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Institute for Transportation

Use of Waste Quarry Fines as a Binding Material on Unpaved Roads

tech transfer summary

November 2021

RESEARCH PROJECT TITLE
Use of Waste Quarry Fines as a Binding Material on Unpaved Roads

SPONSORS
Iowa Highway Research Board
(IHRB Project TR-747)
Iowa Department of Transportation
(InTrans Project 18-656)

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The mission of the Institute for Transportation (InTrans) at Iowa State University is to save lives and improve economic vitality through discovery, research innovation, outreach, and the implementation of bold ideas.

This project investigated the effects of using five different types of quarry fines in granular roadway surfaces by conducting laboratory tests and constructing test sections in Boone and Jones counties in Iowa to determine the most cost-effective and best performing options.

Goal and Objectives

The goal of this project was to examine the performance of using quarry fines byproducts to stabilize granular roadway surfaces and to determine the most cost-effective quarry fines options providing the best serviceability. The objectives of this project were as follows:

- Determine the stiffness and strength of unpaved road materials blended with different sources and types of quarry fines
- Determine the performance of field test sections built with optimum quarry fines content
- Analyze the benefit-cost ratio and cost-effectiveness of these options

Problem Statement

Chemical stabilization is a common method to improve the binding of coarse aggregates in unpaved roads; however, chemical stabilization is typically not the most economical or easy to apply. Given the need for a serviceable granular road system, it is vital to find alternative materials and methods to stabilize unpaved roads in a sustainable, economical, and environmentally friendly way.

One of the potentially effective alternatives is the use of quarry fines, which have been successfully used to replace sands in concrete and asphalt mixtures. However, quarry fines have not yet been widely used in unpaved road systems, even though they have great potential to be used as a source of high quality and economical fines.

Clay Slurry test section in Boone County, June 2020

Background

Granular-surfaced (unpaved) roads are large portions of road systems in the US, and particularly in Iowa. The sustainability of unpaved roads is critical to the rural economy, given these roads provide access to rural areas and enable the transportation of agricultural products.

Unfortunately, heavy traffic loads and freeze-thaw cycles can cause extensive damage to unpaved roads, leading to material loss, surface erosion, rutting, and potholes. The rate of deterioration (or damage) is directly correlated to the quality of the granular aggregate materials used during the construction of an unpaved road. If the quality of coarse aggregates is low, the aggregates can crush under traffic loads, increasing the fines content in the aggregate matrix. In other cases, the quality of the aggregates may be high, but the aggregates float on the road surface due to a lack of adequate fines to bind the particles of the aggregate matrix together.

County engineers and their employees invest considerable effort in managing and maintaining granular roads. When maintenance and construction of granular roadways become costly, counties may spend a considerable portion of their budgets to purchase granular materials, excluding placement and maintenance, just to replace the materials lost during the service life of a granular road.

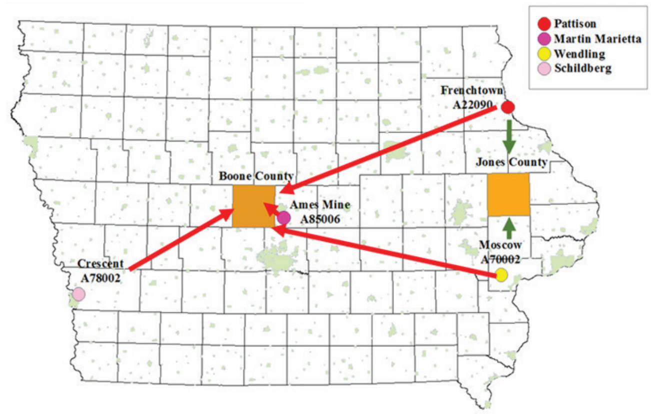
Project Description

Laboratory Tests

- The researchers tested quarry fines in the laboratory, as well as the existing surface aggregates and subgrade materials from the test sites, to evaluate their plasticity indices and shape characteristics. The tests helped to determine the optimal amounts of fines to mix with the existing surface aggregates at the test section locations.
- The laboratory tests included sieve and hydrometer analyses, Atterberg limits, compaction, miniature vane (mini-vane) shear, pocket penetrometer, setting time, slaking, X-ray fluorescence (XRF), and California bearing ratio (CBR).

Test Section Construction

- The research team selected 5 sources of quarry fines from among 19 quarries across Iowa and those that had the highest plasticity from the laboratory tests to build 4 test sections in Boone County, Iowa, and 3 test sections in Jones County, Iowa.
- The team selected Clay Slurry, Limestone, Moscow, Ames Mine, and Crescent fines to use in test section construction.



Locations of the quarries and test sections in this project

Quarry fines used in test section construction

- After discussions with county engineers, the team selected the two sites given they are among the most populated roads with relatively stiff subbase and subgrade layers and suffer from heavy traffic loads and freeze-thaw effects during the winter and spring seasons.
- The seven test sections were constructed in late October and early November 2019, first in Jones County and then in Boone County. A control section, consisting of existing surface aggregates without quarry fines in each county, was also considered as a base case.

Field Tests

- The team performed field tests and captured digital images of the sites shortly after construction in November 2019 and then again after the freeze-thaw season in March 2020, May 2020, and/or June 2020, depending on the test, to monitor and evaluate the performance of the test sections and control sections.
- The field tests performed included falling weight deflectometer (FWD), lightweight deflectometer (LWD), dynamic cone penetrometer (DCP), nuclear gauge density/moisture, international roughness index (IRI), and dustometer to determine the stiffness, strength, in situ density, moisture content, roughness, and dust emission, respectively, of the surface materials.
- The team also collected samples from the sections to conduct sieve analysis and hydrometer tests to evaluate the changes in gradation, fines content, and gravel-to-sand (G/S) ratio, as well as total breakage of the surface materials over time.

Benefit-Cost Analysis

- The team conducted several benefit-cost analyses based on construction costs, estimated cumulative costs, and observed performance measures, including gravel loss, total breakage, fines content, G/S ratio, surface stiffness, surface CBR, dust emission, and surface roughness, to determine the most cost-effective quarry fines options.
- The team considered a variety of maintenance scenarios for renewing 2 in. of the surface materials whenever maintenance is required and based on the relative performance of the sections for 20, 30, 40, and 50 years of service life.
- The team calculated a benefit-cost ratio for each performance measure while considering the different service lives and maintenance frequencies, and then calculated an overall performance-based benefit-cost ratio by assigning weighting factors to the individual values based on the relative importance of each of the measures.

Key Findings

- The laboratory and field test results showed that stabilization of the existing surface aggregates with quarry fines could improve the performance of the sections by reducing gravel loss, total breakage, and dust emission, and by improving the mechanical properties of the surface layer, including stiffness and shear strength.
- Over time, an increase in fines content and decrease in gravel content were observed for all sections. However, the stabilized sections had better performance than the control sections regarding these two factors in both counties.
- The Moscow and Limestone sections in Jones County and the Moscow and Ames Mine sections in Boone County had the best overall performance and cost-efficiency.
- The Clay Slurry sections in both counties had the highest construction costs, and, with the exception of dust emission, performance was similar to that of the other sections in both counties. The increased construction costs made the Clay Slurry a less cost-effective option for both counties.

Implementation Readiness and Benefits

The project showed that mixing quarry fines with surface aggregate materials could be an efficient way to reduce costs due to the binding provided by such materials, which can help reduce gravel and thickness loss. Thus, use of quarry fines on unpaved roads could be a more economical and environmentally friendly alternative to chemical stabilization.

It would be useful to investigate the effectiveness of mixing additional types of quarry fines with surface aggregates in more locations, over more extended periods, and with different subgrade and subbase, weather, and traffic conditions. In doing so, stabilization with quarry fines from adjacent quarries and in more counties could capture a more precise view of the efficiency of implementing quarry fines as stabilizers.

Recommendations for Future Research

Specific research activities could include the following:

- Build new test sections in different regions to examine a broader range of local quarry materials, traffic loads, and subgrade conditions
- Find quarry fines with higher plasticity and cementitious behaviors from other quarries and around new site locations to reduce the hauling costs
- Mix quarry fines with recycled materials instead of virgin aggregates alone to reduce construction costs and improve sustainability
- Investigate the binding effect of subgrade and subbase materials stabilized by quarry fines to help reduce freeze-thaw effects on the subsurface layers
- Perform additional benefit-cost analysis studies on construction and maintenance of low-volume roads with different materials, stabilization methods, or other conditions
- Investigate the effects of maintenance costs for projects related to stabilization with quarry fines and over longer durations (e.g., two to five years)
- Develop statistical models to predict the performance of road layers based on the available data from granular road projects