

Geo-EnvironMeet 2025

GSP 359

Geoenvironmental Contamination and Waste Containment

Selected Papers from Geo-EnvironMeet 2025
Louisville, Kentucky • March 2–5, 2025

EDITED BY

Arvin Farid, Ph.D., P.E.
Kevin Foye, Ph.D., P.E.
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GEOTECHNICAL SPECIAL PUBLICATION NO. 359

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of the American Society of Civil Engineers

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Published by the American Society of Civil Engineers

Published by American Society of Civil Engineers
1801 Alexander Bell Drive
Reston, Virginia, 20191-4382
www.asce.org/publications | ascelibrary.org

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Errata: **Errata, if any, can be found at https://doi.org/10.1061/9780784485699**

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ISBN 978-0-7844-8569-9 (PDF)
Manufactured in the United States of America.

Preface

The Geotechnical Special Publication (GSP) presented here compiles papers from GeoenvironMeet 2025, the ASCE Geo-Institute's Geoenvironmental Engineering conference, held from March 2–5, 2025. This event marks nearly four decades since the inaugural geoenvironmental specialty conference. Held every six to eight years, it serves as a vital platform for addressing current issues in our field. The theme of the 2025 conference, "Sustainability and Resilience of the Geoenvironment in Facing a Changing Climate," underscores our commitment to tackling pressing challenges. GeoenvironMeet 2025 drew a diverse audience of geoenvironmental professionals, fostering invaluable exchanges amidst the backdrop of unprecedented industry challenges. While the conference featured numerous discussions and networking opportunities, this publication offers a focused selection of papers centered on Geoenvironmental Contamination and Waste Containment. These topics were chosen for their shared technical subdisciplines and relevance to the conference theme, reflecting ongoing and emerging developments in the field. The rigorous review process adhered to ASCE GSP standards, with each of the submitted manuscripts evaluated by two or more independent peer reviewers. Publication required consensus from at least two peer reviewers. We extend our heartfelt gratitude to the session chairs and reviewers whose dedication ensured the success of both the conference and these proceedings. It is our hope that this compilation serves as a valuable resource for the geoenvironmental engineering community in the years ahead.

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Suitability of Ureolytic Microbe in Limiting Desiccation-Induced Volumetric Shrinkage Strain of Lateritic Soil for Waste Containment Purposes

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ABSTRACT

Mitigation of desiccation shrinkage crack in compacted engineered landfill cover and liners is a common problem in geo-environmental studies. The attendant consequence of such shrinkage cracks is the outflow of toxic contaminant into ground water. The urgent need to reduce carbon footprint in the environment coupled with the unsustainable practice of using agro-bio-waste ashes and industrial waste as admixture component of compacted materials in engineered landfill; scientist over several decades have developed a green approach of stabilizing compacted soil for engineering purposes. This study is directed on the use of a novel approach in which inorganic compound (calcite) is precipitated through bioactivity of urease enzyme in microbiologically mediated fine-grained soil. Compacted specimen was prepared by mixing 25% [i.e., one-third of (0.5, 6, 12, 18, and 24) × 10^8 cells/mL] microbe's suspension densities and then flooded in three cycles with 75% (i.e., two-third 0.5 M) cementation solution. Specimen was extruded from the mould and volumetric shrinkage strain (VSS) was examined up to 30 days at room temperature of 25°C ± 2°C. The results showed that VSS reduced marginally with increased bacteria cell density on one hand and increased with moulding water content as well as compaction energy on the other hand. Bio-treated specimen for most part of the results recorded VSS less than 4% permissible criterion for compacted barrier in waste containment application. The calcite content determined by acid wash method increased with cell density and decreased from top to base of one-third sliced section for the various bacteria cells. The evaluation by scanning electron microscope (SEM) and X-ray diffraction (XRD) analysis confirmed the presence of calcite that mitigated desiccation shrinkage strain with non-visible crack on specimen. This study showed the potential of MICP in reducing desiccation shrinkage strain against flow of undesirous pollutants.

INTRODUCTION

With growing population and enlargement of cities, the utmost need of sustaining clean environment is a common problem especially with the improper ways of conserving and management of municipal solid waste (MSW) around the world. Containing municipal solid has been a daunting challenge because not much attention is given to its long-term effect and sustainability of the environment. The commonplace conventional method of municipal waste containment is through landfill, where clays of very low permeability is compacted and conveniently used as placement for covers and liners with target purpose of mitigating leakage and leaching of deleterious substance into groundwater (Kang & Shackelford 2010). Compacted barriers are most often than not exposed to seasonal variation of: (1) wet state with eventual

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swell characteristics of the barrier and (2) dry conditions with ensuing temperature rise thus leading to loss in moisture with resultant drying of the barrier. The result of such occurrence for a high clay content material employed as engineered placement in waste containment is linear volumetric change and diverse desiccation crack formations that propagate on surface and cut through its thick placement (Tang et al., 2020). Consequently, it inflicts considerable adverse effects on its sustainability for use as engineered barrier especially as the mechanical and hydraulic performances of the soil may be compromised. Cracks destabilise the engineering reliability and integrity of the clay soils as well as cause adverse effect on its allowable strength capacity (Wei et al., 2020). The network of wide-ranging cracks is a diffusion pathway for fluid transport and may rapidly increase the hydraulic conductivity at a much faster rate than the adjoining matrix (Li et al., 2016). The resultant effect includes colossal degradation of the soil and loss in durability, failure of foundation, embankment, dams and slopes, and other infrastructures etc.

The use of industrial and bio resource waste in ameliorating volumetric shrinkage cracks has yielded promising results in several studies (Osinubi & Eberemu, 2011). However, the unforeseen failure of engineered barrier caused by marginal shrinkage is the most frequent subject of distress. This has been reported to pose serious environmental implication where the shrinkage occurrences result to shear failure and crack propagation thus creating pathway for toxic fluid to migrate down to groundwater (El- Varank et al., 2011). Lime and cement have shown great potential in shrinkage reduction and suppression of crack emergence in soils (Al-Taie et al., 2016) but at high initial water content, lime and cement did not completely suppress the soil desiccation cracking. The irreversible environmental degradation caused by cement production among other several industrial processes are responsible for greenhouse gas emission (USEPA 2019). These challenges prompted researchers to develop innovative approaches for ameliorating shrinkage strain in clay soils.

Microbial-induced calcite precipitation (MICP) is an environmentally friendly and cost effective technique that has emerged as an alternative for geotechnical protocols in soil re-engineering. MICP has been used to improve the engineering behaviour of soil (Osinubi et al., 2018). The characteristic mechanisms of MICP are represented by equations (1) and (2) in which pH increases and thus makes the environment favourable for the precipitation of calcite.

$$CO(NH_2)_2 + 3H_2O \xrightarrow{Urease\ enzyme} 2NH_4^+ + HCO_3^- + OH^- \quad (1)$$

$$Ca^{2+} + HCO_3^- + OH^- \rightarrow CaCO_3 + H_2O \quad (2)$$

MICP has been successfully used in geotechnics and geo-environmental studies with promising laboratory outcomes that are continuously being upscaled in field applications. Osinubi et al. (2018) at lab scale, used ureolytic *Bacillus pumilus* to study the shrinkage strain of lateritic soil and established a compaction plane of VSS $\leq$ 4 % bio-treated optimally with 24 x 10^8 cells/ml. The potential of MICP in ameliorating desiccation crack in bentonite was reported by Guo et al. (2018). Similarly, MICP in bio-remediation of desiccation cracking in clay soil was reported by Liu et al. (2020). However, there is still inadequate quantitative data on VSS in bio-treated soils. This study focused on the use of *Bacillus megaterium*, which possesses active ureolytic enzymes capable of hydrolysing urea into calcite precipitate. The mechanism, which is centered in MICP technique, was aimed at evaluating its quantitative and qualitative (via microanalysis) effects on the VSS of compacted lateritic soil.

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MATERIALS AND METHODS

Soil, bacteria isolation and identification: Soil used in this study was sourced from Abagana ((6°10′00″ N and 7°0′0″ E), Anambra state, Nigeria. *Bacillus megaterium* microbe was isolated by enrichment culture techniques. In this study 10 g soil was suspended in 100 ml of distilled water and serial dilutions were made. 100 µL of the suspended soil solution of different dilutions were extracted and dispensed on the surface of HiChrome Bacillus Agar (HCBA) plates, which is a conscientious medium for isolating *B. megaterium*. The inoculated plates were incubated at 28 - 30^{o} C for 48 hours after which colonies were observed on the plates. Cells from colonies were aseptically scratched from the agar surface and suspended in sterile water and then observed under light microscope at x40 magnification. The isolated bacteria were characterised using series of microbiological and biochemical tests for confirmatory identification for *B. megaterium* (Sura and Hiremath, 2019).

Cementation and bacteria concentration: The choice of cementation concentration for volumetric shrinkage study was 0.5 M because this concentration had been established to give a robust result consistent with strength, which suggest an efficient urease activity from *B. megaterium* that triggered calcite availability for bio-cementation (Etim et al., 2022; Etim et al., 2023). The procedure for inoculation and preparation of the various bacterial cell concentration (cells/ml); (1.5, 6. 12, 18 and 24) x10^{8} cells/ml correlated to McFarland scale 0.5, 2, 4, 6 and 8MF, respectively (Etim et al., 2022).

Sample preparation and testing: Compacted specimens were prepared by first mixing one-third bacterial solution and then diffusing via surface percolation two-third 0.5 M cementation solution in three cycle at intervals of 6, 12, and 24 hours from each cycle. Volume obtained for pore volume of bacterial and cementation solutions are given in eqs. (3)-(5). Specimens were cautiously extruded from the moulds and placed on laboratory work bench at 25-30^{o} C temperature for volumetric shrinkage assessment using digital vernier caliper for dimensional recording. The shrinkage strain was monitored up to 30 days and computational difference between the initial volume (mould volume) and volume at 30 days is the shrinkage strain. The percentage shrinkage strain was computed/evaluated using eq. (6):

$$\mathrm{TPV} = \frac{\mathrm{OMCn}}{100} \times \text{Weight of soil sample} \tag{3}$$

$$\mathrm{VB}\left(\frac{1}{3\mathrm{rd}}\right) = \frac{25}{100} \times \mathrm{TPV} \tag{4}$$

$$\mathrm{VCS}\left(\frac{2}{3\mathrm{rd}}\right) = \frac{75}{100} \times \mathrm{TPV} \tag{5}$$

Where: OMCn= optimum moisture content of natural soil; TPV=Total pore volume; VB=volume of bacterial (ml) and VCS=volume of cementation solution

$$\text{Volume shrinkage strain, } VSS\ (\%) = \frac{V_{INITIAL} - V_{FINAL}}{V_{INITIAL}} \times 100 \tag{6}$$

On completion of shrinkage strain assessment, calcite content by acid wash method was determined from typical specimen compacted with British Standard light, BSL (or standard

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