Documenting the Historical Use of Taconite Byproducts as Construction Aggregates in Minnesota – A GIS-based Compilation of Applications, Locations, Test Data, and Related Construction Information

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ABSTRACT
Aggregate shortages are causing increasing concern for population centers across the country. Meanwhile, Minnesota’s taconite mining industry generates over 125 million tons of mining and processing byproducts annually that hold aggregate potential of traprock quality. Materials such as blast rock, coarse crushed rock, and coarse tailings (collectively known as Mesabi Hard Rock) have been staples of northeastern Minnesota road construction for over four decades. Infrastructure is already in place to move these materials to markets throughout the country to augment local aggregate resources.

Because these highway construction applications are not widely known outside of northeastern Minnesota, this study was undertaken to: 1) document how and where taconite byproducts have been used; and 2) assemble related test data. Letters, interviews, site visits, and searches of archived records were the primary modes of data collection.

The product is a project report with a stand-alone Microsoft Access (or Excel) database and an ArcView GIS product containing mappable Mesabi Hard Rock usage locations with accompanying data. Topics that users can query include byproduct type, location, application, date, authority, and contact person. With such information, users can determine the applicability of this resource to their own projects.

Major findings:
• 400+ documented usages in Minnesota from 1960 to 2006, including 1,120 usage miles of roadway pavement and fill
• Primary Usages:
  1) Bituminous pavement (hardness, durability, and 100% fractured faces ideal for Superpave mixes)
  2) Fill (free-draining, ready-made fine aggregate equivalent)
• Minnesota Department of Transportation leads usage
INTRODUCTION

Aggregate shortages in general, as well as shortages of competent aggregates, will become increasingly prevalent in many areas of the country as demand grows and states expand or rebuild the infrastructure necessary to serve an increasing population. Large metropolitan areas such as Minneapolis-St. Paul and Chicago are particularly susceptible to aggregate shortfalls due to such factors as urban sprawl resulting in “land-locked” quarries (resource sterilization), permitting issues, and unfavorable public perceptions.

Tepordei and Bolen (1) put this issue in perspective as follows:

“The total projected cumulative production of aggregates — crushed stone and construction sand and gravel — during the next 25 years is estimated to be 92 billion tons, slightly more than the total amount of aggregates mined between 1900 and 1999. These projections suggest that very large quantities of crushed stone and construction sand and gravel will be needed in the future and will have to come, at least in part, from resources yet to be delineated” (our emphasis).

One solution to this growing problem is to increase the use of unconventional aggregate sources that are also, in effect, recycled industrial materials. Importantly, the use of recycled materials is encouraged under the “Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU),” Public Law 109–59—Aug. 10, 2005 119 Stat. 1787, as follows:

SEC. 5203. TECHNOLOGY DEPLOYMENT.

“(2) GOALS.—The goals of the innovative pavement research and deployment program shall include—

“(A) the deployment of new, cost-effective, innovative designs, materials, recycled materials (including taconite tailings [our emphasis] and foundry sand), and practices to extend pavement life and performance and to improve customer satisfaction;”

Byproducts of Minnesota’s taconite (iron ore) mining industry, which include blast rock, crushed taconite rock, and coarse taconite tailings (collectively known as Mesabi Hard Rock), not only represent some of the “yet to be delineated” aggregate resources discussed by Tepordei and Bolen, they also represent the types of recycled materials encouraged by SAFETEA-LU. Comparable to trap rock in quality, these materials have been staples of the road construction industry on Minnesota’s Mesabi Iron Range for over four decades (2).

The Mesabi Range – the historic iron ore/taconite mining district of northeastern Minnesota – extends about 100 miles from Grand Rapids at its southwest to near Ely at its northeast terminus (Fig. 1). There are currently six taconite mines and accompanying processing facilities operating on the Mesabi Range (Fig. 1B). Together, they generate about 125 million tons of these mining and processing byproducts every year, a figure that is more than double the entire state’s annual aggregate usage. A seventh, Cliffs Erie (LTV), closed in 2001. While not all of these taconite materials are suitable or available for use, the potential is still enormous.

Infrastructure for moving taconite aggregates throughout the country is already in place, due to 50 years of shipping taconite pellets. The taconite industry is served by major highways, two major railroads, and ship-loading facilities on Lake Superior at Silver Bay, Taconite Harbor, Two Harbors, and Duluth, Minnesota, and in Superior, Wisconsin (Fig. 1A and 1C). Materials trucked or railed to the Minneapolis-St. Paul metro area can be loaded onto barges for shipment down the Mississippi River.
FIGURE 1  Location maps of the Mesabi Iron Range with respect to:  A - Great Lakes shipping (3); B – taconite mining operations (2); and C – Railroads (4).
Since the year 2000, the Natural Resources Research Institute (NRRI), University of Minnesota Duluth, has been investigating how these vast quantities of taconite mining byproducts can be used for construction aggregate purposes on an expanded basis. With major support from the U.S. Department of Commerce, Economic Development Administration, the NRRI is presently conducting a comprehensive three-year (2006 - 2008) research and demonstration program designed to: 1) identify new and economically viable uses for Minnesota taconite aggregates, i.e., Mesabi Hard Rock, in road construction, road repair, and other applications where crushed stone aggregate is needed; and 2) conduct demonstration projects inside and outside Minnesota, including several targeted Upper Midwest states (5).

A variety of aggregate materials are used throughout the Midwestern region of the United States in highway construction. Because taconite aggregates will have to compete with these existing materials based on both their physical attributes and the net value they will bring to a road project, a decision was made to make them more recognizable to potential end-users by “branding” them Mesabi Hard Rock™ relative to NRRI’s broad-based taconite aggregate program (5). To be clear, Mesabi Hard Rock™ is neither identifying nor endorsing a specific commercial taconite aggregate product, but instead is used as a unique shorthand descriptor for taconite-based aggregates in general. However, given the technical nature of this TRB report, it is appropriate for the trademark (™) symbol to be omitted to avoid any misinterpretation of its intended use.

The compilation and documentation of historical (and new) technical information on taconite aggregate usage in Minnesota – the subject of this study – is a major and necessary part of the NRRI research program. Why? Because if taconite aggregates are to gain greater acceptance beyond the immediate usage area, potential end-users – especially those in the Minneapolis-St. Paul area and in surrounding states – will want documented assurance that these materials have, and can be, used stand-alone or blended with local aggregates to produce more competent and durable pavements and other aggregate-based products.

To do so, a GIS product was produced documenting the historical use of taconite byproducts as construction aggregates in Minnesota, with particular focus on its use in road construction. Included in the GIS product are the various available aggregate products, their applications, locations of use, and supporting documentation including, where available, Minnesota Department of Transportation (Mn/DOT) design plans and specifications, and test data. The objective is to provide an accessible means to engineers, designers, contractors, and others of determining the applicability of taconite aggregate products for their individual needs. The remainder of this report is devoted to: 1) describing how this objective was achieved; and 2) presenting the study’s findings.

OVERVIEW

**Taconite Aggregate Products**

Taconite is an iron bearing sedimentary rock composed of alternating chert and slate units of varying thickness. It is very hard, dense, low-grade iron ore. Taconite mining and pellet production generate three aggregate-applicable byproducts:

1. Taconite Blast Rock
2. Coarse Crushed Taconite Rock
3. Coarse Taconite Tailings.
Blast rock is “waste” taconite rock that must be drilled, blasted, and removed to gain access to the mineable taconite ore. Blast rock can range in size from large slabs to fine powder. It generally refers to material that is greater than 6 inches in size. Blast rock can be used for armor stone or riprap, or it can be processed to specification to produce ballast material and other coarse taconite aggregate fractions.

Coarse crushed rock is “waste” taconite rock that has undergone crushing or grinding to meet a particular size specification, e.g., -2½ inch, -¾ inch, -½ inch. This material is derived from further processing of blast rock during pellet production or by separate crushing operations. Crushing produces angular particles, while grinding produces rounded particles. Physical testing by Mn/DOT’s Office of Materials in Maplewood, Minnesota, of taconite aggregate samples collected from four distinct iron-formation “waste” horizons (ledges) showed the taconite rock to generally meet or exceed the durability criteria Mn/DOT has set for Class A rock. For example, the four samples tested as follows: absorption ranged from 0.54% to 1.8%; Los Angeles Rattler (LAR) ranged from 14% to 17%; and magnesium sulfate soundness ranged from 0% to 4% (\(^6\)).

Coarse taconite tailings are a byproduct or “waste” produced during the concentrating portion of the taconite pellet production process. They are by far the most frequently used taconite aggregate product. Coarse taconite tailings are a market-ready product (fine aggregate equivalent) that is - 3/8 inch in size and contains very low fines (-200 mesh). A very consistent product is generated by three of the taconite producers – Minntac, ArcelorMittal Steel Minorca Mine, and United Taconite – as a result of using a process that separates coarse tailings out of the system before they are mixed with the fine tailings produced by further crushing. The amount of fines (-200 mesh) contained in the coarse taconite tailings from these three operations is generally < 2.5% (\(^7\)). Currently, coarse tailings are not separated from fine tailings in the Hibbing Taconite (Hibtac) and Keewatin Taconite (Keetac) concentrators. Combined tailings flow as a slurry to the tailings basin in two flumes at Hibtac, and through a pipe at Keetac. While some size separation is achieved as the larger particles settle out of the slurries near the points of entry to the basins, coarse tailings from these two operations have a more variable size distribution.

Taconite Aggregate Usage in Northeastern Minnesota

Highway projects in northeastern Minnesota routinely utilize taconite aggregates for construction aggregates. Many segments of US Trunk Highway 53 (US TH53) from Duluth to International Falls are paved with bituminous mixes containing taconite byproducts. This is also the case for other major highways in the region, including Minnesota Trunk Highway 61 (Minnesota TH61) from Duluth up the North Shore of Lake Superior to Grand Marais; Minnesota/US TH169 from Ely to Grand Rapids; and Minnesota TH1 from Ely to Illgen City on the shore of Lake Superior (Fig. 2). Figure 2 also shows the 2006 annual average daily traffic (AADT) volumes for major highways in northeastern Minnesota (\(^8\)).

Highway segments may also rest on base, sub-base, subgrade and / or embankment of coarse taconite tailings, overlie culverts resting on and backfilled with coarse taconite tailings, or incorporate taconite tailings as filter rock in edge drains. In addition, coarse taconite tailings are used in bituminous mix as a crack-sealing compound. Municipalities across the Mesabi Range, as well as the city of Duluth, have used taconite byproducts in city streets for drainage, fill, subgrade, base, bituminous non-wear and wear courses, and bituminous overlays.

From Mn/DOT to the highway departments of St. Louis, Lake, and Itasca counties and the Public Works departments of local municipalities such as Virginia, Hibbing, and Grand...
Rapids, taconite byproduct usage in road construction has been widespread and well documented over the past forty-plus years. Identification of existing roadways and structures that incorporated taconite byproducts into their composition provides excellent opportunities for conducting follow-up field observations and locating historical source material from which to draw test cores. Evaluation of such cores can help determine how these materials wear over time and under severe usage and climate conditions, as some structures have been in place for over forty years. Relating structural performance to physical test data, as collected from archived records, can enable prediction of future performance, and yield a historical base on which to proffer these materials as suitable aggregate materials for in-state and out of state distribution.
RESEARCH METHODS

Documenting where taconite byproducts have been used as construction aggregates began with sending out an introductory letter describing the project and its prescribed outcome. Letters were sent to over 50 individuals representing Mn/DOT; St. Louis, Lake, and Itasca counties; northeastern Minnesota municipalities; contractors; engineering firms; testing firms; and industry representatives.

The letters were followed up by phone contact seeking documented and anecdotal usage information and supporting materials such as plans, maps and test data. Responses were very positive, and generated further contacts, resulting in over 100 individuals contributing to this survey.

Mn/DOT allowed access to its construction files, which provided a wealth of project and construction-related data. In addition, Mn/DOT District 1, Duluth, hosted a meeting of current and retired engineers and others that had been involved in using taconite byproducts on state road projects. Their recollections and descriptions of, and hands-on experience with, taconite-based aggregates provided valuable insights to the project. Discussion centered on usage locations, applications, product value and handling characteristics.

All of the data collection tools and methods just described, i.e., a copy of the introductory letter, a listing of contributing individuals and their corresponding affiliations, and highlights of various discussions, and other supporting information/documentation, are available as supplemental project products.

DATA COMPILATION AND GIS PRODUCT

Project Data Compilation

Information regarding the past use of taconite aggregates was obtained from archived and current project files and from interviews. Historical usage data collected for this project were assembled into the following two main products:

1) Mesabi-Hard-Rock_Usage_110807 Spreadsheet / Database; and
2) EDA MHR Usage 0607 ArcView GIS Product (map and shape files).

Usage Spreadsheet / Database

An inventory of the reported historical uses of taconite byproduct aggregates was created in the Mesabi-Hard-Rock_Usage_110807 Excel spreadsheet to document all usage data obtained from this study. Data may be project- or site-specific and reference a specific mappable location, or it may be more general in nature and reference area. Data entered include: project name, project type, project location, project number, project size, type of product used, test data availability, application and source of information. Each data item has been given a NRRI unique number that consists of the county code plus 3 digits. In addition to project data, definitions and a listing of available test data are also included in the spreadsheet.

ArcView GIS Product

A map, EDA MHR Usage 0607, was created in ArcView 3.3 format using shape files obtained from the Minnesota Department of Transportation (Mn/DOT) and the Minnesota Department of Natural Resources websites. All project data that had mappable locations were incorporated into the base map. Projects for this study appeared to fall into two main categories: roads and structures. Roads were further subdivided into road projects with known beginning and end
points, and road projects with only general locations. To plot the projects, three ArcView themes were created and are included: Road – Line, Road – Point, and Structure – Point. Project data from the Mesabi-Hard-Rock_Usage_110807spreadsheet were then joined to project locations using the NRRI unique number.

Many of the project files obtained from Mn/DOT included standardized forms containing project field data (e.g., gradations, oil content in bituminous). Maps, test data and other related documents were scanned so that copies of the original documents are available.

**PROJECT FINDINGS**

**Data Collection Results**

Over 400 usage records for taconite aggregates have been entered into the project spreadsheet / database. These records span the time from 1960 to 2006, a period of 46 years. Data were obtained from original project files containing design specifications, test sheets, and construction diaries, and from provided maps and project listings. Supplemental information was obtained via phone conversations.

Multiple usage records may exist for a given geographic location if multiple byproducts, e.g., coarse crushed rock and coarse taconite tailings; multiple applications, e.g., bituminous wear / non-wear, base, sub-base, subgrade; or multiple years, e.g., 1970, 1995, were involved. On occasion, multiple usage records may have been created for a specific project when more than one source provided information pertinent to the project. This was done in an effort to attribute the information to the source for reference purposes.

**Data Trends**

*Product Usage Distribution*

The predominant usage for taconite aggregates over the past 46 years has been in bituminous pavement (Fig. 3). Three factors have contributed to this. First, coarse taconite tailings are market-ready “as is,” i.e., no additional processing is required for them to meet specifications as fine aggregate equivalent or select granular borrow. Second, the mines long considered coarse tailings to be a waste product, so it was often available at a minimal cost. Changing times and economic conditions have now placed value on this byproduct. A third factor was the 2361TT (taconite tailing) overlays that were predominant from the 1970s into the 1990s. These overlays used 100% taconite tailings and produced a strong durable surface with excellent skid resistance properties. Taconite tailing overlays were laid down throughout Minnesota in the 1970s in areas as diverse as Minneapolis, Willmar, Moorhead, Duluth, and the Mesabi Iron Range. Some of these overlays are still in place. A down side to the 2361TT mix was the higher oil content (7.5%) required due to the angular nature and low fines content of the tailings.

In more recent years, taconite tailings have been incorporated as one of several components in bituminous mix design. In 2001, major highways in the vicinity of Eveleth, Gilbert, and Virginia, Minnesota received taconite tailing overlays. While some contained 100% taconite tailings, others contained varying percentages. An advantage to working with coarse taconite tailings, in addition to the wear properties they impart to pavements, is that they provide excellent control of volumetric properties in mix designs, making it possible to pass all state and county specifications (D. Gustafson, pers. comm., 2006).
Coarse crushed taconite rock aggregates have only come into use during the last decade. While taconite operations have brought contractors in for the past thirty years to crush waste rock for on-site use, little thought was given to outside sales. A local contractor began a mine site ballast production operation in 1989. By 2006 production had grown and 2.3 million tons of taconite aggregate was being crushed to specification (D. Klun, pers. comm., 2007).

Blast rock, unless further crushed to produce coarse aggregates, sees more limited use. Some has been used as armor stone for safe harbor construction along the north shore of Lake Superior and as riprap. However, greater interest has been expressed recently for using blast rock for waterway/shore land protection applications because taconite has a higher compressive strength and specific gravity and is more durable than most conventional rock. It is less likely to break down under wave action and more likely to stay in place. Blast rock has also seen growing use in landscaping applications.

**General Applications**

Seven general applications have been identified for the taconite aggregates, without regard to product (i.e., blast rock, coarse aggregate, or coarse tailings) (Fig. 3):

1) Bituminous Pavement
2) Fill
3) Drainage
4) Soil Amendment
5) Concrete Pavement
6) Concrete Structures
7) Other
In the spreadsheet / data base each application is further subdivided into general uses and specific uses (Fig. 4).

FIGURE 4 Mesabi Hard Rock Usage spreadsheet, subdivisions of taconite aggregate application.

Bituminous pavements and fills account for nearly all (92%) of the product uses and will be discussed in more detail below. A third general application is for drainage. This would include edge drains running parallel to pavements. Drainage is often a consideration in choosing coarse taconite tailings as fill. Tailings serve a dual purpose in many locations. While performing as subgrade, sub-base, or base, they also effectively drain water away from the road surface. Their typically low (<2.5%) fines content inhibits water being drawn up to the surface by capillary action, which also minimizes frost-heave (7).

The soils application is an interesting one, unrelated to road construction. In one instance, coarse taconite tailings were used in a 50:50 mix with topsoil to alleviate drainage problems on the Virginia Golf Course. The other applications involved coarse taconite tailings that were hauled to Indiana, Ohio and Texas for use as a soil amendment in farm fields.

The “Other” category includes winter sand, landscape rock and exterior building stone. Use of taconite tailings for winter sand goes back to the 1960s. It was applied on Minnesota...
TH61, along Lake Superior’s north shore, and other roads in Lake County. Today it is used in Mn/DOT’s Virginia district in a 50/50 mix with road salt.

**Bituminous Pavement**

Taconite aggregate usage in bituminous pavement was reported to fall into three categories: roads, airports, and parking lots. Use of taconite aggregates in bituminous roads was by far the dominant usage. The 100% fractured faces of the coarse crushed aggregates and the coarse tailings, coupled with superior hardness and durability, make taconite aggregates ideal for Superpave mixes. One of the first Superpave projects done in Minnesota was an eighteen-mile stretch near Floodwood on US TH2 in the 1990s (Fig. 2), and coarse taconite tailings were used in the mix.

The airport category is a fairly recent development for taconite aggregates, going back to 1999. Due to strength and durability, taconite aggregates are seeing use at small regional airports and in aprons and runways at the Duluth International Airport.

Figure 5 provides more insight into how taconite aggregates are being used in bituminous road pavements. These categories are based on data as provided. It is likely that in a number of cases, what was provided as “wear course,” for example, would actually fall under “overlay.”

**Road Fill**

Taconite aggregates have been used in all aspects of road fill, from subgrade up to base, and as embankment fill (Fig. 6). Coarse taconite tailings make up the bulk of taconite fill aggregates. They are used as base, sub-base, subgrade, granular and select granular material.

Coarse crushed taconite aggregates are increasingly used as base material in total reconstruction projects, as well as in new construction. The photo in Figure 7 shows taconite aggregate used as base on the 6th Avenue reconstruction project in Virginia, Minnesota. According to the City of Virginia, Minnesota, Engineer, this project, done in 2006, used 2 to 6 feet of coarse taconite tailings as common or select borrow and 24 inches of ¾-inch coarse crushed taconite as sub-base and base (B. Hennis, pers. comm., 2007).

**Embankment Fill**

As shown in Figure 6, only two occurrences of embankment fill are included in the database. One of these, however, accounts for nearly 1.82 million tons of coarse taconite tailings: construction of the US TH53 / Minnesota TH169 interchange north of Virginia, Minnesota in 2004 and 2005 (Fig. 8).

Coarse taconite tailings are used as fill and embankment material as their low 200-minus content and interlocking angular shape makes for strong, free-draining set-up (2). They generally meet the specification for select granular. Coarse tailings are placed with water to maximize particle consolidation. However, Mn/DOT engineers report that a 3-inch cap of a graded aggregate is required to reduce fluff in the upper surface as moisture is lost in the free-draining tailings.

The value of coarse taconite tailings as embankment fill also has been recognized by the mining companies for the construction of tailings basin dams. Coarse tailings have a high friction angle which helps minimize slope failure. For example, these basin dams average 60 feet high at Hibbing Taconite but can be considerably higher.
FIGURE 5  Specific uses of taconite aggregates in bituminous pavement.

FIGURE 6  Specific uses of taconite aggregates in road fill.
FIGURE 7  Coarse crushed taconite aggregate used as base material on 6th Ave. in Virginia, Minnesota, 2006. Photo by M. Meinders Patelke.

FIGURE 8  Coarse taconite tailings as embankment fill on US TH53 / Minnesota TH169 interchange construction north of Virginia, Minnesota. Photo by K. Adolfs.
Large volumes of coarse taconite tailings, as above, have generally been used only in close proximity to the taconite mines for fill and embankment purposes. This is changing, however. Trainloads of tailings were hauled to Duluth, Minnesota for reconstruction of US TH53 in 2004 and 2005. They were used in the roadbed and as geotechnical fill behind high retaining walls.

_Taconite Aggregate Highway “Usage Miles”_

From project specification books and plotting project start and stop points in ArcView, “usage miles” were obtained for a significant number of database entries. Usage miles are defined as the number of miles a given application (i.e., bituminous pavement, fill, drainage, etc.) was used on a project. If taconite aggregates were used for more than one application on any given project, the total usage miles would reflect the sum of usage miles for the individual applications. Thus, the project usage miles could be, in certain cases, 2 or 3 times the actual project length.

The total usage miles of taconite aggregate use, where determined, is 1,120 miles. Broken down by application, this comes to 974 miles of bituminous pavement and 124 miles of fill. The usage miles of fill may be overstated. The count for fill assumes that the aggregate was used for the entire length of the project.

Taconite aggregate usage miles for road fill applications can be broken down by type as follows:

- Base 70 miles
- Sub-base 44 miles
- Sub-base/subgrade 3 miles
- Subgrade 6 miles

The figures include both coarse crushed aggregate and coarse taconite tailings. Base and sub-base are the most common uses.

_Taconite Aggregate Use in State, County and Municipal Projects_

Project numbers, where available, are included in the database, indicating the project’s responsible authority, i.e., state, county, or municipality. A total of 105 project numbers were obtained. Project authority breaks down as follows:

- SP (State Project) 80
- SAP (State Aid Project) 10
- MSAP (Municipal State Aid Project) 7
- CP (County Project) 6
- MP (Municipal Project) 2

Over 85% of the cited projects were sponsored by Mn/DOT, a figure biased by Mn/DOT being the dominant source of our data.

**PROJECT SUMMARY**

Changing times and economics have altered the perception of what was once termed “waste” in the taconite mining industry. “Waste” has potential to become a premier aggregate resource. Coarse taconite tailings, together with blast rock and crushed taconite rock, comprise what has been termed Mesabi Hard Rock, aggregate products bearing the strength and durability of trap rock. Coarse tailings exit the ore concentrating process as a market-ready product. Blast rock and coarse crushed rock, once thought of merely as waste rock to be removed and stockpiled in order to get at the iron ore, now are crushed to specification to produce aggregate products.
Taconite aggregates have been a staple of the road construction industry on the Mesabi Iron Range in northeastern Minnesota for over four decades, particularly in areas of close proximity to taconite mining operations (Fig. 9). Locally it has been primarily used in road construction for fill and bituminous pavements. Cities such as Duluth, Virginia, Hibbing, Eveleth, and Mountain Iron, as well as Mn/DOT and the local county highway departments, have found these “waste” products to be a valuable resource, particularly the coarse tailings that serve as ready-made fine aggregate equivalent. Infrastructure to distribute taconite aggregates is already in place due to 50 years of shipping taconite pellets.

This project has built a database and GIS product of locations where taconite aggregates have been used in Minnesota. It is searchable by project number, location, product, application, general or specific use, contact source, and more. Specific notations about a given entry can be found in the remarks column. This database / GIS project can be used by parties interested in taconite aggregate products as a guide to usage locations for visual inspection or further testing by means of coring. It provides references to state, county, and municipal personnel, as well as contractors, engineers, and industry representatives that can address issues related to the use of these aggregate products.

As NRRI’s taconite aggregate research program continues, more use data will be obtained and added to the existing database and GIS product, and updates will be made available.

ACKNOWLEDGEMENTS
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Locally, over 100 individuals have contributed to this compilation of the historical use of taconite byproducts as construction aggregates in the state of Minnesota. Engineers, administrators, technicians and operators, current and retired, from state, county, and municipal governments and government agencies, engineering firms, construction companies, testing laboratories, consulting firms, taconite mining operations, and industry support groups have provided the project data and supplemental information contained in the GIS product. We gratefully acknowledge each of these contributors.

Special recognition is due to several retired and current Mn/DOT personnel for providing access to project data. This includes: D. Marvin Hill (former Senior Transportation Specialist), Al Schenck (former head of analytical laboratory), Kevin Adolfs (Resident Engineer), and Ted Sexton (Resident Engineer).
FIGURE 9  Map of taconite aggregate usage in Minnesota, modified from Oreskovich and Patelke (2).
REFERENCES


