Executive Summary, Research Readiness Level Assessment, and Technology Transfer

Gravel Road Performance Enhancements

Research Objectives

The overall goal of this project is to develop, through rigorous laboratory tests, new guidelines for a wide range of Nebraska-specific gravel road materials and to develop a modeling tool to determine the optimized gradation to achieve a target gradation and plasticity and binding capacity, respectively, which will maximize the performance and durability of gravel roads. To accomplish this goal, the research team has established the following objectives:

1. Identify and review the current state of the practice for other state DOTs and industry (Midwest states in particular) via reports and an online survey/interview on the topic of gradation and stabilization guidelines used for gravel roads.
2. Conduct a thorough laboratory study to quantify the effects of variations in gradation and plasticity on the geomechanical characteristics of gravel road geomaterials.
3. Identify the optimum gradation and plasticity ranges that will lead to increased strength and reduced damage from freezing-thawing cycles.
4. Develop an optimized gradation modeling tool that uses laboratory index properties of aggregates to determine relative proportions of fresh aggregate, fines, and stabilizer materials to be added to achieve an optimized target gradation and plasticity.

Research Benefits

The maintenance of gravel roads can consume significant portions of county budgets. Improving the longevity of granular roads by optimizing the performance of surfacing materials will reduce the consumption of virgin aggregate required for surfacing, as well as the frequency of required maintenance. As a result, counties will consume fewer aggregates which are finite natural resources, thus leaving more funds to devote to other pressing social, economic, and environmental needs. The project will generate more broadly applicable stabilization techniques, which county engineers can use to achieve such improved longevity of gravel roads.

Principal Investigator

Bora Cetin (P.I.)
Michigan State University

NDOT Lead TAC Member

Bruce Barrett, PE, Pavement Design

Background

Approximately 72,134 miles of gravel roads (39 miles state highway) exist in the 194,938-mile road network in the State of Nebraska. Two of the most common distresses for gravel roads are rutting and wash boarding. Rutting often occurs when the moisture content of gravel roads is high. These distresses are recurring across the state. The sustainability of granular roadways is very important to the rural economy since these roads provide access to rural land and enable the transportation of agricultural products. Many counties spend significant portions of their budgets on maintenance and rehabilitation of gravel roads. Opportunities exist to improve the performance of the gravel roads which would reduce the maintenance frequency and would yield significant cost savings. The proposed research project will examine several stabilization and construction methods that pose strong potential to minimize damages of gravel roads. A range of potential stabilization technologies to address these issues will be studied, including crushed rock embedment, gradation optimization, and the possible addition of angular material, and waste fines. The proposed study will conduct a comprehensive laboratory study to evaluate the efficiency of different treatment methods on improving the performance of granular road. Gravel road materials (along with the subgrades) will be collected from different locations in Nebraska that experienced significant road distresses. Data (e.g., resilient modulus, California bearing ratio (CBR), abrasion, freeze-thaw durability) will be measured and evaluated to quantify the treatment effectiveness. A primary outcome for this research is to optimize the NDOT gradation for gravel surfacing with materials that are locally sourced. In addition, this research will also develop a data-driven model to estimate the type and amount of materials to be added that would improve the performance of gravel roads via use of simple index properties.

Conclusion

Nearly 30% of roads in the U.S. are unpaved, significantly impacting rural connectivity with Nebraska alone having approximately 75% unpaved roads. This study systematically evaluates local materials to improve gravel road performance, reduce maintenance frequency, and decrease financial burdens on counties. Survey responses revealed that nearly 70% of counties follow NDOT specifications for gravel road design, while more than 90% lack knowledge of local material quality. The most common distresses identified were raveling, loss of crown, dust, and improper drainage. These findings indicate that construction practices rely heavily on experience, rather than systematic design, highlighting the need for a performance-based approach. To address this, commonly used gravel road materials were identified. Seventeen different materials—13 surface materials and 4 subgrade soils—were collected from four counties for laboratory evaluation. Comprehensive testing assessed index properties, while repeated triaxial tests determined the mechanical behavior of granular surface materials. Maximum dry unit weight (MDU) values ranged from 111 to 138 pcf, with corresponding optimum moisture content (OMC) values between 3% and 11.3%. Resilient modulus (MR) tests showed inconsistent results, ranging from 10 ksi for sand-dominant materials to 30 ksi for open-graded materials. Virgin materials performed poorly in permanent deformation (PD) tests and were deemed unsuitable for road surfaces due to constructability, maintenance, and drainage limitations. A granular stabilization technique was implemented by mixing additional granular materials (e.g., gravel, crusher run, and fine-grained soils) to correct deficiencies in particle size distribution (PSD), shape, and plasticity. After extensive trials, 31 optimized blends were proposed. These blends exhibited increased dry unit weights, averaging 134 pcf, and consistent stiffness, with MR values ranging from 8 ksi to 27 ksi, predominantly at the higher end. Additionally, they showed nearly a 100% improvement in permanent strain accumulation across most blends. Performance enhancements were attributed to increased mechanical interlock, inter-particle friction, and binding, as well as reduced aggregate breakdown. Exposure to freeze-thaw cycles had no effect on MR but increased PD, indicating a reduction in material stability under repeated cycles. Stepwise regression models were developed to predict MR and PD directly from index properties such as particle size distribution, specific gravity, and plasticity. An Excel-based gradation optimization tool was developed to determine the required proportions of existing and fresh aggregates for an optimized gradation range. This tool incorporates road geometry and material characteristics to provide precise material quantities, ensuring improved consistency and performance in gravel road construction and maintenance

Executive Summary, Research Readiness Level Assessment, and Technology Transfer

Interested in finding out more?
Final report is available:
HERE

NDOT Recommendations Based Off Research Project – 2025 – RRL4

This research resulted in the development of an Excel-based Gradation Optimization Tool for the Nebraska Department of Transportation (NDOT). The tool was designed to estimate the type and quantity of materials needed to enhance the performance of gravel roads using simple index properties. Building on the success of this initial phase I, Gravel Road Performance Enhancements – Phase II of the project was proposed and approved starting September 2025. The primary objective of Phase II is to verify and calibrate the tool's predictive accuracy under real-world conditions. Nebraska Highway 65, located near Pawnee City, Nebraska, was selected as the test site due to its moderate traffic volume and relatively stable truck percentage, making it an ideal location to assess the tool's effectiveness under realistic field loading scenarios. Phase II aims to provide immediate implementable results for NDOT Gradation and construction guidelines will be developed for NDOT implementation consideration. These guidelines will include clear specifications and language for developed gradation properties and additive type and amount selection methods for enhancing the performances of gravel roads in Nebraska.

- *As provided by Bruce Barrett, Lead TAC Member*

Research Readiness Level (RRL) Assessment

RRL 4

Level 4: Implementation

Research/technology - Follow up upon completion of phase II – 3 years.

Technology Transfer

Webinars/Presentations

- Bulduk, Mehdi and Cetin, Mehdi. (2024). "*Gravel Road Performance Enhancements.*" 66th Annual Convention held by the Nebraska Concrete & Aggregates Association.

This brief summarizes Project SPR-FY23(014)
"Gravel Road Performance Enhancements"
Nebraska Department of Transportation Research Program