Research, Development, and Marketing of Taconite Aggregate

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TERRA Innovation Series
MnROAD Research Conference
Minneapolis, MN
October 4, 2011
Quick review of basics
Taconite is a hard, dense rock composed largely of an intimate mixture of quartz and magnetite ($\text{Fe}_3\text{O}_4$), plus varying amounts of iron oxides, carbonates, and silicates (Davis, 1964).

Map source: Oliver Iron Mining Division, United States Steel Corporation (Goldich and Marsden, 1956)
Location of Mesabi Range Taconite Operations
Enormous Aggregate Potential of Taconite Mining Byproducts
## Comparative Statistics: U.S. Crushed Stone* and Minnesota Taconite†

<table>
<thead>
<tr>
<th>2007 Production Statistics</th>
<th>United States Crushed Stone</th>
<th>Minnesota Crude Taconite</th>
<th>Taconite as a % of US Crushed Stone</th>
</tr>
</thead>
<tbody>
<tr>
<td>Production (metric tons)</td>
<td>1,600,000,000</td>
<td>132,474,649</td>
<td>8.3%</td>
</tr>
<tr>
<td>Employment: quarry and mill</td>
<td>81,900</td>
<td>3,724</td>
<td>4.5%</td>
</tr>
<tr>
<td>Number of quarries</td>
<td>3,710</td>
<td>6</td>
<td>0.2%</td>
</tr>
<tr>
<td>Metric tons per employee</td>
<td>19,536</td>
<td>35,573</td>
<td>182.1%</td>
</tr>
<tr>
<td>Average production per quarry/mine</td>
<td>431,267</td>
<td>22,079,108</td>
<td>5119.6%</td>
</tr>
</tbody>
</table>

- **>130,000,000** tons of crude ore mined in 2007
- **Similar tonnages of byproduct** (rock and fine aggregate) are generated annually by Minnesota taconite mines
  - This is equivalent to about **1/12th** of the United State’s annual crushed stone production

*USGS
†Minnesota Dept. of Revenue
From January 1, 2006 to June 30, 2010, a comprehensive research and demonstration program was undertaken by the University of Minnesota Duluth Natural Resources Research Institute (NRRI). The program’s main objectives were to:

- Assess the suitability of Minnesota Iron Range taconite byproduct and co-product materials for road construction and repair applications
- Identify new and economically viable uses for these materials
- Support demonstration projects inside and outside Minnesota
Final Report Published

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

Respectfully Compiled and Submitted by:

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and Mr. Steven A. Hauck, Project Administrator

This report was prepared under an award from the
U.S. Department of Commerce
Economic Development Administration

Natural Resources Research Institute
University of Minnesota Duluth
5013 Miller Trunk Highway
Duluth, MN 55811
Technical Summary Report
NRRI/TSR-2010-01
November 2010

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.

November, 2010
Technical Report
NRRI/TSR-2010-01
Blast Rock: boulder to +6 inch (+15cm) rock created by blasting; used as-is

- Armor Stone
- Rip Rap
- Landscaping Stone

Coarse Crushed Rock: -6 inch (-15cm) rock that can be further crushed to specification

- Bituminous and Concrete Aggregate
- Railroad Ballast
- Road Base

Coarse Tailings: -3/8 inch (-10mm) processing plant byproduct, ready-made fine aggregate equivalent

- Bituminous and Concrete Aggregate
- Select Granular
- Road Base
- Road Sub-base
- Embankment Fill
- Friction Surfacing
- Seal Coat / Slurry Seal
- “Dike-in-a-bag”
Much of the aggregate rock will come from low grade horizons within the iron formation.
NRRI geologists have identified and prioritized potential aggregate horizons across the entire Mesabi Iron Range.
If taconite rock has value as aggregate, it could reduce stripping costs, making more ore accessible.
Today’s focus: Value-added uses, products, and technologies & What’s next?
Value-added niche products and technologies

- High-quality wear-resistant aggregates for friction surfacing systems, upper course of composite pavements, and/or thin-lift asphalt
- Taconite-based pothole repair and paving compounds
- Microwave-based pothole and pavement repair, and chemical-free deicing
Formulation of taconite rock usage in highway mix designs: asphalt and concrete testing

University of Minnesota Department of Civil Engineering, Pavement Research Institute (strength testing of asphalt and concrete mixes)

“Using Mesabi Hard Rock as coarse aggregate improved all mechanical properties of the concrete. While there was very little increase in compressive strength, no increase at 7-days and 1% increase at 28-days, the flexural strength was much improved with a 12.6% increase at 28-days.” (Rohne, 2009).

Mn/DOT MnROAD test facility, Albertville, MN (left), and 4.75mm Stone Matrix Asphalt (SMA) using taconite fine aggregate (right)
A 1976 Federal Highway Administration (FWHA) report stated the following about taconite:

"The serviceability of these taconite overlays has been exceptional. It has been found that the use of coarse taconite tailings definitely improves the skid resistance of pavements in which it is used. In the future, taconite tailings may be specified as the sole material used for surface overlays because of their skid resistance qualities."
Friction aggregates start where coarse tailings end...

Example: Taconite tailings discharge at Keewatin Taconite: June 2011 (photo used with permission of United States Steel, Minnesota Ore Operations)

Some specialty friction products – when graded, dried, and bagged – can sell in the neighborhood of $200 per short ton.
New projects that use taconite friction aggregates are pending for Michigan and Ohio
Recent Activities

- Comparative testing of friction materials at NCAT (begun in the Spring)
  - 8 friction aggregate types from around the country, including taconite. Calcined bauxite from China is the competition. Results are pending.

- Approval of taconite friction aggregates by NYDOT
  - "The aggregate tested very well. There is another piece of information which is not on the test sheet and that is the friction level. Because Taconite is 100% noncarbonate, it has the highest possible friction rating of STF1."
  - 5 Cycle Soundness Test - Magnesium Sulfate (Test Method NY 703-06): Soundness loss of 2.7
Current FHWA-supported project

“Performance of Taconite Aggregates in thin lift HMA”
NRRI, Mn/DOT, and U of M Dept. of Civil Engineering

The project’s focus is on mix design, cold-temperature testing, and leachate characterization
In Germany: upper wear course made with durable aggregate. Typical section: a 3 to 5cm upper lift made with high-quality crushed aggregate.

Source: Tompkins et al. (2009), “Design and Construction of Austrian and German Two-layer Concrete Pavements”
Value-added niche products and technologies that take advantage of the chemistry and mineralogy of taconite materials

Improved repair for all seasons

- Taconite-based pothole and pavement repair compounds
- Microwave-based pothole and pavement repair
Research by NRRI’s scientists shows that certain taconite co-products and by-product materials can be used in non asphalt-based cold-mix pothole patching compounds.

- This research has resulted in a patent and a licensing agreement with TCC Materials/Cemstone.

“Coleraine Mineral Research Lab fills potholes with byproduct of iron mining”
Published on April 28, 2008, Duluth News Tribune (MN)
Water-add formulation
Field Test: MnROAD September 1, 2011
Installation
Finished

Taconite patch

Concrete patch with accelerator
Thermal Imaging

Prepared hole (pre-filled)

After first pour

~1 hr. later
• Joint research conducted with Dr. David Hopstock has shown that taconite is an excellent microwave absorber.

• The work conducted during the EDA program led to a research collaborative agreement with Microwave Utilities, Inc. (MUI) of Monticello, MN

• This concept has implications for pothole patching, debonding ice from pavements or airport runways, and re-heating asphalt pavements for in-place reclamation or re-compaction.
With support from the Local Operational Research Assistance (OPERA) Program, microwave technology was tested for rapid cold weather pothole repair, using recycled asphalt pavement (RAP)…

Pothole repair field trial, March 2009, Anoka County, using a truck-mounted 30kW unit

Portable unit provided by Vern Hegg, Microwave Utilities, Inc.

…taconite materials, and recycled asphalt shingles.

Summer 2010 test with RAP and updated 50kW unit at NRRI
March 30, 2011 test near Twig, MN. A second test was conducted in Anoka, MN, on April 8, 2011.

Thermal imaging courtesy of Nicole Flint, Mn/DOT
Anoka, MN pothole repair
Anoka repairs as of April 27, 2011.

<table>
<thead>
<tr>
<th>Holes</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Holes 1-5</td>
<td>Hole 1 (front) to Hole 5 (back)</td>
<td></td>
<td></td>
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</table>
Word spreads, and interest increases
DULUTH, Minn. (AP) — Minnesota researchers are trying an experimental way to fix potholes that uses powerful microwaves to heat the patch mix at the very site where the craters develop. As an added dividend, the technology provides a use for taconite waste and recycled asphalt and shingles.

During the summer, road crews can permanently repair potholes with “hot mix,” an asphalt-based mixture that bonds well to the holes. But in the winter, when the ground turns cold and many hot-asphalt plants close, crews must resort to temporary “cold patches,” which are usually pulverized by spring, leaving roads pockmarked and dangerous. “It’s incredible how much damage a pothole can do to a car,” says Kirk Kjellberg, an equipment salesman with Microwave Utilities in Monticello, Minnesota.

The company’s wintertime solution is to thoroughly thaw a hole with a 100,000-watt industrial microwave unit, boil out any moisture, and add asphalt. Conventional asphalt works fine, but Kjellberg is working with the Natural Resources Research Institute in Duluth to make a microwave-specific mix from recycled shingles and taconite tailings, especially since improved oil-refining technology is reducing asphalt supplies. The next step is to nuke the pothole again, heating the mix to about 300 degrees Fahrenheit to vulcanize the asphalt and create a tight bond. In all, the process takes less than 10 minutes.

Successful field trials in Minnesota have proved the concept. Kjellberg is uncertain what the commercial version will be like, but he envisions an all-in-one vehicle that would deploy the microwave, squirt out asphalt, and roll it flat. By his estimates, it will be several years before the mix hits the road.
Add value to offset transportation cost

From UTAC…

Based on the vessel draft survey (pers. comm., Mike Urie), a total of 2,171.55 NT of the ¾” product and 3,545.35 NT of the 1 ½” aggregate were shipped.

…to Hallett Dock in Duluth…

…to Chicago, Illinois, on June 2, 2009
What’s next?
$1.9 Million Spurs Job Creation for Northeastern Minnesota Mining Cluster
October 3, 2011

(Northland's NewsCenter)---A $1.9 million federal grant will help strengthen mining and steel businesses in the Northeastern Minnesota Mining Cluster.

The Natural Resources Research Institute in Duluth plans to continue to develop new products to assist with mineral recovery and research with the help of an $800,000 grant.

"We will be extending our aggregate program which is basically taking waste rock from mining and using it for growing businesses that are associated with road construction," Michael Lalich, Director of NRRI said.
Further Implementation

- Working with Lake County to secure additional federal support (via a TIGER Discretionary Grant) to rehabilitate, resurface, and upgrade County State Aid Highway (CSAH 14)/Forest Highway 36 in Lake County, MN, between Lake County CSAH 2 and the Lake/St. Louis County line to a 10-ton all-season capacity, with a durable bituminous pavement utilizing taconite mining byproduct rock for aggregate, reclaimed asphalt, and locally available sand.
Minnesota’s iron mining industry not only provides significant economic opportunities from the iron ore itself, but from innovative use of by-product and co-product materials generated in the course of mining and extraction of the iron ore.
Collectively, these materials can add value and sustainability to the overall iron mining activities while contributing quality materials needed for rebuilding and improving our nation’s transportation infrastructure.
• Taxpayers expect (and should get) longer service life from their roads
  ▪ They can get that from the materials used in their construction

• Adopt performance-based construction practices and policies that place a higher value on sound engineering and design principles, material quality, and life-cycle costing
  ▪ This approach can result in better and safer roads, and a significantly improved return on investment to the United States government and its taxpaying citizens.
Thank you

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