Iowa State University
Institute for Transportation

Coarse Aggregate Deterioration in Granular Surfaces and Shoulders

tech transfer summary

April 2025

RESEARCH PROJECT TITLE
Coarse Aggregate Deterioration in Granular Surfaces and Shoulders

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Iowa Highway Research Board
(IHRB Project TR-769)
Iowa Department of Transportation
(InTrans Project 18-683)

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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.

A clearer understanding of the deterioration mechanisms of the coarse aggregate used in granular-surfaced roads and shoulders can help county engineers better plan construction and maintenance activities.

Objective

This research aimed to characterize changes in the microstructural and engineering properties of coarse aggregates as they are exposed to weathering and traffic loads typical of the granular surfaces and shoulders of Iowa roads.

Background

Approximately 74% of Iowa's 89,000 mi secondary road network consists of granular-surfaced roads, commonly referred to as gravel roads. Granular-surfaced roads in Iowa typically have a traffic-bearing surface of crushed carbonate rock (limestone or dolostone) obtained from local bedrock quarries or mines.

Coarse aggregates, which are the primary constituent of the granular surfaces of gravel roads, undergo both physical and chemical degradation due to weather and traffic loads. This degradation affects their engineering and geological properties and, ultimately, their longevity. The high solubility and low hardness of carbonate minerals make carbonate rock especially prone to chemical and physical breakdown.

The granular surfaces of these roads must be renewed as often as every three years, which imposes significant financial demands on county highway departments.

Cetin et al. 2019

Granular-surfaced road in Iowa

Problem Statement

Despite the importance of granular-surfaced roads to the economic fabric of Iowa and their requirements for regular maintenance and rehabilitation, we lack a robust understanding of not only the deterioration mechanisms most responsible for the breakdown of coarse aggregates but also the geological factors that make one coarse aggregate perform better than another.

Research Description or Research Methodology

The research involved the collection of data and coarse aggregate samples from quarries and in-service roads over time and the geotechnical and geological laboratory testing of the samples.

Laboratory test data were gathered from two Iowa Highway Research Board (IHRB) projects, and new tests were also performed on materials left over from the projects:

- TR-704, in which test sections were constructed with Bethany Falls Limestone (BFL), Lime Creek Formation (LCF), and Oneota Formation Dolomite (OFD) Class A aggregates
- TR-721, in which field test sections (Optimized Gradation with Clay Slurry [OGCS], Aggregate Columns, and Control) were constructed in Howard, Hamilton, Washington, and Cherokee Counties and sampled over multiple years

Additionally, new Clean and Class A coarse aggregate samples were collected from Crescent, Macedonia, Atlantic, Moore, Pedersen, Alden, Gehrke, Montour, and Clayton Quarries.

Geotechnical laboratory testing, image analysis, and both petrophysical testing and petrographic inspection were carried out to identify the chemical (e.g., dissolution of primary minerals, precipitation of secondary minerals) and physical (e.g., abrasion, freeze-thaw cycles) weathering processes responsible for coarse aggregate deterioration.

Geotechnical tests included measurement of particle size distribution (PSD) through traditional sieve and hydrometer tests, gyratory compaction tests to simulate the effects of traffic loading, and 2D-image analyses to study changes in particle morphology during gyratory testing and field service.

Li 2013

Gyratory compactor

Coarse aggregate particles from Gehrke Quarry for 2D image analysis

Key Findings

- The Class A materials from the Pedersen, Crescent, and Moore Quarries produced the lowest total breakage values during gyratory compaction testing, with the Pedersen aggregates exhibiting the smallest changes in morphology.
- The Clean aggregates from the Alden and Gehrke Quarries had the highest breakage values and among the largest changes in morphology during gyratory compaction testing.
- In TR-704 and TR-721, the highest rates of breakage in field test sections were typically observed within the first few months after placing new aggregates for construction or maintenance and tended to decrease thereafter.
- For TR-704, the BFL had the highest total breakage while the OFD had the lowest breakage, and the LCF materials had only slightly greater breakage than the OFD. Overall, the BFL materials yielded the greatest changes in morphological parameters over time, whereas LCF exhibited slight changes and OFD exhibited the smallest changes.
- For TR-721, the materials from the OGCS sections had the best overall performance in terms of the smallest relative decreases in gravel fraction, smallest increases in sand and fines fractions, smallest cumulative total breakage values, and smallest changes in particle morphological parameters.
- The materials from the Aggregate Columns sections exhibited intermediate performance, and those of the Control sections exhibited the poorest performance.
- For the geological tests, each aggregate source was composed of at least four different rock types. The Class A samples from TR-704 showed a significant difference in the relative abundance of rock types compared to the Clean samples. In general, the less durable rock types, such as those with higher clay contents or greater porosities, experienced a greater reduction in abundance over time.

Recommendations for Future Research

- To further quantify the field performance and coarse aggregate deterioration of various material blends and of chemically and mechanically stabilized test sections, analyze additional data and samples from field test sections constructed in TR-704 and TR-721.
- To expand the results of the present study, analyze a wider variety of quarry materials and field test section samples from around the state using the methods of this study.
- To expand the methods of this study, quantify the deterioration and field performance of recycled or synthetic aggregates or those stabilized with various chemical or mechanical methods to assess the differences in breakage and morphology over time.
- Construct and monitor new field test sections using the materials that had the best performance and lowest deterioration in this study.
- To enhance the usefulness of 2D image analyses, image data can be further mined to investigate a wider range of morphological parameters beyond the six examined in this study.
- To better understand particle breakage and abrasion at the microscopic scale for both gyratory compaction in the laboratory and traffic loading in the field, perform scanning electron microscope (SEM) imaging on the remaining samples.

Implementation Readiness and Benefits

Through a clearer understanding of the deterioration mechanisms of carbonate coarse aggregates, critical material properties can be identified that will better guide the decision-making process used by county engineers and geologists to plan the construction and maintenance of granular-surfaced roads and shoulders.

To implement the results of this research, county engineers can select from the material types that produced the least breakage in quarry samples and field test sections, as evaluated in this research through both gyratory compaction tests and field PSD curves over time.

Ultimately, the results of this research can help decision-makers act in the best interest of taxpayers by minimizing the life-cycle costs of constructing and maintaining granular-surfaced roads while providing a safe and reliable transportation network for rural communities and producers.

References

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