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and Xiang, W. N. 2017. “ Review onbiologically based grout material to prevent soil liquefaction for groundimprovement”. International Journal of Geotechnical: 1-6References: Last but not the least, future experiments might beperformed on samples having a different degree of saturation and initialdensity to check the efficacy and accuracy of the proposed study. Furthermore, other different tests like triaxial test etc.

may be employed to check thebehavior of treated soil under different mechanical and hydraulic conditions. Stabilization using MICP is very cost effective compared to other conventionaltechniques and a very green, sustainable and eco-friendly technique whichpromises a great future. Proper field testing to confirm lab resultsSlower microbial process Limit of aerobic bacteria is not effective in deep soils Excessive ammonia production beyond human safetyWhile this study might be extensive, it certainly is boundby its scope but it would serve as a benchmark for future studies of MICP onfine-grained soils. Problems with MICP will still be present for futureresearch to be carried out upon such as: Potential Output: This study would be the first of its nature to study thedistribution of bacterial solution through the sample and an attempt atachieving homogenous treated sample.

Fine-grained soils will be investigatedand how their properties respond to microbial treatment, which in turn woulddecrease its various problems, would be presented. Bacterial and cementationreagent concentration would be altered as well to find the average trend andput forward an optimum content of both. All of these observations are either notlooked into or literature regarding them is very little and hence this studyserves as a foundation for future work in this regard. Research Significance: For phase-2, the bacterial solution would be injected intothe sample, which should probably a column or a large tank, and analyze thedistribution of the bacterial solution along the sample. According to Whiffin(2007), balancing the rate of urea hydrolysis in the column with the deliveryof reactants via the flow rate is essential to precipitate calcium carbonate atlocations where required. In order to produce a more homogeneous result, thebalance between supply and conversion needs be shifted.

For example, fasterflow rates will move the cementation reactants further into the column allowingless time for reaction along the path, and similarly lower conversion rateswill leave more reactants in the fluid, also resulting in further infiltrationdistances. The precipitation amount will be measured by the increase in PH andcalcium carbonate content throughout the sample. The whole sample will bedivided into smaller (equal) samples for lab testing to check the homogeneity. Treated samples and untreated samples will be exposed toDirect Shear and 1-D Consolidation tests. Graphical and analytical comparisonswould be drawn between both types of samples for their differences in shearstrength and settlement behaviors. The coefficient of compression (Cc), thecoefficient of compressibility (mv) and Coefficient of Recompression (Cr)values would be calculated from oedometer tests to predict the primaryconsolidation and compressibility potential of both samples. To determine theshrink-swell potential, the coefficient of linear extensibility (COLE), liquidlimit (LL), Plasticity Index (PI) and Free Swell Index would be determined forboth treated and untreated samples and collectively a comparison will be done. This study will be divided into two phases: the first phasewill check the effect of MICP on the properties of soil while the second phasewould aim to achieve a homogeneous distribution of calcium carbonate throughoutthe soil.

For the purpose of the phase-1, soil samples will be collected anddivided into two groups; treated and untreated samples. Bacteria will becultured in the lab so as to promote the growth of its colonies while thecementation reagent would consist of Urea, Calcium Chloride and Nutrient broth. Furthermore, the bacterial concentration would be kept constant and content ofcementation reagent would be altered.

This would be the first set of treatedsamples, while the other set would have constant cementation reagent andbacterial content would be changed. The effect of both the bacterial andcementation reagent content on the treatment would be analyzed and an optimumamount of both would be found. Research Methods: Since microbial ground improvement is a recent and new methodof altering soil properties, therefore it still has a lot of room forimprovement.

The center of research in this field has always been sandy soils, to bring about cohesion in them and reduce their permeability, and fine soilshave not been researched enough for MICP. The major obstacle for Geotechnicalengineers over the past years has been the large-scale application of MICP. Inall the studies conducted, homogenous distribution of the bacterial content wasnot achieved in the samples. There is a primary restriction on the transport ofmicrobes in soil matrix because of the size of pore throats makes bio-grouttreatment not deeper in soils (Kumari 2017). Also, urease-producing bacteria inbio-grout development are aerobic which means it cannot precipitate carbonatesdeep in the ground due to the absence of oxygen and a weak precipitate isformed.

There is also limited research carried out on fine-grained soils, whichproperly documents the comparison of treated and untreated samples and commentson whether MICP could be as effective in clayey soils as it is in sandy soils. Another issue with urease-driven MICP is excessive production of ammonia beyondsafety threshold (Yu et al. 2015). To avoid this problem, asparaginase-basedMICP process produces less ammonia, as reported by Li et al. (2015), howeverfurther research regarding this is needed. Gap in Literature: Some studies conducted on fine-grained soils include Saffariet al (2017) in which fine swelling soil was treated with differentconcentrations of MICP. The results revealed that the biological treatmentincreased the soil peak internal friction angle by 14%, while the soil cohesionwas almost tripled for the sample treated by the bacterial solution withoptical density (OD) of 2. 3 (Saffari et al 2017).

Compressibility and shearstrength of a fine-grained organic soil was tested before and after microbialtreatment, which showed a 20% increase in the carbonate content of the organicsoil (Hanifi, Waleed, Ibrahim 2015). Shear Strength was also reported to haveincreased as well as the compressibility decreased. In order to evaluate the potential MICP, a 5-m sand columnwas treated with bacteria and cementing reagents under conditions thatsimulated field conditions (Whiffin, van Paassen, and Harkes 2007). To evaluatethe potential of bio-grout for field applications, it was scaled up for alarger sandbox of size 100 m3 where sand was treated and homogenous treatmentwas attempted.

The results concluded with turning sand into bio-sandstone bybio-grout with UCS as high as 12 MPa (van Paassen et al. 2009). As high as UCSvalue of 34 MPa was reported in soil while using bio-grout at different MICPtreatments (Whiffin 2004). Unconfined compressive strength and permeabilitytests were performed on sand samples and MICP treatment increased the strengthof the treated samples (Al Qabany and Soga 2013). The magnitude of thisincrease depended on the concentration used in the treatment. The use of ahigh-urea calcium chloride concentration solution resulted in a rapid drop inpermeability, whereas the use of a low-chemical-concentration solution wasfound to result in a more gradual and uniform decrease in permeability. Bacillus pasteurii, now reclassified as Sporosarcinapasteuriis, a highly urease active bacteria, plays an important role in CaCO3precipitation (Bang et al

2001, Dejong et al 2006, Dejong et al 2010). Thebacteria along with $CaCl_2$, Urea and nutrient broth are injected into the soilas a solution which produces crystals of calcium carbonate in the soil matrixby urea hydrolysis and cements the soil.

Previous studies regarding this method have been majorly conducted onsandy/coarser soils. These drawbacks of conventional techniques provide enoughreasons to look for an alternative method which guarantees cost effectivenessand environmental safety along with a greater depth of improvement and notinterfering with natural groundwater flow. Microbial calcite precipitation hasrecently been a center of research for geotechnical engineers as it is notenvironmentally damaging and is cost-effective in achieving desired qualitiesof soil. Also, Whiffin (2007) demonstrated improvement of the load-bearingcapacity of the soil without making the soil impermeable to fluids.

Current Methods of ground improvement include densification, solidification, dewatering, replacement, mechanical compaction andcement/chemical grouting. All of these methods of improvement are either costlyor environmentally unfriendly. The cost of chemical-based soil grouting isestimated between $2 and $72 per cubic meter of soil, while the costs of theraw materials for the bio-grouting could be in the range from $0.

5 to $9. 0 perm3 of soil in cases when the waste materials are used as carbon source formicrobial growth (Ivanov and Chu 2008). Bio-grout is also calculated as cheapermaterial over conventional grout in another study (Suer et al.

2009). These traditional measures are unsuitable forthe treatment of large amount of soils due to their limitation of the zone ofinfluence or due to the high viscosity or short hardening time of the injectedgrouts. Furthermore, these techniques significantly lower the permeability ofthe soil that prevents groundwater flow and limits the injection distance, making large-scale treatment unfeasible (van Paassen et al.

2009). Background Literature: In this study, the effects of bacterial calciteprecipitation on the settlement, bearing capacity and swelling potential of afine-grained expansive soil will be studied. The degree of homogeneity ofcalcite precipitation throughout the sample would also be studied as it is amajor concern for the application of this method in the actual field. Inprevious studies, it has been attempted to check the depth of improvement bythis method (Whiffin 2007) but not achieved yet.

Shear strength of afine-grained soil has also been successfully increased with MICP (Safari et al. 2017) and organic soil had its compressibility coefficient, as well as themagnitude of its primary consolidation, decreased (Canakci, Sidik and Kilic2015). Research done on finer soils is still very limited and a propercomparison of the changes, the bacterial precipitation brings about in thetreated soil with respect to the untreated soil will be presented in thisstudy. The aim of this research is to look into a cost-effective andeco-friendly method of improving the shear strength, decreasing settlement andswelling of a fine swelling soil by MICP. Percentage of Bacterial contentsadded to the soil will be varied in order to find the optimum microbialcontent. Furthermore, an attempt will be made to develop a method ofapplication of MICP on a larger scale, analyze the depth of improvement andattempt at achieving a homogenous distribution of microbial treatment. Aims and Objectives: These problems are majorly associated with clayey soils andtherefore microbial calcite precipitation would be used to remediate theseproblems. Another problem discussed in this study would be the unevendistribution of calcium carbonate which is precipitated by bacterial action.

This results in an uneven strength achievement in the sample which is notfeasible in field application. Swelling of soil is defined as an increase in the volume ofsoil when it is exposed to moisture and a soil shrinks when it dries out. Shrink-swell nature of soil can cause differential settlement, ground heave andfoundation cracks. These type of soils are known as Expansive soils such asmontmorillonite and bentonite or soils which have a greater fraction of thesewill exhibit such behavior. Estimates of the total cost of damage due toswelling soils, one of the least publicized geologic hazards, were estimated at$2 to $7 billion in the U. S. in 1987 (Jones and Jones, 1987) and can beconsidered to be as much as twice today.

Under loads, all soils will settle, causing settlement ofstructures founded on or within them. Soil Settlement is defined as thedecrease in the volume of a soil mass, when a load is applied on it, due to theexpulsion of air and water from the voids. If the settlement is not kept to atolerable limit, the desired use of the structure may be impaired and thedesign life of the structure may be reduced. Structures may settle uniformly ornon-uniformly. The latter condition is called differential settlement and isoften the crucial design consideration (Budhu, M.

2006). Statement of Problem: Treating sandy soil using a microbially induced calciteprecipitation (MICP) process has been studied substantially in the past years. However, it is still a challenge to apply this approach to treat fine-grained. This research would explore the application of microbially induced calciteprecipitation (MICP) method, which is used to produce calcium carbonatecrystals in the soil matrix by urea hydrolysis using a urease-producingbacteria, to mitigate problems associated with fine-grained such as excessivesettlements, low bearing capacity and high shrink-swell potential.

In paststudies, MICP has been used to improve the properties of different soils withsuccessful results but background literature of the effects of MICP onfine-grained soils is still very limited and thus the objective of thisresearch is to provide research results related to that based on laboratoryscale testing. Current Geotechnical measures to improve soil propertiesthrough mechanical or chemical means provide satisfactory results but these arevery costly and are not environment-friendly. Therefore, soil stabilization bythe use of bacteria/microbes has recently emerged as a new method for alteringsoil properties.

Biomineralization has been proven to be environmentallyfriendly and cost-effective method of improving the properties of soilaccording to the need of the project. Bio-mineralization is the process wheremicro-organisms produce minerals mainly carbonate products that provide a basisto develop Bio-grout (Kumari 2017). Changes made by this precipitation to thesoil could improve the mechanical properties (strength, stiffness, cohesion, friction), decrease the permeability and modify the strength properties of soil(Whiffin, van Paassen, and Harkes 2007; DeJong et al. 2010). Ground Improvement deals with the modification of soilproperties so that it meets the performance and strength requirements of thestructure that is to be built upon it. The rapid shift of population towardsurban areas demand a great deal of construction and civil infrastructure toaccommodate the general public. This makes it compulsory to have improved soilconditions in order to avoid any financial or loss of life due to excessivedeformations in the soil.

Introduction: