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RESEARCH PROJECT TITLE
Low-Cost Rural Surface Alternatives Phase III: Demonstration Project

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Low-Cost Rural Surface Alternatives Phase III: Demonstration Project

tech transfer summary

This Phase III demonstration project helped identify economical and effective granular roadway stabilization methods that Iowa counties can implement with readily available equipment.

Project Goals

The primary goal of this project was to identify practical and effective stabilization methods for granular roadways in Iowa by testing the performance and evaluating the construction and maintenance costs of several stabilization methods, which were selected in consultation with the project technical advisory committee (TAC).

Additional goals of this Phase III demonstration project were to distribute the test sections in four counties across Iowa to cover a wider range of aggregate sources, subgrade soil types, and weather conditions than the previous Phase II demonstration project and identify methods that counties can implement using their own staff and equipment or equipment that can easily be rented.

Problem Statement

Granular-surfaced roads throughout Iowa are subjected to large numbers of freeze-thaw cycles and significant traffic loads from heavy agricultural machinery. Frost boils, potholes, and rutting occur on granular road surfaces after each freeze-thaw cycle season. Under these conditions, granular roadways deteriorate significantly and can consume significant portions of county roadway budgets for maintenance and rehabilitation.

Most of the damage occurs in the spring thaw period, when liquid water cannot drain efficiently and becomes trapped above the zone of frozen soil, causing the saturated unbound granular materials to lose strength. Moreover, heavy agricultural traffic loads in spring and low-strength aggregate sources in some regions of Iowa further compound the problems, leading some county engineers to post load restrictions or frost embargos.

Rutting and frost boils in Howard County in spring 2019

Many Iowa counties spend significant portions of their roadway budgets on granular-road maintenance and rehabilitation

Background

The approaches typically used by county engineers to deal with moisture-related damage include temporarily spreading rock on the affected areas, lowering or improving drainage ditches, tiling, bridging the areas with stone and geosynthetic covered by a top course of aggregate or gravel, coring boreholes and filling them with calcium chloride to melt lenses and provide drainage, and regrading the crown to a slope of 4% to 6% to maximize spring drainage. However, most of these maintenance solutions are aimed at dealing with frost boils after they occur.

To prevent or minimize freeze-thaw damage in the first place, literature on a range of potential stabilization technologies, including chemical (e.g., fly ash, polymers), mechanical (e.g., geogrids, geocomposites), and biological methods (e.g., lignin, enzymes, organic liquids), was studied in the previous Iowa Highway Research Board (IHRB) Phase I project.

In the previous Phase II IHRB Low-Cost Rural Surface Alternatives: Demonstration Project (Li et al. 2015), several of the identified stabilization methods from Phase I were implemented to improve the performance and minimize freeze-thaw damage of granular-surfaced roads. Test sections were constructed over a two-mile stretch of heavily traveled roadway that required frequent maintenance, and the performance of test and control sections was assessed via extensive field testing over a period of two years. Several of the stabilization methods were demonstrated to greatly improve performance and reduce maintenance costs over the duration of the Phase II project.

Regrading a newly placed granular-roadway surface layer of steel slag

Objectives

This Phase III project was a continued investigation for which additional chemical and mechanical stabilization methods were studied. The specific objectives of this research project were as follows:

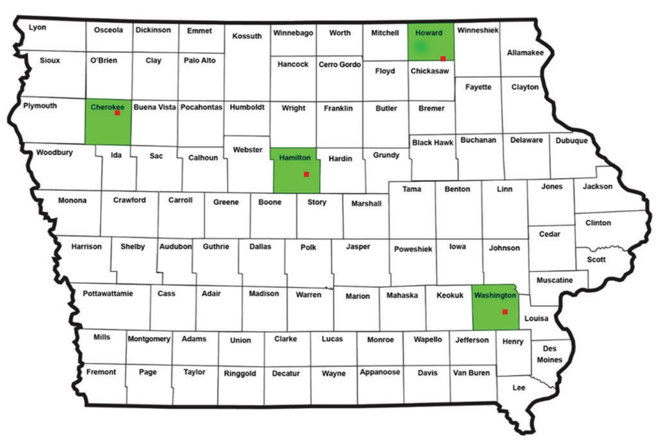
- Construct mechanically and chemically stabilized test sections in four counties across Iowa
- Perform extensive laboratory and field tests to characterize the materials and assess the field performance and maintenance requirements of the various stabilization methods after seasonal freeze-thaw cycles
- Assess the construction and maintenance costs and identify effective and economical stabilization methods for the soil and climate conditions of Iowa
- Translate the research results into practice

Research Description

For this study, 31 test sections were constructed and monitored in four counties across Iowa. The selected test sites were as follows:

- Vail Avenue between 300th Street and 310th Street in Hamilton County
- Old 21 Road between 480th Street and 490th Street in Cherokee County
- 100th Street between Pine Avenue and Quail Avenue in Howard County
- 260th Street between Palm Avenue and Quince Avenue in Washington County

All four locations had similar annual average daily traffic (AADT) levels, which were estimated at 70 vehicles per day (vpd) for Hamilton County, 100 vpd for Cherokee County (increasing to 160 vpd for the aggregate columns section), 90 vpd for Washington County, and 110 vpd for Howard County.



Locations of the test sites in Hamilton, Cherokee, Howard, and Washington counties

These test sites were also selected because they exhibited frost boil problems and experienced high volumes of heavy truck and concentrated animal feeding operation traffic.

In consultation with the TAC, the following eight types of mechanically stabilized test sections were selected for construction in Howard and Cherokee counties:

1. Aggregate columns
2. Optimized gradation with clay slurry (OGCS)
3. Ground tire rubber mixed at 20% by volume in a 2 in. base layer of aggregate and covered by a 2 in. surface layer of aggregate (in Howard County only)
4. Recycled asphalt pavement (RAP) mixed at 50% by volume with aggregates
5. 2 in. Harsco slag surface over 2 in. existing aggregate base
6. 2 in. Phoenix slag surface over 2 in. existing aggregate base
7. 4 in. Harsco slag surface over subgrade
8. 4 in. Phoenix slag surface over subgrade

The following five types of chemically stabilized test sections were constructed in Washington and Hamilton counties:

1. Cement-treated subgrade (in Washington County only)
2. Cement-treated aggregate surface course (in Washington County only)
3. BASE ONE (a silicic acid, sodium salt, concentrated liquid stabilizer)
4. EMC SQUARED 1000 (a neutral pH, non-ionic, concentrated liquid stabilizer)
5. Claycrete (an ionic, concentrated liquid stabilizer)

Based on the favorable performance of the mechanical aggregate columns and OGCS methods in the Phase II project, they were also used to construct additional test sections in Washington and Hamilton counties. This enabled additional data on the performance of these two methods to be obtained for the full range of material and weather types encountered in the four counties.

The performance of the stabilized test sections was evaluated over a period of two years through extensive field and laboratory tests, as well as digital image surveys and surface condition rating reports, which were completed by the grader operators.

The field tests included falling weight deflectometer (FWD), lightweight deflectometer (LWD), dynamic cone penetrometer (DCP), and nuclear density gauge (NDG) tests. Samples of the surfacing materials were collected on several occasions before and after each winter and were evaluated through laboratory tests including sieve analysis, Atterberg limits, compaction, shear strength, and durability tests.

The construction costs and maintenance costs were tracked with the assistance of the county engineers, and an economic analysis was conducted to compare the relative cost effectiveness of the different stabilization methods.

Tanker used for spreading clay slurry in Cherokee County

Consistency of clay slurry and aggregate at beginning of blade mixing process in Washington County

Clay slurry and aggregate near the end of the blade mixing process in Washington County

Consistency of clay slurry and aggregate near the end of blade mixing process in Washington County

Key Findings and Conclusions

Except for the cement-stabilized subgrade method, which had the highest construction cost due to the equipment and materials required, the other stabilization methods examined were relatively economical as they required materials and equipment that are readily obtainable by counties, and they used conventional construction methods.

Overall, the Claycrete, EMC SQUARED, and BASE ONE sections had the lowest construction plus maintenance costs, followed by the average costs of the OGCS and aggregate columns sections, and then the 4 in. cement-treated surface course. The RAP sections had relatively high materials cost with little improvement in performance, while the four types of slag sections had relatively higher construction costs, primarily due to the large hauling costs involved.

The laboratory and field tests revealed that many of the test sections remained stabilized long after construction, but their performance varied considerably. Additionally, the ground tire rubber section failed because the surface course was too unstable immediately after construction.

Overall observations and conclusions based on the results of this project are as follows:

The OGCS sections generally exhibited good strength performance based on DCP-California bearing ratio (-CBR) correlations and good surface course elastic modulus values from LWD and FWD tests. Based on the improved performance and relatively economical construction and maintenance costs, the OGCS method is considered cost-effective.

The RAP sections showed marginal improvements in strength over that of the control sections and no improvement in modulus from LWD and FWD tests. Considering the lack of performance and the rising cost of RAP due to its increasing demand for pavement construction, it is not considered to be a cost-effective stabilization method at this time.

All of the steel slag sections showed good initial strength and stiffness after construction, but strength decreased significantly over the two-year period of the study. Due to the high hauling costs involved, this method may only be economical for counties located near slag sources.

The aggregate columns sections did not perform better than the control sections in this Phase III study. The columns used in this study were larger 12 in. diameter by 7 ft deep ones, whereas, smaller 8 in. diameter by 6 ft deep columns performed very well in the previous Phase II study.

The 12 in. cement-treated subgrade section showed extraordinary improvements in strength and stiffness. However, it was not economical compared to the other stabilization methods examined.

Spraying compaction water over Phoenix slag in Howard County

Drilling hole with skid steer-mounted power auger for aggregate columns installation, which showed relatively poor performance for this project despite good performance of smaller columns in previous projects

The 4 in. cement-treated surface section showed excellent strength performance and was relatively economical to construct. However, it did exhibit several potholes requiring application of surfacing aggregates after two years. For this method, engineers need to factor in the material and hauling costs for portland cement, as well as the cost to rent a milling attachment if they do not already own one.

The three concentrated liquid stabilizers (BASE ONE, EMC SQUARED, and Claycrete) had similar construction costs that were among the most economical of all stabilization methods examined. These methods all showed good performance in Hamilton County, but did not perform as well in Washington County.

Implementation Readiness, Benefits, and Recommendations for Further Research and Practice

Beneficial stabilization methods should provide good performance at acceptable costs. In this study, the steel slag test sections showed good performance in the beginning but exhibited reduced freeze-thaw resistance over time and had high hauling costs. The 12 in. cement-treated subgrade method performed well but does not meet the overall project goal, which was to identify economical and effective stabilization methods that counties can implement by themselves with readily available equipment.

Other than the cement-stabilized subgrade method, which requires use of a large powder spreader and road reclaimer, the necessary materials and equipment for the various stabilization methods are readily obtainable by counties and utilize conventional granular roadway construction methods at relatively low cost.

Based on the test results and cost summary presented in the final report, the most suitable stabilization methods meeting the project goals are the 4 in. cement-treated surface and OGCS methods, as well as the BASE ONE, EMC SQUARED, and Claycrete liquid stabilizers.

For the concentrated liquid stabilizers, care should be taken to closely follow the manufacturer's recommended construction methods with particular attention to the amount and type of subgrade soils incorporated and the amount of compaction water added.

The 4 in. cement-treated surface method had a relatively low cost and provided good performance against freeze-thaw damage. Given this method was only applied in Washington County, further study is recommended to determine whether it can be widely applied with similar success in other regions of Iowa. To reduce potholes and make the surface easier to maintain, additional materials, such as cement slag, lime kiln dust, or fly ash, could be incorporated to increase ductility.

The OGCS method improved the DCP-CBR strength values as well as the stiffnesses, and after the slurry was applied by the tanker trucks, the method was easily implemented by county secondary roads departments with existing equipment and crews.

The company that processes the clay slurry now sells the product in the form of a pre-treated and dried aggregate containing the clay binder, which should reduce construction costs related to hauling the large amounts of water contained in the slurry. However, additional studies are recommended to develop construction methods and measure the performance of such aggregates pre-treated with the clay binder.

The sections treated with the Claycrete, BASE ONE, and EMC SQUARED liquid stabilizers in Washington County did not perform as well as those in Hamilton County. Since these three chemical stabilization products showed good performance in Hamilton County at relatively low cost, further studies are recommended to examine how their effectiveness can be improved for the typical freeze-thaw conditions in Iowa.

The influence of the type and gradation of both surfacing aggregates and subgrade soils should also be studied to better understand why the three liquid stabilizers performed better in Hamilton County than in Washington County. When building new test sections, construction quality control measures should be used to ensure the best performance of liquid stabilizers on future research projects.

For example, field measurement of moisture content during construction would not only help ensure that the materials are compacted close to their optimum moisture content (OMC) as determined by laboratory compaction tests but also indicate when materials are wet of optimum due to precipitation and therefore require aeration by blading or mixing. Additionally, field soil density tests, such as sand cone, rubber balloon, or nuclear gauge tests, could be performed during construction to help determine if compaction is adequate and to provide better information for making field adjustments.

Finally, the influence of moisture content on the thermo-hydro mechanics of aggregate columns should be studied to understand their relatively poor performance in this project despite good performance of smaller columns in previous projects. The moisture content is related to the regional subgrade and weather conditions and should be carefully evaluated including consideration of the local topography as well as nearby creeks and other water sources such as culverts or drainage pipes beneath the sections. All of these factors may contribute to the moisture content and therefore the final performance of a test section.

Reference

Li, C., J. Ashlock, D. White, and P. Vennapusa. 2015. *Low-Cost Rural Surface Alternatives: Demonstration Project*. Institute for Transportation, Iowa State University, Ames, IA. https://intrans.iastate.edu/app/uploads/2018/03/low-cost_rural_surface_alternatives_demo_w_cvr.pdf.