Mineralogical Characterization of Pavement Aggregates in Maine

Final Report
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About the Transportation Infrastructure Durability Center

The Transportation Infrastructure Durability Center (TIDC) is the 2018 US DOT Region 1 (New England) University Transportation Center (UTC) located at the University of Maine Advanced Structures and Composites Center. TIDC's research focuses on efforts to improve the durability and extend the life of transportation infrastructure in New England and beyond through an integrated collaboration of universities, state DOTs, and industry. The TIDC is comprised of six New England universities, the University of Maine (lead), the University of Connecticut, the University of Massachusetts Lowell, the University of Rhode Island, the University of Vermont, and Western New England University.

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16 Abstract
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Abstract

Paving represents a significant cost for transportation infrastructure in the State of Maine. With a low population density and high road density, the State of Maine has significant paving needs. The adverse climate conditions across the diversity of environmental conditions in the state leads to a variety of issues for the durability of pavement. Currently, pavement aggregates are sourced from many local and regional aggregate vendors, and very little information exists regarding the mineralogy of pavement aggregates used throughout the state for paving projects. With increasing costs over recent years and decreasing pavement durability, it is essential to characterize the mineralogy of pavement aggregates in order to evaluate its durability. The purpose of this project is to characterize the mineralogy and texture of pavement aggregates from the primary aggregate sources currently in use by MaineDOT. These data will be used to investigate the relationship between pavement durability and the mineralogic properties of the source aggregates, in order to inform future decisions regarding pavement aggregate sourcing.

Chapter 1: Introduction and Background

1.1 Project Motivation

Paving represents a significant cost for transportation infrastructure in the State of Maine. With a low population density and high road density, the State of Maine has significant paving needs. The adverse climate conditions across the diversity of environmental conditions in the state leads to a variety of issues for the durability of pavement. Currently, pavement aggregates are sourced from many local and regional aggregate vendors, and very little information exists regarding the mineralogy of pavement aggregates used throughout the state for paving projects. With increasing costs over recent years and decreasing pavement durability, it is essential to characterize the mineralogy of pavement aggregates in order to evaluate its durability. The purpose of this project is to characterize the mineralogy and texture of pavement aggregates from the primary aggregate sources currently in use by MaineDOT. These data will be used to investigate the relationship between pavement durability and the mineralogic properties of the source aggregates, in order to inform future decisions regarding pavement aggregate sourcing.

1.2 Research, Objectives, and Tasks

Significant questions remain as to the extent to which different rock types (aggregate sources) affect the durability of pavement throughout the state of Maine. The primary objectives of this project are to:

1) Characterize the mineralogy of the source aggregates listed in Table 2
2) Characterize the grain size and textures (where possible) of the source aggregates
3) Evaluate the overall geology of accessible quarry sites to determine the homogeneity of the source aggregates

1.3 Report Overview

Pavement aggregates in Maine are sourced from local and regional quarries without knowledge of the underlying geology. As Maine faces high paving costs from pavement durability issues, investigating the mineralogy of pavement aggregates could help inform future aggregate sourcing for more durable pavement. The mineralogy and grain size of pavement aggregates affect how environmental factors influence pavement durability from the behavior between bitumen and aggregate. This behavior is impacted by components of mineralogy, including chemistry and morphology, and can influence cohesion properties such as adhesion and absorption, stripping, and freeze-thaw. Our goals throughout this project were to 1) characterize the mineralogy of the designated source aggregates, 2) characterize the grain size and textures of source aggregates, and 3) evaluate the overall geology of quarry sites to determine homogeneity of source aggregates. This report details the methods used to accomplish these objectives and the results of mineralogy for the designated quarries.

Chapter 2: Methodology

2.1 Materials

Quarries were first evaluated for overall geology, including homogeneity and structures. Samples were collected from quarries with the goal of being representative of the homogeneity of each quarry. This was based on the mineralogy of rock within the quarry—homogeneous quarries had only one sample rock type, while heterogenous quarries had multiple to represent the different rocks that make up the aggregate. Homogenous quarries will behave more predictably as aggregate due to the consistency of the source material. Quarries were visited in person to accomplish this when possible, and samples from quarries that we were unable to visit were sent from DOT labs. Quarries that we were not able to visit and did not receive samples from are crossed off the list in the results.

2.2 Test Setup & Process

Samples were then observed and analyzed in the lab to characterize the mineralogy and textures. The first observation was for grain size, which determined the subsequent analysis either by optical petrography or X-ray diffraction (XRD). Coarser grained samples were prepped for thin sections and then sent to the University of New Brunswick for thin section making. Fine grained samples were prepped for XRD by crushing the rock into fine powder and were analyzed at the University of New Brunswick and the Illinois State Geological Survey.

Thin sections were used for optical petrography under a polarizing microscope to determine the mineralogy and observe micro-scale textures and structures. Mineralogy and abundance of each mineral was recorded for each thin section made, then categorized into a rock type and formation when possible. Optical petrography was performed using a Zeiss Axio Imager M2.m polarizing light microscope in both plane polarized and cross polarized light. Images of the thin sections are provided in the results.

X-ray diffraction (XRD) uses x-rays to analyze the internal structure of a mineral and results in semi-quantitative mineralogy, which includes a full mineralogy and abundance of minerals. This was performed on the majority of samples as most were too fine grained for optical petrography to be useful. The results were then categorized into rock type and formation when possible. Some samples for XRD were collected from DOT labs as crusher dust and aggregate, and do not have the initial geologic context to aid in interpretations.

XRD methods are as follows: X-ray powder patterns for all samples were measured using a Bruker D8 Advance spectrometer. Fine powder samples were packed into the circular well on the sample-holder, after which it was placed on the sample stage for scanning. The diffractometer was equipped with a two circle (theta-theta) goniometer housed in a radiation safety enclosure. The X-ray source was a sealed, 2.2 kW Cu X-ray tube, maintained at an operating current of 40 kV and 23 mA. The X-ray optics was that of standard Bragg-Brentano para-focusing mode with the X-rays diverging from a divergence slit (1.00 mm) at the tube to strike the sample and then converging through an anti-scatter receiving slit (1.00 mm) and a detector slit (0.20 mm). The goniometer was computer controlled with independent stepper motors and optical encoders for the θ and 2θ circles with the smallest angular step size of 0.0001° 2θ. Samples were scanned in the range of 5-80° 2θ. A step size of 0.02° and a step time of 1.0 sec were used during the measurements. A peltier-cooled solid-state [Si(Li)] detector (Sol-X) with a useful energy range of 1 to 60 KeV was used as the detector. No correction was made for K_β radiation. A set of 2° Soller slits were used in order to lower horizontal beam divergence. The software suite for data collection and evaluation was windows based. Data collection was a manually-controlled JOB program that employs a DQL parameter file. The raw data obtained from the spectrometer was analyzed and refined by the program EVA (Bruker). Analysis was performed with MDI JADE.

Chapter 3: Results and Discussion

3.1 Data

Sixteen quarries were visited in person to collect samples and evaluate the homogeneity of each quarry. Samples were obtained for all other quarries through MaineDOT partners. Results were compiled for each quarry, including descriptions of the quarry and hand samples, mineralogy by thin section or XRD, grain size classification, rock type and formation, pictures, and geologic maps. These results are compiled in a Pavement Mineralogy matrix in a Microsoft Sharepoint folder hosted by MaineDOT. Rock type varies widely between quarries; looking at pavement durability on roads that use each aggregate may help to correlate a certain mineralogy with observed durability.

Link to sharepoint folder: https://stateofmaine.sharepoint.com/teams/MaineDOT-MTExResearch/Shared%20Documents/Forms/AllItems.aspx?id=%2Fteams%2FMaineDOT%2DMTExResearch%2FShared%20Documents%2FMineralogical%20Characterization%20%2D%20UMaine&viewid=d6db20b4%2Dbc5b%2D47ea%2D8a8b%2Dac40343d60c2

In the Pavement Mineralogy matrix, each quarry is detailed with the following information:

- Quarry Name
- Location
- Company/Owner
- If samples were obtained, and when
- If the quarry was visited in person
- Sample names
- Mineralogy (% of each mineral), and if the mineralogy was determined by observation in thin section or by XRD
- Hand sample observations, including grain size, rock type, and formation names
- Quarry descriptions, with live links in the matrix to the descriptions, geologic maps, DOT and MCG test reports, and photos

Chapter 5: Conclusions and Recommendations

The pavement mineralogy matrix assembled during this project can be used to inform decisions regarding the use of certain aggregates for paving in Maine. Based on the input of our geological weathering expert, we have learned that the adhesion of certain minerals within the pavement is quite different from the behavior of minerals within the weathering environment. Thus, we do not feel that many correlations can be made between those two fields, and recommend consultation with those whose expertise lies in the material properties of pavement adhesion to bitumen and the processes associated with paving.

Overall, the observations regarding the pavement aggregates used in Maine are that the mineralogy is highly variable from quarry to quarry, and that within certain quarries, there can be significant heterogeneity in rock types and mineralogy. The qualitative observations of the geology of each quarry should be a valuable resource for evaluating the use of each aggregate source for paving. The specific mineralogical summary of each aggregate source can be compared to qualitative and quantitative data for pavement durability, leading to hopefully some patterns of which aggregates behave better, and if there is are mineralogical or quarry-related observations that dictate pavement durability.

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