by means of these products is not certain.

The present technique involves using alkaline suspensions of sodium silicate, products which are easily available but which have proved to have numerous disadvantages.

Indeed, the lime present in construction materials and certain ground, once in contact with sodium silicate causes the formation of a silica gel, due to the excess

of silica in relation to the sodium in the treatment solutions.

Sodium silicate is in fact a colloidal solution of silicic acid in soda and its neutralisation leads to its transformation into gel by electric discharge of the silicic ions which condense to form polysilicic ions.

The premature formation of a silica gel has the consequence of blocking an injection so that certain cavities cannot be reached. Moreover, the gelling is never complete because soda remains in the structure of the gel. On the other hand, the gels obtained are not stable in time and tend to dissociate again releasing soda which constitutes a source of pollution and of instability which is not negligible.

The present invention enables the disadvantages of the known agents to be overcome in that it provides a sealing and/or consolidation agent which can easily be injected even into microfissures of the order of about 10μ and having a very great reactivity with respect to lime, capable of leading to a mineralization of the ground and/or construction materials by the formation of stable and insoluble hydrated lime silicates, more particularly tobermorite ($2 \text{ SiO}_2 \cdot 3 \text{ CaO} \cdot 3 \text{ H}_2\text{O}$), thus ensuring the lasting quality of the treatment applied to this ground and these materials.

Tests carried out on test-pieces have, indeed, enabled it to be shown that when the agent according to the invention was used, no gelling occurred through percolation through

porous micromortars, nor was there any appearance of a layer of gel at the outlet of the test-pieces.

The formation of crystals of hydrated lime silicate, more particularly of tobermorite, by means of the agent according to the invention, was able to be confirmed by various examinations by X-ray diffractometry.

Thus the sealing and/or consolidation agent according to the invention enables:

(a) an excellent injection into the cavities and microcavities present in the ground and/or construction materials,

(b) the formation of stable and insoluble hydrated lime silicates,

(c) a stability which is durable in time, of the products formed after injection,

and (d) a quasi-total absence of pollution to be ensured.

The present invention relates to a sealing and/or consolidation agent for ground and/or construction materials, which can be used by injection, characterised in that it appears in the form of a concentrated alkaline solution of silica, which is non-colloidal, obtained by dissolving silica with an average diameter of particles less than approximately 100 μ at ambient temperature, in soda, the ratio $\text{SiO}_2/\text{Na}_2\text{O}$ being less than 2 and the silica content of the solution being greater than approximately 20% by weight.

The non-colloidal nature of the agent according to the invention has been able to be proved qualitatively by the Tyndall effect (measurement of the nephelometric index).

5 The silica used may be silica in the pure state or preferably siliceous products containing at least 80 to 90% by weight of SiO_2 of a non-vitreous structure.

 Among the preferred compounds, particular mention may be made of pyrogenic silicas likewise called smoked silicas
10 which originate from industrial waste, kieselguhr, gaize or silica aerogels.

 Since the granulometry of the silica or of the siliceous product is of great importance with a view to obtaining a rapid and complete dissolving in the soda, it should therefore
15 if possible be less than 100μ but preferably less than 50μ .

 It goes without saying that according to the invention other siliceous products such as those mentioned above may be used insofar as they satisfy the necessary solubility criteria.

20 The soda used to dissolve the silica preferably appears in the form of a solution comprised between 35°B and 37°B , that is to say having a density comprised between about 1.32 and 1.35.

 During the dissolving, a certain exothermicity occurs
25 which it is not necessary to control insofar as no unfavourable effect has been noted with regard to the reactivity of the

sealing and/or consolidation agent.

The ratio $\text{SiO}_2/\text{Na}_2\text{O}$ likewise assumes a great importance, which, as indicated above, should be less than 2 but preferably comprised between 1.5 and 1.8. Indeed, in the case of a
5 higher ratio than 2, the silica would tend to form a gel and therefore to prevent a satisfactory injection into the deepest of the microfissures or microcavities.

The maximum content of silica is not critical insofar as the ratio $\text{SiO}_2/\text{Na}_2\text{O}$ remains below 2. Nevertheless,
10 for practical reasons relating, in particular, to the viscosity of the agent according to the invention, this content is generally not greater than approximately 30% by weight and is preferably comprised between 23 and 27%.

It has actually been observed that in order to obtain
15 a satisfactory injection it was desirable that the viscosity of the sealing and/or consolidation agent according to the invention should be comprised between about 5 and 50 cP, preferably between 20 and 30 cP, an appropriate viscosity being able to be obtained by dilution with water.

20 The agent according to the invention may further contain certain additives capable of improving the penetration into the fissures or cavities.

According to a modification of the invention, the sealing and/or consolidation agent may contain lime or
25 a calcium salt such as calcium chloride, formate, acetate or propionate for example.

The addition of lime or of a calcium salt is more

generally recommended for the treatment of certain ground and/or materials which are poor in lime.

In ground and materials rich in hydrated lime, the silica dissolved in the agent according to the invention is able to lead, after reaction, to the formation of hydrated lime silicates (tobermorite). This is not the case, however, with ground and/or materials which are particularly poor in hydrated lime for which it is necessary to make up directly for this absence by an addition of industrial lime or indirectly by means of a calcium salt.

When the agent according to the invention contains lime, this is generally present in a quantity such that the ratio CaO/SiO_2 is greater than 0.3, the maximum ratio being 1.50.

According to the invention, a calcium salt is preferably used, more particularly calcium chloride insofar as, after its neutralization by the soda, it leads, not only to the lime formed, but also to a non-polluting salt (sodium chloride).

The dissolved silica therefore reacts with the lime formed to provide insoluble and stable hydrated lime silicates.

The amount of calcium salts should be sufficient with a view to the total neutralization of the soda, since an excess of soda is liable to give rise subsequently to pollution phenomena. Although an excess of calcium salt may be used, it is preferable, according to the invention, to use the stoichiometric amount necessary for the neutralization of the soda contained in the agent.

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Although the enrichment of the sealing and/or consolidation agent according to the invention with calcium salt constitutes a preferred form of embodiment, this contribution may nevertheless be made by injecting a solution of calcium
5 salt prior to the injection of the agent. Such a method necessitates two successive injections, however, and consequently makes the treatment longer and more expensive.

The various studies carried out with the agent according to the invention have enabled it to be shown that the formation
10 of the crystals of tobermorite occurred about 10 hours after the injection and that their formation continued for about 7 days after the injection.

The X-ray diffraction or scanning electronic macroscopic examinations have shown a great abundance of crystals of
15 hydrated lime silicates after 7 days.

The very satisfactory reactivity observed is explained by the activity of the dissolved silica and by the freshness of the solution.

The present invention likewise relates to a method
20 of sealing and/or of consolidation, this method consisting in injecting under pressure the agent according to the invention as defined above, into cavities or microcavities in the ground or into fissures or microfissures in construction materials, by means of conventional injection appliances.

25 The method according to the invention is intended, in particular, for the treatment of ground to be sealed or consolidated, whether it is a question of fissured rocks or of alluvial deposits.

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For fissured rocks, a drill-hole is first made and then the agent according to the invention is injected by the techniques known as advancing injection or rising injection.

5 For alluvial deposits, because of the risks of cave-ins, a method is used which is now conventional, known as "tube with cuffs" (French Patent No. 986.619).

The injection pressure is generally comprised between 5 and 20 bars and the amount of consolidation and/or
10 sealing agent between 30 and 40% of the volume of the ground which it is intended to treat.

During the sealing work, the treatment can be checked by taking a sample which is subjected to permeability measurements.

15 A ground of alluvial deposits having a permeability of about 10^{-3} m/s will change over to a permeability of about 10^{-6} - 10^{-7} m/s after injection and hardening.

With the object of making the invention better understood,
one example of embodiment and of use of the sealing and/or
20 consolidation agent according to the invention will now be described by way of illustration and without any limiting character.

EXAMPLE

A drill-hole 10 m in depth is made in a ground rich
25 in very permeable lime (permeability of 10^{-2} m/s) with a view to the sealing treatment of a volume of $\frac{1}{2}$ ground of 1 m^3 .
An injection tube is introduced into the drill-hole and

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the injection of a solution obtained by dissolving 170 kg of silica with an average granulometry of about 50 μ in 300 litres of soda at 36°B and 70 litres of water (the characteristics of the solution after formation were the following: ratio $\text{SiO}_2/\text{Na}_2\text{O} = 1.8\%$; $\text{SiO}_2 = 26.6\%$; $\text{Na}_2\text{O} = 14.8\%$; $\text{H}_2\text{O} = 58.6\%$ viscosity 40-50cP), is then effected under an initial pressure of 3 bars. When the refusal pressure has stabilized at about 10 bars, the injection is stopped which has proved to correspond to an amount of solution injected of the order of 320 litres.

After one week, a fresh measurement of the permeability enabled it to be confirmed that it had changed to 10^{-6} m/s, denoting a perfect sealing of the ground treated.

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CLAIMS :

1. A sealing and/or consolidation agent for ground and construction materials, which can be used by injection, comprising a concentrated alkaline solution of silica, which is non-colloidal, obtained by dissolving silica with an average particle diameter of less than approximately 100μ in soda at ambient temperature, the ratio $\text{Si}_2\text{O}/\text{Na}_2\text{O}$ being less than 2 and the silica content of the solution being greater than approximately 20% by weight.
2. An agent according to Claim 1, wherein the silica used is a siliceous product containing at least 80 to 90% by weight of SiO_2 of a non-vitreous structure.
3. An agent according to Claim 2 or Claim 2, wherein the silica is pyrogenic silica (smoked silica), kieselguhr, gaize or a silica aerogel.
4. An agent according to any one of the preceding Claims, wherein the ratio $\text{SiO}_2/\text{Na}_2\text{O}$ is between 1.5 and 1.8.
5. An agent according to any one of the preceding Claims, wherein the maximum silica content is not greater than approximately 30% by weight.
6. An agent according to Claim 5, wherein the maximum silica content is between 23 and 27% by weight.



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7. An agent as claimed in any one of the preceding Claims, wherein its viscosity is between 5 and 50cP.
8. An agent according to Claim 7, wherein its viscosity is between 20 and 30cP.
- 5 9. An agent according to any one of the preceding Claims, wherein it contains lime in a ratio of CaO/SiO_2 greater than 0.3 with a maximum ratio of 1.5.
- 10 10. An agent according to any one of the Claims 1 to 8, which contains a calcium salt.
- 10 11. An agent according to Claim 10 which contains calcium chloride, formate, acetate or propionate.
12. An agent according to Claim 11 which contains calcium chloride.
13. An agent according to Claim 10, wherein the calcium salt is present in an amount enabling the
15 soda to be totally neutralised.
14. A method of sealing and/or consolidating ground and construction materials, which comprises injecting under pressure, by conventional techniques, a sealing and/or consolidation agent as claimed in any one of
20 the Claims 1 to 13.



15. A method according to Claim 14, wherein prior to the injection of the sealing and/or consolidation agent as claimed in any one of the Claims 1 to 13 a solution of a calcium salt is injected.
- 5 16. A method according to Claim 15, wherein the solution of calcium salt is a solution of calcium chloride.
- 10 17. A sealing and/or consolidation agent substantially as herein described with reference to the accompanying example.
18. A method of sealing and/or consolidating ground and construction materials substantially as herein described with reference to the accompanying example.
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