Electrokinetic stabilisation of peat using a biobased ground improvement technique

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Peat soils are organic soils that are an accumulation of partially decayed vegetation and are unique to natural areas called peatlands. These soils are a challenge to civil engineers as they are not suitable foundation materials: they are soft, weak soils and are subject to settlements due to various mechanisms (e.g., peat oxidation, drying shrinkage, consolidation, and secondary compression). Ground improvement is therefore often used to enhance peat properties as a foundation soil, usually by a method of inducing consolidation, which is, however, not suitable for existing infrastructure; besides, in a peatland environment, consolidation with consequent drainage and lowering of the water table would be undesirable, leading to the release of greenhouse gases to the environment. Alternatively, chemical stabilisers can be used to improve peat properties. Along these lines, one promising recently introduced biochemical ground improvement technique is Microbially Induced Calcite Precipitation (MICP); MICP is used to produce biocement naturally, through the metabolic activity of microbial enzymes[1]; this biocement binds soil particles together, leading to an increase in the strength and stiffness of the soil. This technique has emerged as a sustainable alternative to conventional chemical ground improvement methods (e.g., cement or lime) for various civil engineering applications. However, limitations related to the injection of biocementation treatments in peat are challenging for the MICP process. Thus, researchers have recently adopted electrokinetics (EK) to effectively achieve this process for soft, fine-grained soils [2]. In addition to clays (studied in [2]), peats and organic soils are suitable candidates for EK treatment, as the diffuse double layer on the humus particles, and inorganic soils induce and enhance EK phenomena [3]. The use of EK to implement MICP treatments in peat soils can potentially solve many of the challenges of the peat biocementation process, as it can (a) lead to a less heterogeneous distribution of calcium carbonate precipitation in the fine-grained soil and avoid local clogging, (b) control groundwater levels so that peat oxidation and settlements of existing infrastructure are prevented, and (c) be used to remove by-products of the process or recover carriers [3]- [5].

Previous laboratory-based work of our research team has proven the feasibility of using EK to biocement an organic soil, i.e. a foundation soil of UK railway embankments for the first time, using indigenous ureolytic bacteria from the project site[3]–[6]. Identifying several indigenous non-pathogenic bacteria capable of biocementing peat was studied to reduce interference in local microbial ecology. According to our studies [3]-[6], biocementation treatment resulted in a strength increase of up to 82% (165% when MICP was combined with EK -see Figure 1), a decrease in swelling of 40 %, a compressibility decrease of 47 %, and a drying shrinkage decrease by 16%.

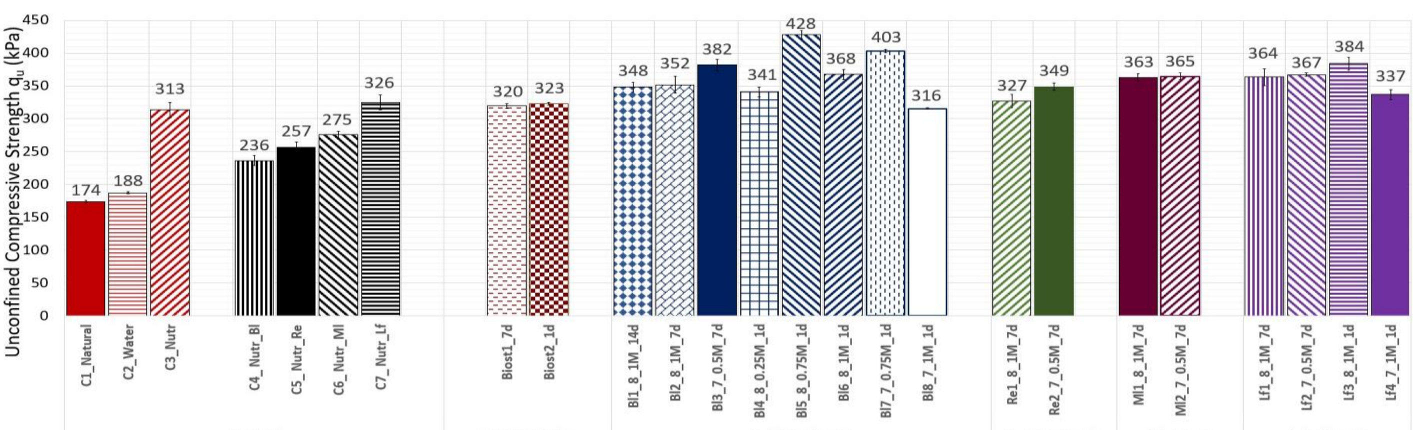

Figure 1: Unconfined compression strength of peat via EK mediated by indigenous bacteria[3]

Ongoing research funded by the European Commission (project *NOBILIS*), now focuses on different metabolic pathways of indigenous bacteria used to produce biocement, while also consuming CO_2 during the biocementation process. It also aims to realise biocementation in situ combined with EK as a viable ground improvement method for problematic organic soil. Initially, we envision developing CO_2 sequestering biocementation in the laboratory and will implement the soil treatments using electrokinetics. We will then subsequently optimise the system by modelling the EK process. The improvement of the geotechnical properties of the peat in situ using the processes developed in the laboratory will be evaluated. Environmental Impact Assessment (EIA) and Life Cycle Analysis (LCA) of biocementation will be conducted to assess the solutions' economic, environmental, and overall sustainability based on the pilot field study.

Work in progress has first assessed the possibility of using the indigenous bacteria studied in [3]-[6] to this effect. All four bacteria were shown to produce carbonic anhydrase (CA) enzyme (Figure 2) and can thus consume CO_2. They are therefore candidates for further study in *NOBILIS* together with new isolates from a different location next to the railway.

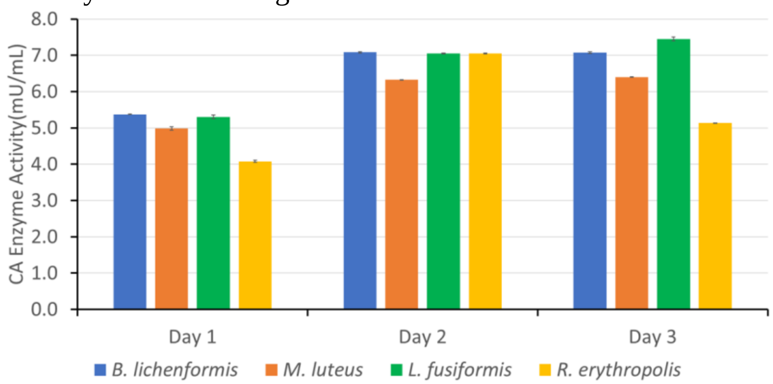

Figure 2: Enzymatic activity of the carbonic anhydrase-producing bacteria

The successful development of the proposed techniques is of great practical importance for linear infrastructure owners interested in finding cost-effective and sustainable ground improvement techniques. Moreover, in this application consumption of CO_2 in the processes can potentially be significant. Anticipated benefits are the contribution to climate change adaptation (infrastructure resilience) and mitigation, as the proposed methods combine CO_2 capture with developing novel, superior ground improvement processes.

Keywords: Electrokinetics, biocementation, Carbonic anhydrase, peat, ground improvement.

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