Research Brief

Wisconsin Highway Research Program
Project 0092-22-05
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Weight-Volume Relationships and Conversion Factors for Soils and Aggregates of Wisconsin

Objective

- Determine and update expansion and conversion factors for geomaterials used in large earthwork construction projects
- Conduct a comprehensive review of current practices among other state DOTs
- Develop an excel-based tool to accurately estimate the expansion and conversion factors of geomaterials between different states

Benefits

- This research provides a comprehensive framework for precise earthwork calculations
- Insights from this work offer a thorough understanding of the behavior of geomaterials under different conditions

Principal Investigator

Bora Cetin, PhD.
Michigan State University
cetinbor@msu.edu

Project Manager

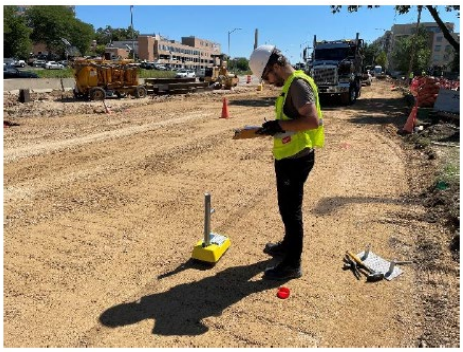
Andrew Zimmer
WisDOT
andrew.zimmer@dot.wi.gov

Background

Earthwork construction involves the excavation, hauling, and placement (cut-haul-fill) of geomaterials including soils and aggregates. Geomaterials experience considerable volume changes during the cut-haul-fill cycle, including expansion from the “bank” state to the “loose” state after excavation and shrinkage from the “bank” state to the “compacted” state after construction. Generalized or material-specific expansion and conversion factors can be used to estimate weight-volume relationships in each state, thereby providing a quantitative basis for more accurate earthwork design, bidding, and construction. This research aimed to develop accurate earthwork expansion and conversion factors for various geomaterials, thereby enhancing the accuracy of earthwork calculations for Wisconsin’s roadway construction.

Methodology

Researchers focused on understanding existing practices of earthwork calculations through a review of state DOTs’ methodologies via survey. Following this, the team collected and analyzed soils and aggregates, including recycled and large-sized aggregate materials. Lab tests were conducted to determine key properties and characteristics of these materials. Field tests were conducted to measure in-situ density and moisture conditions in different material states (e.g., bank, loose, compacted). The findings from these were used to develop an excel-based tool designed to accurately estimate conversion and expansion factors for various geomaterials based on their index properties.



In-place density and moisture content test by nuclear density gauge (NDG) at in Dane County (left) and St. Croix County (right)

Results

Survey results from 26 state DOTs were obtained to understand existing practices of earthwork calculations and show that only about

"The Weight-Volume Relationships and Conversion Factors for Soils and Aggregates of Wisconsin study will greatly assist WisDOT engineers more accurately estimate earthwork volumes, which will reduce costly change orders during construction." – Andrew Zimmer, WisDOT

31% of the DOTs surveyed provide specific expansion factor equations for commonly used soils. Less than half of the DOTs consistently align their design expansion factors with post-construction data. For aggregates, the survey results were less conclusive, with only about 23% of DOTs providing conversion factors, and a notable lack of consistent data alignment between design factors and post-construction results.

These findings reveal that practice for applying earthwork factors substantially relies on personnel experience and a wide variety of methodologies, thus highlighting the need for a more systematic approach. To address this, the research team conducted a comprehensive field and laboratory testing on 29 aggregates and 14 natural soil types collected across Wisconsin. Test results were used to develop a suite of expansion and conversion factors for natural soils and aggregates in various states of compaction (bank, loose, compacted). Expansion factors for natural soils from the compacted to bank state show considerable variation, with factors for sands ranging from 1% to 15%, silts at 12%, and clays between (-5)% to 9%. Results for aggregates show a range of conversion and expansion factors between 1.50 to 1.98 and 27% to 60%, respectively. There are notable variations in factors across different material types, in particular with over consolidated clays.

Recommendations for Implementation

The research emphasizes the need for region-specific expansion factors, especially for consolidated clays, to accurately reflect their unique expansion rates. Future studies should examine the densification effects of heavy machinery during clearing and grubbing operations. Moreover, expanding the database to encompass a wider range of soil types and aggregates is essential for refining predictive models.

For field applications, particularly with large-sized aggregates, it's important to extensively utilize the study's developed methods. This includes employing the developed *In-Place Density Measurement by Water Replacement Method* in the field and the *Alternative Compaction Method* for large-sized aggregates in the laboratory. The potential for using *3D Lidar Scanning on dump trucks* to enhance loose density measurement accuracy is highlighted, although this requires meticulous coordination with contractors and quarries to minimize operational disruptions.

In addition, future research should consider employing unit weight measurements at various excavation depths, which could lead to the development of a modification factor for improved accuracy in expansion factors. Furthermore, it is recommended that the proposed expansion factors be adopted for aggregates.

Interested in finding out more?
Final report is available at:
WisDOT Research website

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