

Geotechnical Frontiers 2025

GSP 367

Planning and Design for Future Generations

Selected Papers from Geotechnical Frontiers 2025
Louisville, Kentucky • March 2–5, 2025

Edited by
Melissa S. Beauregard, Ph.D., P.E., ENV SP
Aaron S. Budge, Ph.D., P.E., BC.GE

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PLANNING AND DESIGN FOR FUTURE GENERATIONS

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Melissa S. Beauregard, Ph.D., P.E., ENV SP
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Preface

This is the fifth volume of six Geotechnical Special Publications (GSPs) containing papers from the Geotechnical Frontiers 2025 Conference held in Louisville, Kentucky on March 2-5, 2025. Geotechnical Frontiers occurs every six years and is the merging of the Geosynthetics Conference and the annual Geo-Congress replacing both events in 2025. This popular event is where the geotechnical, civil and geo-professional communities unite to share developments in geotechnical engineering and technologies. The four-day event featured more than 200 exhibits, plus a comprehensive program of short courses, panel discussions, round table discussions, technical paper lectures and posters presented by top industry experts as well as the industry's most influential plenary speakers. Geotechnical Frontiers 2025 was organized by the Advanced Textile Association's Geosynthetic Materials Association and the American Society of Civil Engineer's Geo-Institute. The congress was attended by a wide range of geo-professionals including engineers, contractors, academicians, equipment manufacturers, geo-technologists, researchers, and service, material and tooling suppliers.

This publication culminates two years of effort by the technical planning committee whose focus has been to continue the success of the previous meetings in the Geotechnical Frontiers conference series. Many individuals are responsible for the content of this volume, all of whom served in the efforts to maintain the standard set by previous proceedings. An international call for papers and a rigorous peer review process yielded nearly 300 accepted technical papers that were presented in 37 technical and special sessions, in addition to invited keynote presentations. Papers were reviewed in accordance with ASCE GSP standards. Accordingly, each paper was subjected to technical review by two or more independent peer reviewers. Publication requires concurrence by at least two peer reviewers.

The Editors would like to express their appreciation for having been provided the opportunity to be a part of this Congress' organization along with their sincere thanks to the numerous session chairs and reviewers. We hope that these proceedings will be of use to the geotechnical engineering community for many years to come.

The Editors,

Melissa S. Beauregard, Ph.D., PE, ENV-SP, M.ASCE, U.S. Army Corps of Engineers

Aaron S. Budge, Ph.D., PE, BC.GE, M.ASCE, Minnesota State University, Mankato

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Application of Low-Carbon Cement with Recycled Concrete Aggregate Fines for Enhancing Sustainability and Durability of Transportation Infrastructure

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ABSTRACT

Transportation infrastructure such as pavements over weak subgrades suffer distress from cyclic environmental stressors that affect long-term serviceability and durability. Traditionally, Ordinary Portland Cement (OPC) is used to improve such soils to improve the resiliency of the pavement foundation systems. However, the production and use of OPCs are often associated with significant carbon dioxide emissions, which affects the sustainability goals of such applications. Using recycled concrete aggregate (RCA) fines (fRCA), a byproduct of the demolition of concrete structures, as a sustainable co-additive with low-carbon cement stabilizers could lead to the use of millions of tons of concrete waste that is produced annually and otherwise landfilled. Therefore, a research study was performed to evaluate the use of fRCA as a co-additive with low-carbon Portland limestone cement (PLC) stabilizer to treat problematic expansive soils through engineering studies. First, the dosage of cement and cement with fRCA was optimized using the unconfined compressive strength. Subsequently, laboratory studies, including wet-dry and freeze-thaw durability tests, were performed on untreated, PLC-treated, and PLC-fRCA-treated soil specimens after a target curing period. Ten percent PLC by dry weight of soil was determined as the required dosage for target performance, whereas 15% and 30% fRCA with a lower cement dosage were found to provide comparable performance as 10% PLC-treated soils. fRCA co-additive application was found to be effective in significantly improving both strength and durability after 7 days of curing. Overall, the application of fRCA with PLC was noted to be an eco-friendly solution to enhance the properties of problematic subgrades for effectively mitigating long-term serviceability and durability issues.

INTRODUCTION AND BACKGROUND

Climate change has emerged as one of the major challenges for transportation practitioners. Intense and recurring climate change events have rendered the maintenance and operation of a reliable and sound transportation infrastructure, which is the bedrock of the socio-economic growth of any country and region (Prus and Sikora 2021), increasingly challenging. Transportation infrastructure and the industry are contributors to roughly one quarter of global greenhouse gas (GHG) emissions, with the numbers still on the rise (Zhang and Fujimori 2020). Within the industry, road transportation accounts for over half of these emissions, with hefty

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contributions from system and infrastructure development, alike (McCollum et al. 2018). While there is an increased impetus towards reducing fossil fuel-related emissions through electrification and the development of green transportation, the existing research in sustainable transportation infrastructure development is still in its embryonic stage. Studies reported that the reduction of GHG and especially CO_2 emissions by half may be possible just by making use of present-day best practices and technology (Shiel 2009, Karlsson et al. 2020). Moreover, with multi-faceted strategies, including optimization of material use and recycling of construction materials, it may be possible to achieve near net-zero emissions within the next two decades (Karlsson et al. 2020). It is, therefore, imperative to devise new methodologies for the utilization of recycled materials in sustainable transportation infrastructure development.

Application of recycled materials from construction and demolition (C&D) waste is already underway for sustainable development and offsetting adverse climatic effects associated with transportation infrastructure construction and rehabilitation (Aslam et al. 2020, Bamigboye et al. 2021, Aytekin and Mardani-Aghabaglou 2022). However, there is a need for the identification of more avenues of consumption for recycled materials, as over 60% of global C&D waste is still landfilled (Ferdous et al. 2021). Recycling and utilization of C&D waste, such as recycled concrete aggregates (RCA), can save billions of dollars annually, not only from the conservation of natural resources but also from a reduction in costs associated with the disposal of solid waste. Past studies have indicated that sand-sized Recycled Concrete Aggregate Fines (fRCA) have a huge potential as a co-additive to traditional binding agents for soil stabilization due to their cementitious properties, which help in improving mechanical strength, durability and reducing shrink/swell potential and plasticity (Kianimehr et al. 2019, Tabatabaie Shourijeh et al. 2022). Therefore, the utilization of recycled byproducts in the chemical stabilization of problematic subgrade soils could serve as a huge opportunity for reducing the C&D wastes.

Weak subgrades are susceptible to moisture intrusion and are associated with multiple distresses, including rutting, leading to frequent maintenance and rehabilitation (Jang et al. 2022, Biswas et al. 2023). Calcium-based stabilizers such as Ordinary Portland Cement (OPC) are time-tested and the most widely used material to enhance durability and resilience through precipitation of several phases of Calcium Silicate Hydrate (C-S-H) and Calcium Aluminate Hydrate (C-A-H) binding gels (Chou et al. 2024). C-S-H and C-A-H are initially gelatinous products that significantly therefore improve soil strength and overall engineering performance (Barman and Dash 2022). As a result, chemically treated soils exhibit higher Unconfined Compressive Strength (UCS) as well as improved stiffness, workability, and a reduction in plasticity (Biswas et al. 2021). However, cement production has attracted a negative spotlight for its adverse environmental impacts, including depletion of non-renewable natural resources, excessive energy consumption and emission of significant quantities of GHG (Jang et al. 2024). Studies report that the cement industry is the second-largest contributor to industrial CO_2 emissions, accounting for roughly 25% of global industrial CO_2 emissions (Chen et al. 2022). These environmental costs associated with OPC production limit its application without adversely affecting the sustainability goals of road infrastructure projects. Therefore, it was hypothesized that using fRCA as a co-additive with low-carbon cement stabilizers for chemical stabilization of soil would accrue dual environmental and economic benefits by effective utilization of C&D waste while increasing the serviceability and durability of the transportation infrastructure system.

A research study was designed and performed to understand the benefits of using low-carbon Portland lime cement (PLC) with fRCA, to improve the long-term serviceability and durability

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