



Revolution in Geotechnics

Bacteria build biodikes

GeoDelft is hoping to unleash a geotechnical revolution with the help of a new technique. By stimulating natural soil processes, they are able to change the physical properties of soil. Bacteria that can transform sand into sandstone play the main role. The main application: dike consolidation. The process is (not yet) suitable for peat dikes, but stabilisation of our dikes using so-called biocement seems to be possible.

It seems too good to be true: Soil bacteria in a dune or dike that can cement sand grains together in-situ to form sandstone. According to ir. Waldo Molendijk, Business Development's Sector Director at the GeoDelft research institute, this is the dike consolidation method of the future. 'This all started several years ago when I heard from a colleague that someone in Australia was busy restoring sandstone monuments using bacteria. It was only later that we realised in Delft what the possible implications could be for geo-engineering applications,' says Molendijk. In the meantime, the Australian researcher in question - Vicky Whiffin - based her doctoral thesis on developing an in-situ biocementation process, and GeoDelft has carried out several successful laboratory tests with 'flown-in' bacteria.

Molendijk: 'GeoDelft is in fact concentrating on two possible applications using soil, namely soil consolidation and soil obstruction.' With soil obstruction, Molendijk is aiming for *biosealing*: by giving 'soil-inhabiting' bacteria the right diet, they produce a slimy substance. This makes the soil less permeable, including for moisture. 'Using this approach, it is possible for example to seal a leaking construction pit.' The bacteria's diet in this case consists mainly of sugars and starch. The microbes are fed by injecting the foodstuffs into the soil at the right location. 'After a number of successful laboratory tests, we will soon be starting a test project at a secret location. We will know whether this test has been successful after about a month.'



LIME

Soil consolidation is the second application on which GeoDelft is focusing, with a view towards dike reinforcement. 'We have not progressed quite so far with this yet, but laboratory tests so far have been successful,' says Molendijk, showing a cylinder-shaped piece of sandstone as he talks. 'In contrast to the method we use for obstruction, we introduce bacteria into the soil to achieve consolidation. This is because the cement-producing microbes are normally only found on the soil surface. They are unable to survive long at greater depths, as they need oxygen.'

GeoDelft used bacteria sent by the Australian researcher, Whiffin, for the laboratory tests: 'Under the right conditions, the microbes produce a type of lime, also known as calcium carbonate (CaCO_3), chalk, or calcite. This is a crystalline material that is responsible for hardening natural sandstone. If the bacteria produce calcite in sand, this lime sticks the sand grains together like a type of cement. This leads to the formation of a sandstone that is similar to natural sandstone.'

The final strength of the sand body depends upon the number of rinses with bacteria and nutrients (in this case mainly salts). 'During the first rinse, lime formation will only cause the grains to join at the contact surface. This means that the sand is rather crumbly,' says Molendijk. 'The second rinse leaves a thicker layer of calcite behind on the grains, so that the hardening increases. After the third rinse, a strength results that is similar to natural sandstone. The material is not the same, but is nonetheless permeable.'

The possibility to control the degree of hardening is a considerable benefit. 'Water pressure is unable to develop if the material is permeable. A soil retaining structure that allows nothing to pass through runs the risk of being pushed over. This is also why it is not an option to keep the microbes in the first rinse alive by injecting oxygen, instead of injecting new bacteria during each rinse. The oxygen ensures that iron in the groundwater precipitates, so that a non-permeable structure results.'



Microscopic view of sand grains,
joined in places by calcite crystals

WORK-HORSE

Cementation can therefore be achieved in controlled laboratory conditions. There are, however, a number of obstacles that need to be overcome before the technique can be used in-situ. For this reason, GeoDelft would like to use bacteria from The Netherlands, rather than from Australia.' Although it is not a legal requirement, GeoDelft finds it preferable not to introduce "foreign" bacteria to Dutch soil,' says Molendijk. 'This means that we must investigate which bacteria make the best work-horse. It is not a question though of a unique bacteria which is capable of this. We must just attempt to select the most suitable, and try to cultivate it.'

The next step is to investigate the extent to which temperature differences between the laboratory and the soil outside have an effect. 'In general, bacterial activity decreases by a factor of two with a temperature decrease of 10 °C. It is still not clear whether this also holds true for this process.' According to Molendijk, it is also necessary to develop a number of calculation models. 'Think of computer programs which allow you to determine which treatments are necessary to achieve a particular underground shape, or the number of rinses required to achieve a certain strength.'

Molendijk believes that this technique can form the basis of a new way of approaching geotechnical problems. 'Biological processes always play an important role in the creation of new soil properties. By stimulating the correct natural processes we can control these properties.' The economic success of the biodike project also depends, however, on other factors. Molendijk: "As far as this is concerned, the fact that an already-existing tool can probably be used for the injection process is a substantial advantage. The bacteria will probably only be inexpensive enough if they are cultivated on a large scale. The first test bacteria were relatively expensive because of the cost of their air ticket from Australia.'

DREDGED SPOIL

GeoDelft has so far only tried out the biological process on sand. Molendijk also thinks that the first application will be dike strengthening along the coast. 'With clay, for example, I foresee greater problems. As it is much more dense than sand, it is more difficult to infiltrate with a bacteria-containing rinse. Peat is even more difficult. It is not only injection that would be more problematic, but also binding the organic fibres could cause a problem. For the present,

then, we are only focusing on sand. Apart from our dunes, we can also think of temporary soil retaining structures, the repair of foundations, and consolidating dredged spoil so that it can be used as building material.'

<http://www.geodelft.nl>

<http://wwwstaff.murdoch.edu.au/~vwhiffin/biocement.html>