

**Final Compendium Report
To the Economic Development Administration**

**Research, Development, and Marketing
of Minnesota's Iron Range Aggregate
Materials for Midwest and National Transportation Applications
Project # 06-79-05068**



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The statements, conclusions, and recommendations in this report are those of the authors and do not necessarily reflect the view of the Economic Development Administration.

EXECUTIVE SUMMARY OF PROGRAM

Authors' note: Given the program's wide-ranging and extensive scope, this final report is assembled and presented as a compendium. First, synopses of the program's major tasks and overall findings are presented in an Executive Summary. Then, all technical reports (TRs), technical summary reports (TSRs), and/or reports of investigation (RIs) produced during the 2006-2010 period for each major program task, as cited in "Chapter 1: Overview of the Project," are reproduced and presented as stand-alone chapters or sub-chapters. Ancillary reports and documentation relevant to the project are presented in appendices.

Program Outline

Major tasks and areas of interest:

- Introduction of Concept – developing broad interest in the potential use of the by-product materials from Minnesota's iron mines on the western part of the Mesabi Iron Range;
- Preliminary Research – review of basic data on potential aggregate materials, their usage characteristics, the potential for use of the materials in concrete and asphalt mix formulations; and the physical, mineralogical, and chemical properties of potentially usable materials:
 - Historical use of taconite aggregates in road construction within the State of Minnesota;
- Sample Acquisition and Preparation – attainment of representative aggregate materials of various size classes:
 - Sources and sampling – identification and characterization of the various sourced materials;
- Aggregate Testing – the application of standardized test procedures using federal, state, and professional organization methodologies:
 - Minnesota and Other state Departments of Transportation testing;
- Geology, Mineralogy, and Chemistry – developing an understanding on the rock formations, the consistency of aggregate sources for potential supply for various applications, and the environmental properties of the various potential aggregate materials:
 - Geology of the Mesabi Iron Range and aggregate potential,
 - Mineralogical and microscopic characterization, and
 - Chemistry of taconite aggregate and leachate;
- Mix Design – development of engineered mixtures that can be used in various parts of highway construction using both asphalt or Portland cement binding systems:
 - Hot mix asphalt, and
 - Portland cement concrete;
- Innovative Concepts/Uses – development of specialty applications of certain aggregate and iron bearing materials that impart unique, advantageous properties for repair situations:
 - Pothole patching compounds; and
 - Microwave heating (pavement conditioning/annealing), pothole patching, and de-icing
- Demonstration Projects – actual usage of various taconite materials in road projects that reflect the required material properties and gradations needed for effective application:
 - MnROAD Field Demonstrations,
 - Field Demonstrations, and
 - Specialty applications for safety and friction requirements;
- Transportation Logistics and Economics – development of an overall understanding of the transportation routes, transportation means, comparative economics and overall potential of movement of products from mine to end user applications; and
- Communications and Marketing -- communication of project results through various forums and to various potentially interested stakeholders to advance the use of taconite derived aggregate materials in a variety of applications.

Summary Conclusions

As this final report demonstrates, the program's findings clearly show:

1. Taconite aggregate construction materials and value-added aggregate by-products and co-products derived from Minnesota's taconite (iron ore) mining industry have significant potential for providing superior properties to allow longer lasting pavement construction if used in either concrete or asphalt based highway mixtures;
2. Widespread adoption of the potential use of these materials in highway construction in the Midwest U.S. will: a) lead to economic development and immediate job creation in Northeastern Minnesota; and b) provide long-term benefit to the nation's transportation infrastructure needs, including an overall reduction in infrastructure costs associated with building and maintaining highways wherever the material is applied;
3. The expanded use of (and deriving value from) by-products and co-products generated by Minnesota's taconite mining industry represents one leg of a three-legged strategy for assuring the long-term economic stability and competitiveness of the United State's iron ore mining and steel-making industries. In addition, there is significant potential for providing new jobs in logistics services if the widespread use of the materials are adopted throughout the Great Lakes region and beyond;
4. The logistics of bringing the various aggregate products to various Midwestern locations is feasible using unit trains and Great Lakes shipping when the enhanced properties of the aggregate materials are considered in increasing highway longevity and when processed materials are used in value-added applications such as safety friction products and repair compounds;
5. The use of taconite aggregate materials as a complementary material in composite pavement highway applications should allow a balanced approach to increasing highway performance that still allows use of lower cost and inferior quality aggregates in the non-wear foundation course that might be available on a local basis. The harder and more durable taconite-based aggregates are especially suited for wear surface applications where their superior properties can be fully utilized; and
6. This work has provided a sound basis for potential large-scale commercialization of the aggregate materials beyond Minnesota and has resulted in at least three companies actively focused on creating a new market for taconite-based aggregate for a variety of applications. It has also resulted in one company licensing a repair compound developed during the course of project execution, and the interest by several companies in value-added friction products that are used to enhance the safety and traction on bridge decks, bridge approaches, aprons, and other areas needing enhanced properties.

Suggested Continuing Development Activities

The various elements from the current program have clearly demonstrated the broad-based potential for utilizing taconite aggregate materials in highway construction applications (whether in conventional highway construction courses or specialty applications). The key for future widespread adoption of the concepts is to continue the development and necessary support activities for projects of increasing size and importance. In order to establish the full market potential for these products, the following activities are suggested for the future:

1. It is recommended that an accelerated applied research and demonstration project program that facilitates the expanded production and use of taconite mining by-products rock (aggregate) and co-products for state, regional, and national infrastructure projects be pursued. The program should focus in particular on near-term implementation projects that introduce these aggregate materials to targeted markets in project-sized quantities, value-added commercialization opportunities, and promising avenues of taconite-based applied research. To

achieve these goals, future initiatives should focus on, but not be limited to, the following high-priority areas:

- Ongoing product quality assurance testing;
 - Development of mix designs that use high quality taconite aggregate blended with inferior aggregates, and development of composite pavements that use taconite aggregates, especially in their upper wear-course;
 - Production of value-added products derived from coarse taconite tailings, such as high-friction bridge deck and airport runway surfacing aggregates;
 - Development of low-cost bulk transportation of taconite aggregates to infrastructure project destinations in the Great Lakes region, the lower Mississippi River/Gulf region, and other states;
 - Accelerated testing and use of taconite by-products by the U.S. Army Corps of Engineers for waterway maintenance and infrastructure projects, such as armor stone, rip rap, and splash stone, and demonstrating and implementing concepts such as a “dike-in-bag” for levee strengthening and rapid deployment for emergency flood control; and
 - Further development of innovative products and technologies such as: taconite-based pothole/paving compounds; maximizing the use of recycled materials such as asphalt shingles and recycled asphalt pavement (RAP) in taconite aggregate-based mix designs; pursuing microwave-based technologies for all-season pothole and pavement repair, and chemical-free deicing; taconite aggregate-enhanced warm-mix asphalt formulations; and permeable pavements.
2. Investing in our nation's transportation infrastructure is essential for long-term economic growth and job creation. Taconite-based aggregates have superior properties to those aggregates made from softer materials such as limestone, dolomite, sea shells, and other soft materials. Continued development of composite pavement designs where hard, durable aggregates can be used in strategic applications, such as the wear surface of a highway, should be undertaken in order to maximize highway longevity and minimize taxpayer costs in highway construction.