

A Study of Intermediate Geomaterials and Highly Erodible Rock

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Introduction

The primary objective of this research was to measure the erosion potential of Kansas shales at the surface and near the surface at a relatively shallow depth (2–3 ft). Considering the relationship between shale porosity and erodibility, this research also investigated the role of freeze-thaw cycles on shale porosity to predict a timeline of increasing shale erodibility by observing the influence of ambient air freeze-thaw cycles on porosity and pore structure change in shale. Understanding the factors that influence shale erosion is essential for effective asset management and implementation of best practices to prevent or minimize shale erosion. Additional research could result in more comprehensive knowledge of how freeze-thaw cycles and changes in pore structure interact and contribute to shale erosion, leading to more effective preventive measures. A brief literature review of shale erosion and relevant measurements to this research follows this introduction. A detailed methods section covers all standard and newly developed approaches to meet the objectives of this study, and the results and discussion sections offer insights into the findings. The report ends with conclusions and recommendations for implementation.

Project Description

Although substantial research on soil erodibility has recently been conducted at the federal (e.g., NCHRP 915) and state (e.g., K-TRAN: KSU-15-4; K-TRAN: KSU-18-5) levels, information regarding erosion characteristics of rock or intermediate geomaterials, such as shale, is extremely limited. Shale exposure on cut slopes or natural slopes leads to potential erosion. The objective of this research was to measure the erodibility of Kansas shales, specifically loose, weathered material collected from the surface of cut slopes and the denser, intact specimens below. Because erosion characteristics differ significantly, this study also developed a simple method to predict the time over which shale transitions from not erodible to highly erodible. Samples were collected from five sites that had exposed shale on a cut slope, and the loose material at the top of a Shelby tube was reconstituted for erosion testing and constant head testing to determine hydraulic conductivity.

The dense, intact material was tested in the Shelby tube without extrusion for erosion testing and hydraulic conductivity via the falling head permeability test. Falling head tests were performed before and after exposure to controlled freeze-thaw conditions to evaluate changes in permeability and subsequent porosity under Kansas-like environmental conditions—key indicators of erosion potential in shale. An empirical model was also developed to predict the number of freeze-thaw cycles needed for non-erodible intact shales to transform into highly erodible weathered material. The Kansas Department of Transportation could use this thorough analysis to improve decision-making and effective erosion mitigation strategies in similar geological settings. Results of this study also enhance understanding of shale erosion processes, with practical implications for infrastructure safety and environmental protection.

Project Results

Although weathered shales are commonly observed on natural or cut slopes in Kansas, this is not their original condition. Shales degrade gradually from an intact state to weathered sediments, resulting in sediment transport that must be managed. Therefore, accurate prediction of the onset of erosion for intact shales is essential. The simple, effective approach developed in this study used the falling head permeability test on a specimen within the Shelby tube to measure hydraulic conductivity of the samples. The Shelby tube with sample was then exposed to successive freeze-thaw cycles representative of temperatures in eastern Kansas, followed by another series of falling head tests. The results were used to calculate the Kansas shale porosity because an increase in porosity is associated with an increase in erodibility. This method showed how porosity changed under freeze-thaw cycles and established that each site was unique. For example, the porosity of the Toronto sample increased slowly, while the Salina sample increased more rapidly. The novelty of the falling head setup for shale samples in the Shelby tube was its ability to keep the shale samples intact, allowing for accurate measurement of initial porosity and tracking changes due to freeze-thaw cycles. The prediction results showed that the Toronto site would degrade the fastest and Salina the slowest. Two validation tests showed that the model trend is consistent with specimens outside the dataset. Additionally, three of the four degraded specimens, which were not used in model development, fall to the right of the model line, which is conservative.

Project Information

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