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Construction and performance of chemically and mechanically stabilized granular road test sections.

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ABSTACT

Granular-surfaced roadways in Iowa rural area frequently experience damage and degradation from the effect of rainfall, flooding, seasonal freeze-thaw cycles, heavy agricultural machinery and steadily increasing traffic loads. Rutting, potholes and frost boil problems appeared usually and leading these granular roads to unpassable. As a result, many countries have to close damaged roads for repairs and spend significant portions of their budgets on maintenance and rehabilitation of granular roads. Several stabilization methods for granular roads were examined for improving the performance and minimizing damages in Iowa by the previous completed Phase II Iowa Highway Research Board Project TR-664 "Low-Cost Rural Surface Alternatives: Demonstration Project". To investigate additional stabilization methods suitable for use in Iowa, six mechanical and five chemical stabilization methods employing different types of virgin and recycled materials were examined and used to build test sections in this study. Comprehensive construction procedures were developed and 31 test sections were built in four counties distributed geographically around the state of Iowa in August through October 2018. Extensive laboratory, field tests, and photographic surveys were performed prior to construction, as well as after construction to monitor the performance of the demonstration sections. The shear strength and elastic modulus of granular roads surface course were obviously improved by one of the chemical methods, cement treated surface, and three of the mechanical methods, optimized gradation with clay slurry and two slag stabilization methods. The composite elastic modulus was improved by two cement treated methods and two mechanically methods, optimize gradation with clay slurry and aggregate columns. Several equipment was also found that can shorten the construction time and stabilize the soil more efficiently.

1. INTRODUCTION

Granular-surfaced roads in seasonally cold regions frequently experience damage and degradation from the effect of rainfall, flooding, seasonal freeze thaw cycles, heavy agricultural machinery and steadily increasing traffic loads, which leads to extensive damage such as frost heave, frost boils, thaw weakening, rutting and potholes. As a result, many counties spend significant portions of their budget on repair and maintenance of granular roads. Some county engineers have to post load restrictions or frost embargos to reduce heavy agricultural traffic loads in spring, since the saturated unbound granular materials loose strength when liquid water cannot drain efficiently and becomes trapped above the zone of frozen soils in the crucial spring thawing period. In some regions, low-strength of locally available aggregates further compound the problems.

In the previous Phase I Iowa Highway Research Board (IHRB) Project TR-632 “LowCost Rural Surface Alternatives” (White et al. 2013), an extensive analysis of existing literature on the topic of the construction and performance of granular-surfaced roads with respect to freeze-thaw damage and resistance were conducted. Several of the stabilization methods and technologies identified in the study were implemented for improving the performance and minimizing freeze-thaw damage of granular roads in the subsequent Phase II IHRB Project TR664 “Low-Cost Rural Surface Alternatives: Demonstration Project” (Li et al. 2015). Seventeen test sections and five control sections were constructed in Hamilton County on a heavily traveled two-mile section of granular-surfaced road that required frequent maintenance during previous thawing periods. Construction procedures and costs for the demonstration sections were documented and the maintenance requirements were tabulated through two seasonal freeze-thaw periods. The most effective and economical methods suitable for the soil and climate conditions in the Iowa region were identified.

For the currently ongoing IHRB Project TR-721 “Low-Cost Rural Surface Alternative Phase III: Demonstration Project” detailed in this thesis, 31 addition demonstration sections were built in four counties distributed geographically around the state of Iowa utilizing 6 mechanical and 5 chemical stabilization methods and employing different types of virgin and recycled materials. The mechanically stabilized demonstration sections were constructed in Howard County (9 sections total) and Cherokee County (8 sections total), including one control section in each county. The following 8 types of mechanically stabilized sections were constructed in these two counties:

1. aggregate columns
2. optimized gradation with clay slurry
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. thick slag surface overlying 2-in. existing aggregate base (Source #1)
6. 2-in. thick slag surface overlying 2-in. existing aggregate base (Source #2)
7. 4-in. thick slag surface (Source #1)
8. 4-in. thick slag surface (Source #2)

The feasibility of the aggregate column method was verified in the previous IHRB project TR-664, and it had the lowest initial cost of all methods examined, while improving the freeze-thaw performance of the roadway by reducing the occurrence of frost-boils. A new pattern with a denser grid of columns was applied in this study, to help minimize rutting which was observed near the shoulder in the previous study (Li et al. 2015).

In the previous IHRB Project TR-685 "Feasibility of Granular Road and Shoulder Recycling" (Li et al. 2018), the in-situ granular surface materials were recycled by blending them with virgin materials in optimum proportions, and recommended construction procedures were developed. According to the study, a proper gradation of surface materials along with plastic fines for binding can greatly improve the strength and longevity of roadway surfaces, while helping to minimize freeze-thaw damage. The Microsoft Excel-based program developed by Li and Ashlock (2018) in the TR-685 project was utilized in the present study to calculate the quantity of fresh quarry materials needed for mixing with existing surface materials to approach the optimum design gradations. To help bind the coarse aggregates and reduce material loss, the previous study also recommended mixing plastic fines into the top 50.8 mm to 76.2 mm (2 to 3 in.) of the roadway. The goal was to form a surface crust underlain by a cleaner, load-bearing aggregate layer, because the fines can greatly reduce shear strength of granular materials under prolonged wet conditions (Li et al. 2018). The theory is that when the top few inches of the surface course is mixed with clay, the fines perform the desired function of binding the larger aggregates to reduce material loss while preserving the shear strength of the deeper aggregates in the lower part of the surface course. However, the previous study employed bags of powdered bentonite to achieve the desired plasticity, which was labor intensive to incorporate and the bentonite content was significantly reduced after one freeze-thaw season. In this study, a newly available clay slurry from Pattison Sand Company was applied to the optimized gradation mixture instead of using bentonite or local clays.

Method Used:

Soil Index Properties

To determine soil index properties and classification of the geomaterials, particle-size distributions (gradations) were determined by sieve and hydrometer tests, liquid limit tests, and plastic limit tests. The soils were then classified according to American Society for Testing and Materials (ASTM) standard practice for the Unified Soil Classification System (USCS).

Compaction Behavior

The relationships between moisture content and dry unit weight of geomaterials were determined by conducting Standard Proctor compaction test in accordance with ASTM D698 – 12e2 "Standard Test Methods for Laboratory Compaction Characteristics of Soil Using Standard Effort (12,400 ft-lbf/ft3 (600 kN-m/m3))." To prepare fine-grained geomaterials to predetermined moisture contents, the Hobart mixer shown in Figure 4 was used. According to the material gradation, the mold size was selected following the specifications of ASTM D698. For soils containing oversize particles ASTM D4718/D4718M – 15 “Standard Practice for Correction of Unit Weight and Water Content for Soils Containing Oversize Particles” was used.

Shear Strength Tests

To evaluate and compare the effects of the clay fraction on the undrained shear strength properties of compacted geomaterials, unconfined compressive strength (UCS) and California bearing ratio (CBR) tests were performed. These tests are detailed in the following sections.

Durability

The slaking test is not a standard geotechnical experimental test, but rather a test for soil quality to indicate the stability of soil aggregates and resistance to erosion. Slaking is the breakdown of a lump of soil into smaller fragments upon wetting (McMullen 2000). Slaking tests were also conducted in IHRB Project TR-582 to evaluate long-term moisture susceptibility (Gopalakrishnan et al. 2010). In the present study, the 2-by-2 samples were also used for slaking tests, as shown in Figure 7. To perform the slaking tests, specimens of compacted minus No. 40 material were placed on a No. 4 sieve and soaked in tap water at room temperature.

2. RESULT AND DISCUSSION

2.1. In-situ Tests and Laboratory Tests Conducted Prior to Construction:

Prior field and laboratory tests were conducted to evaluate the in-situ soil and existing granular aggregate materials conditions at construction sites. Dynamic cone penetrometer (DCP) and light weight deflectometer (LWD) tests were performed to determine the penetration resistance profiles and composite elastic modulus of the existing roadways. Unconfined compressive strength (UCS), California bearing ratio (CBR), and slaking tests were performed to evaluate the impact of mixing locally available granular aggregate materials with clay slurry.

2.2. Results of DCP and LWD Tests:

The DCP and LWD tests were performed on all four sites on August, 2017. For each site, five DCP tests were conducted to evaluate the in-situ DCP related CBR of surface course and the underlying subgrade to a depth of about 900 mm (36 in.). The nominal thickness of the surface course in four sites was also estimated based on the DCP data. The pre-construction DCP results for Cherokee County and Howard County, which only include mechanical stabilization methods. The pre-construction DCP results of chemically stabilized counties, Washington County and Hamilton County. In Cherokee county, there was no obvious interface between surface course and subgrade since the soil was gradually changing to subgrade form course aggregate. In Howard County, the surface course thickness was calculated to be in the range of 50.8 mm to 101.6 mm (2.0 to 4.0 in).

3. CONCLUSION

All of the demonstration sections can be stabilized well and have good quality surfaces immediately after construction except the section utilized ground tire rubber method. Only 20 % ground tire rubber by volume was incorporated in the bottom 50.8 mm (2 in.) of a 101.6 mm (4 in.) thick surface course, but the ground tire rubber cannot stay in the bottom part results a soft, unstable surface that had to be removed. Applying clay slurry to ground tire rubber section was tried to bind particles, but it did not farm up after couple days.

The mechanical stabilization methods can be easily implemented by county secondary roads departments with available equipment and crews. The clay slurry results in a rather wet construction procedure, but the surface is passable by the end of construction. Disk plow harrow was used in Cherokee County for RAP section, it could allow county engineers efficiently mix surface course materials to uniform. The auger used for aggregate columns installation was always pasted on sticky clay after every drill. Manually cleaning the auger was time consuming but necessary after each drilling in some counties, and resulted installation process slowly. The clean aggregate fill has to be done immediately after the hole was drilled in case collapse, because to the fully saturated subgrade was soft.

Chemical stabilization methods require using RoadHog reclaimer to mix the cement treated surface course and liquid stabilizers effectively and uniformly. The existing of boulders and cobbles in top 152.4 mm (6 in.) could slow the work and cause damage to the bay door hinges.

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