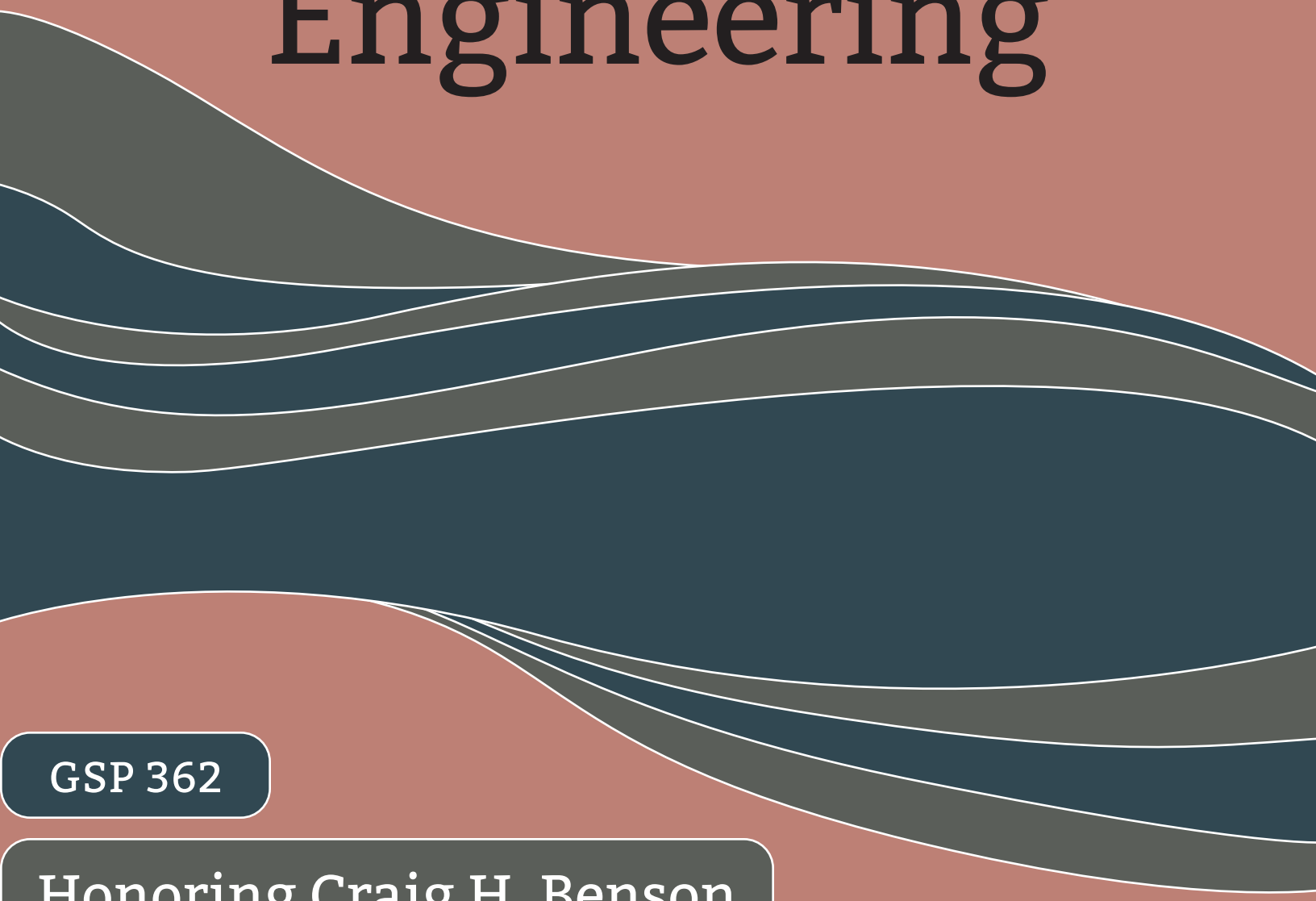
Geoenvironmental Engineering



GSP 362

Honoring Craig H. Benson

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

EDITED BY
Majdi A. Othman, Ph.D., P.E.
Nazli Yesiller, Ph.D.

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Preface

Honoring Professor Craig Benson in Geoenvironmental Engineering

This Geotechnical Special Publication (GSP) is dedicated to Professor Craig Benson, Ph.D., PE, BCGE, BCEE, NAE, in recognition of his outstanding contributions to the field of geoenvironmental engineering. Professor Benson's legacy as a legend in this field is marked by his extensive research and unwavering commitment to advancing our understanding of geoenvironmental processes. Professor Benson's impact on the discipline of geoenvironmental engineering spans several decades. His research has covered a wide range of critical topics including properties and performance of barriers and containment systems, water balance covers, municipal solid waste properties, contaminant migration through barrier systems, bioreactors, elevated temperature landfills, properties and containment of coal combustion residuals leachate, nuclear/radioactive waste containment, sustainability and sustainable infrastructure, beneficial reuse of waste materials, groundwater monitoring and remediation, performance of permeable reactive barriers, pavements, geosynthetics, etc. He championed the field of barrier systems.

Professor Benson received numerous awards that represent the highest honors attainable during his career as summarized in his biography. Similar to the breadth of his remarkable research endeavors, these awards span numerous organizations, agencies, and engineering topics. His career accomplishments include not only research advancements and academic leadership, but also substantial contributions to and leadership in professional service. He had and continues to have significant impacts in geoenvironmental engineering research, education, and service.

As the first and second Ph.D. advisees of Professor Benson (Majdi and Nazli, respectively), we have had longstanding collaborations with him and continue to learn from him. We are delighted to oversee the development of this GSP with our contributing authors to recognize Professor Benson. The GSP contains 16 papers that explore various aspects of geoenvironmental engineering. These papers were written by national and international professionals who studied under Professor Benson or collaborated with him over the last four decades. Topics covered include hydraulic properties of geosynthetic clay liners, beneficial use of waste materials, hydraulic performance of liners, diffusion of chemicals through liner systems, alternative cover systems, and effects of elevated temperature on liner components and systems.

We express our gratitude to Professor Craig Benson for his remarkable contributions to geoenvironmental engineering. Professor Benson's limitless enthusiasm in undertaking entirely new topics and making significant research advancements continues to inspire us all. The outstanding productivity of Professor Benson is unmatched in the field. His dedication to excellence, professionalism, mentorship, and integrity has left an indelible mark on our community. As we celebrate this GSP, we honor Professor Benson's legacy and recognize his enduring influence and impact on the field.

Majdi A. Othman and Nazli Yesiller, 2024

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Biography

Craig H. Benson, PH.D., P.E., BC.GE, BC.EE, NAE

Dr. Craig H. Benson is Wisconsin Distinguished Professor Emeritus at the University of Wisconsin-Madison and Dean of Engineering and Hamilton Professor Emeritus at the University of Virginia. Dr. Benson is a geoenvironmental engineer with expertise in waste management, waste containment systems, recycling and beneficial reuse, and sustainability. He served as Dean of Engineering at the University of Virginia and as a Department Chair and Director of Sustainability Research and Education at the University of Wisconsin-Madison. Dr. Benson has a BS from Lehigh University and the MSE and PhD from the University of Texas at Austin, all in Civil Engineering with an emphasis in geoenvironmental engineering. He is a member of the US National Academy of Engineering (NAE) and the National Academy of Inventors (NAI), as well as a Fellow in the American Association for the Advancement of Science (AAAS).

Dr. Benson has been conducting research related to protection of the environment for nearly four decades, with primary focus on environmental containment of wastes; beneficial use of industrial byproducts; and sustainable infrastructure. He is recognized as a foremost international authority on waste containment systems and is widely sought after for his expertise in design, operation, and performance assessment of waste disposal facilities. His expertise includes municipal solid waste (MSW), hazardous waste (HW), coal combustion residuals (CCR), mining and mineral processing wastes, low-level radioactive waste (LLW), mixed radioactive waste (MW), uranium mill tailings, and bauxite residuals. Dr. Benson leads the Landfill Partnership for the US Department of Energy's (DOE) Consortium for Risk Evaluation with Stakeholder Participation (CRESP), which provides research and technical support on environmental restoration for DOE. He was co-Principal Investigator on USEPA's Alternative Cover Assessment Program (ACAP) and authored the USEPA guidance on design, evaluation, construction, and monitoring of water balance covers (aka ET covers). Dr. Benson also developed the seminal guidance on the engineering properties of final covers for waste containment for the US Nuclear Regulatory Commission (Engineered Covers for Waste Containment: Changes in Engineering Properties & Implications for Long-Term Performance Assessment, NUREG/CR-7028). He served as co-Principal Investigator of the Bioreactor Partnership, an industry-government-academic partnership to develop principles for optimal operation of MSW landfills as bioreactors, and as co-Principal Investigator on the Elevated Temperatures Landfill (ETLF) project, which developed the key principles to manage and avoid highly elevated temperatures in MSW landfills. Dr. Benson is currently evaluating sustainable reuse of historically disposed coal combustion products, developing guidance on managing landfill gas and odor issues and quantifying the physical and social correspondence between landfill odors and odor complaints, and evaluating the efficacy of plastic waste recycling and upcycling. He frequently consults as an expert in waste containment systems and sustainability.

Dr. Benson's research experience involves laboratory studies, large-scale field experiments, and predictive modeling. He has published more than 300 refereed articles based on his research and has received numerous research awards, including the Karl Terzaghi Award, Ralph Peck Award, Huber Research Prize, Alfred Noble Prize, Croes Medal (twice), Middlebrooks Award (twice), Collingwood Prize, and Casagrande Award from the American Society of Civil Engineers and the Award of Merit, Ivan Johnson Award for Outstanding Achievement, and the Best Practical Paper Award (twice) from ASTM International. He is the 2024 Kappe Lecturer for the American

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Academy of Environmental Engineers and Scientists. Dr. Benson has a distinguished record of public service, having served as Editor-in-Chief of the Journal of Geotechnical and Geoenvironmental Engineering, President of the ASCE Geo- Institute (GI), Chair of the GI Geoenvironmental Committee, Vice Chair of the Executive Committee of ASTM Committee D18 on Soil and Rock, Chair of ASTM Committee D18.04 on Hydraulic Properties and Barriers, and Chair of Section 4 of the National Academy of Engineering.

Dr. Benson's research has been funded by a diverse set of sources including industry, local and state government, and federal agencies. His recent research has been funded primarily by the US Department of Energy through the Offices of Environmental Management and Legacy Management, the Nuclear Regulatory Commission, the Electric Power Research Institute, and the Environmental Research and Education Foundation. Early in his career, Dr. Benson was awarded the Presidential Young Investigator Award from the National Science Foundation and the Distinguished Young Faculty Award from the US Department of Energy to support his research.

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Hydration and Cation Exchange Behavior of Two Geosynthetic Clay Liners at an Elevated Temperature

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ABSTRACT

This investigation was conducted to analyze the cation exchange characteristics of a conventional GCL (granular bentonite) and a low-permeability GCL (granular with finer particle size and a small amount of polymer amendment) as a function of hydration time and conditioning fluid. The GCLs were conditioned using deionized water and 2, 50, and 200 mM $CaCl_2$ solutions under zero overburden stress for 1–32 days. Analysis was conducted at 40°C to represent exposure conditions in elevated-temperature containment applications. After conditioning, the bound cations and cation exchange capacity of the bentonites from the GCLs were determined. Higher swelling and higher moisture contents were observed for the conventional GCL than the low-permeability GCL. Swell index decreased with time, most pronounced and most rapidly in high-strength solutions. The exchange complex of the bentonite in the conventional GCL was altered somewhat less by exposure. The exchange complex for the two bentonite compositions demonstrated little variation during hydration and conditioning at the lower solution strengths. The cation exchange processes occurred rapidly with the majority of exchange completed for both GCLs in the first 1–8 days for high chemical strengths.

INTRODUCTION

Geosynthetic clay liners (GCLs) are multi-layered composite geosynthetic materials, which are used in containment and barrier applications for landfills, waste piles, leach pads, liquid waste ponds, tailings ponds, water conveyance canals, and various similar applications. Conventional GCLs used in North America consist of a layer of granular bentonite contained between two geotextile layers. Containment is primarily achieved by the bentonite layer that consists mainly of sodium montmorillonite (NRC 2007). This layer resists the transport of water and soluble contaminants. The chemical composition of the contained liquids or leachates, particularly the valence and also the concentration of the chemical constituents, significantly affect the ability of the GCL to perform as a barrier (Benson et al. 2011).

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