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CIPS – A NEW PERMEATION GROUTING TECHNOLOGY

Abstract
The technology, called CIPS, an acronym which stands for "**C**alcite **I**n **S**itu **P**recipitation **S**ystem", has a potential for its application across a wide range of industries. CIPS mimics the processes that occur in nature when loose sediments are transformed into sandstone and limestone. However, CIPS can achieve the same results in days rather than millions of years. This paper tries to give a report on the reaction method, the characteristics and the application of this new permeation grouting technology.

1. Introduction
The process with the name CIPS was developed by two Australian scientists. Today the company Lithic Technology Pty Ltd and CarboTech Fosroc GmbH develop production facilities for this product and commercialise this technology in the European market.
CIPS is a new permeation grouting technology that can be applied in many different geological formations and engineering or environmental situations. In each of these different situations the desired outcomes will be different. In some situations the requirement may be for preservation of an existing structure and resistance to further erosion or abrasion and the desired result will be only a small strength increase in the treated area. Other situations may require the treatment of a maximum volume of material with a high final strength. All these different situations depend on the target material to be treated, the decisive parameters being grain composition, grain size, porosity, permeability and water content [1].
To match these situations and requirements, the CIPS formulations can be adjusted to give the best possible result. That may mean a predefined strength, a cheapest acceptable result or a quick treatment.

2. Characteristics of CIPS
The calcite in-situ precipitation system (CIPS) compromises two separate water-based solutions. The solutions, called component A and component B, are mixed together at the point of application. The solutions react on mixing to produce calcite or calcium carbonate crystals. CIPS closely mimics the processes that occur in nature when loose sediments are transformed into sandstone and limestone. However, CIPS can achieve the same results in days rather than millions of years and transforms sand soils into permanent rock with similar properties like strength, stiffness or durability.

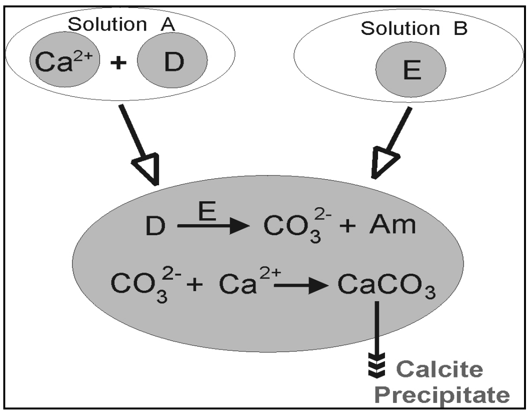

Fig. 1: CIPS solution[2]

This new grouting technology is designed for in-situ application in areas of difficult access. CIPS starts as a low viscosity, water based solution that easily penetrates with a low injection pressure into materials, particularly sand, soil and rock. It will work with almost any porous material; important is that it can penetrate. The calcite crystals adhere to and form cement bonds between the particles with a wide variety of materials – for example: mineral grains (sands), soil, fragmented rock, coal, timber, metals, glass and even plastics.

The CIPS solution permits a re-treatment of the material. For example, a second treatment will precipitate more calcite within each pore space and the coating of calcite cement around each particle will increase in thickness. With increased cement thickness existing bridges between particles will be stronger and new bridges will form between particles that previously were too far apart. This process will occur with each CIPS treatment so that theoretically, after many applications, up to 10 times, almost all particles will be strongly bonded to all their neighbouring particles [1]. The result after the treatments will be a high final strength.

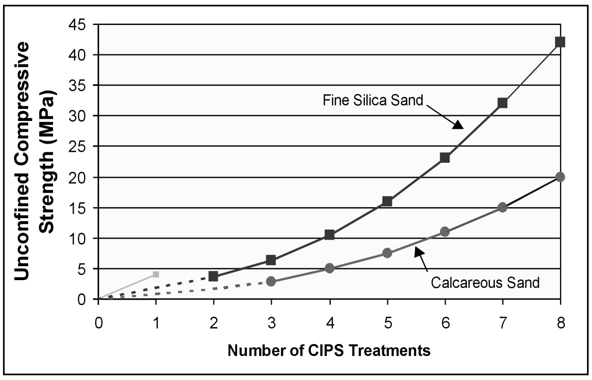

Fig. 2: CIPS solution[2]

One further characteristic is, that the strength of a treated material grows over time. The calcite cement in the pore holes re-crystallize after the formation over several weeks. The result of this grain boundary mobility is an increase of the material strength. Actually, we do not have test results about the scale of strength after a definite time.

3. How CIPS works

CIPS works by the direct precipitation of calcium carbonate from the CIPS solution. There is no reaction with the constituent particles. The calcium carbonate will form mineral cement around the constituent particles, like quartz, carbonate, feldspar or other types of minerals. These particles and their surfaces are excellent nucleation sites for the growing calcite crystals. There is a high potential for the crystals to nucleate and grow on these surfaces rather than in the midst of the CIPS solution in the pore spaces. The calcite crystals that have crystallized from the CIPS solution will grow outward from the particle surfaces and into the pore spaces. They are packed closely together and form a coating or rind around each of the constituent particles in the material; this is the calcite cement. The typical size of one crystal is approximately 0.1 μm diameter and 10 μm in length [1].

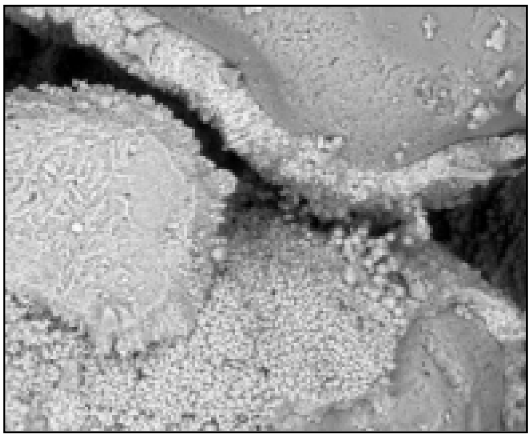

Fig. 3: Electron image, crystals[2]

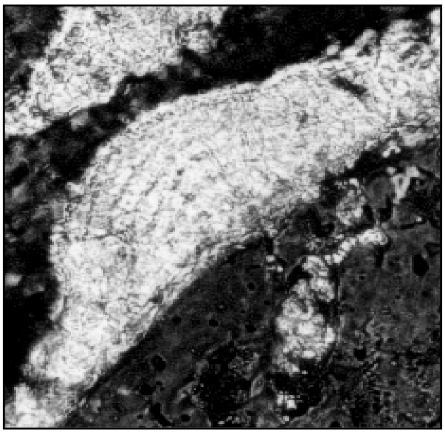

Fig. 4: Electron image ,crystal rinds[2]

Where adjacent grains are close together the cement coating surrounding the two grains come together and interlock, forming a solid calcite bridge or bond between the two particles. In figure 3, you can see the coating around the particles. The CIPS bonding occurs only, when the calcite cement is thick enough and can form a bridge between. The figure 4 shows the crystal sheathing after several treatments. In case of the particles are too far apart, no bridge will form and consequently CIPS does not increase the material's strength.

The calcite precipitation works in dry, wet and water logged areas. In case of a water logged soil, the CIPS solution displaces the existing fluid in the pore spaces and precipitates calcitein amounts of up to 150 grams per litre of solution. In dry or wet materials, the solution fills only the pore spaces and precipitate the crystals. The cementation rate depends on the formulation and can be varied from 6 h to 48 h. Generally said, the next application is possible after approximately 8 h.

4. Applications

Prior to the application, the two solutions are mixed in the ratio A:B = 1:1 to form the charged solution. A suitable application is the injection of the CIPS solution with a mix and pump system. This system requires a special pump with two separated pistons with one tank for component A and one for component B. Both components are pumped in a separate hoses, mixed together in a static mixer and injected into the target material via a pipe. A potential application could be, e.g., the improvement the stability of existing civil engineering structures, such as walls, embankments or foundations of buildings.

Because of the low viscosity with $\nu \cong 3\ m^2/s$, the CIPS solution can also permeate into many target materials under gravity. This kind of application, which means a simple flooding of the surface, is possible wherever the porosity and permeability of the soil or material allow a fast penetration. A part of a railway embankment in London was flooded with CIPS for a trial in late 2001. The idea was to improve the strength of the ash embankment with a simple technique. The test result was positive.

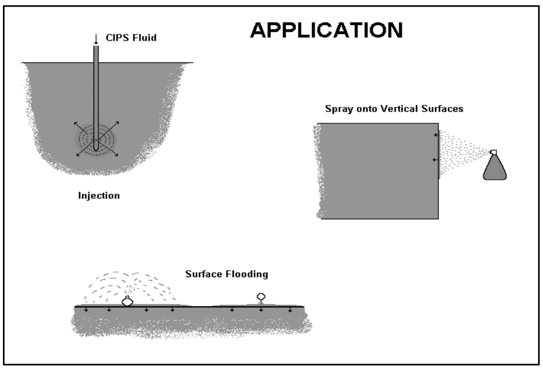

Fig. 5: CIPS application[2]

The last potential operation with CIPS is the spray application onto vertical surfaces. Historic buildings and monuments are often constructed of limestone or sandstone and in many sites, this material has suffered from considerable erosion from wind, rain and corrosion from pollutants. Corrosion involves dissolution of the natural cement that holds the grains together, and erosion involves the removal of loose grains by the action of wind and water. A spray application with CIPS can be used as an in-situ treatment to replace the lost cement between grains, thereby firmly re-bonding loose grains and resisting further erosion. We obtained a first experience with a trail on a heavily corroded limestone wall in the historically important Whalers tunnel in Western Australia in 2001.

5. Conclusions

The CIPS application is still in its infancy. Our first experiences with the calcite precipitation in the laboratory and the field trial show big future prospects for this new grouting technology. One advantage over other grouting methods is the in-situ application. The CIPS solution will be prepared off-site depending on the requirements. A second advantage is the variable application (injection, flooding or spraying), which requires only minimal effort and is easy to apply compared to other grouting methods. CIPS is a water-based solution and that means it penetrates easily in a lot of different substrates. In 2003, we still have to learn a lot about that grouting product and its capabilities. Our project team is looking forward into an interesting future.

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[1] CIPS Application Design Parameters, Lithic August 2002

[2] Presentation by Dr G. Price, Thailand 2003