NRRI TSR 2007/05

A Brief History of the Use of Taconite Aggregate (Mesabi Hard Rock™) in Minnesota (1950s – 2007)

By

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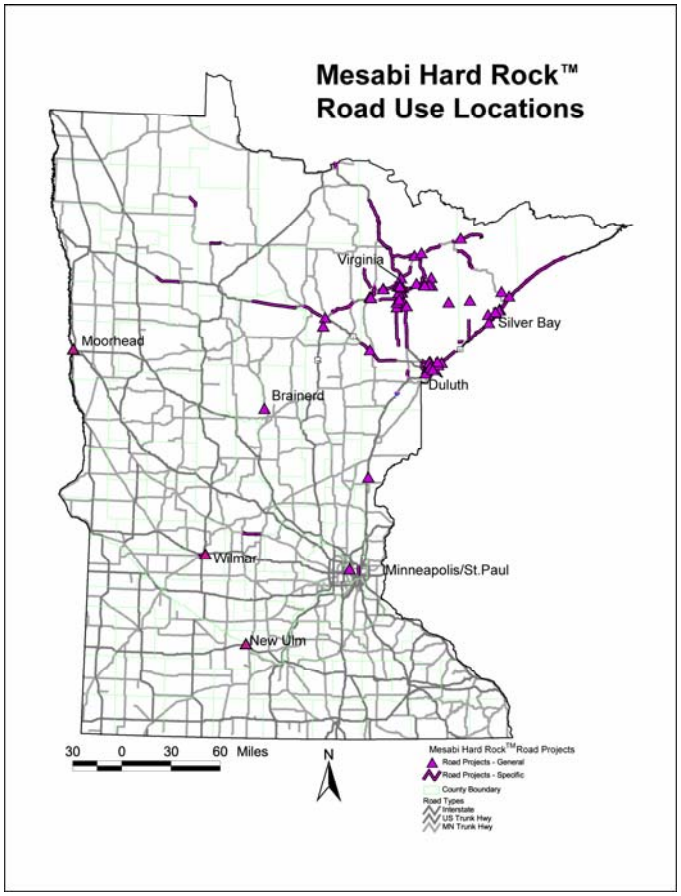

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Cover Photo
Minnesota's Mesabi Hard Rock™ historic use locations.

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ABSTRACT

Taconite aggregates (collectively termed Mesabi Hard Rock™) have been used as construction aggregate in Minnesota for nearly 50 years, dating back to the early days of the taconite industry. Coarse taconite tailings are a ready-made, free-draining, fine aggregate equivalent suitable for use as select granular and fine filter aggregates. Their angular interlocking form, when placed with water and covered with Class 5, produces sound embankment fill material. Their hardness, strength and durability produce superior wear and friction properties in bituminous mixes. This, coupled with 100% fractured faces, makes them ideal for Superpave mixes. Their cleanness (very low -200 mesh) makes them a valuable tool for adjusting volumetric properties in bituminous mix design. Crushed taconite rock brings the same hardness, strength and durability to the coarser aggregate size fractions, making it ideal for crushing to desired specifications for use as fill, filter material and the coarse aggregate component in bituminous and concrete mixes.

Historically, taconite aggregate products have been used most when road construction, maintenance, and repair projects are in close proximity to the taconite operations, i.e., on the Mesabi Range. The 1970s and 1980s saw the use of coarse taconite tailings spread to the Twin Cities metropolitan area, as well as to the southern and western reaches of the state for use in bituminous overlays and surfacing. The 1990s and 2000s saw taconite aggregates become a staple of Duluth area bituminous contractors and road constructors, to the degree that they are used in some capacity in nearly every project.

Millions of tons of taconite byproducts are produced every year in the mining and pellet production process. Couple this with nearly 50 years of production and the enormous size of this resource becomes obvious. While much of this material is consumed by the taconite mines for day to day operations (haul roads, tailings dams, shovel pads, drill hole stemming, etc.), much remains stockpiled and available for use. Infrastructure already in place for shipment of pellets (roads, railroads, and Lake Superior docks and ship-loading facilities) can be accessed for shipment of aggregates throughout the United States and beyond.

This report is a historical narrative of the highlights of taconite aggregate usage as road construction aggregates in Minnesota. It documents how taconite byproducts have evolved from stockpiled "wastes" to become premium "in-demand" aggregates suitable for meeting today's infrastructure needs.

BACKGROUND

Taconite mining and processing began on the Mesabi Iron Range in the mid-1950s. Since those early days, prodigious amounts of waste or byproducts suitable for use as construction aggregates have been generated in the processes leading to the production of taconite pellets. (See Oreskovich et al., 2007, Appendix A-3 for a description of the taconite production process.) Today, with six taconite plants in operation (Fig. 1), millions of tons of byproducts are produced annually. Among those byproducts usable to the construction industry are blast rock, cobber rejects (non- or weakly-magnetic crushed material that remains following a magnetic separation process), and coarse taconite tailings. Blast rock is suitable for crushing to spec, i.e., ballast, coarse aggregate, Class 5, etc.

The first two taconite operations to come on line were Reserve Mining Company (present site of Northshore Mining Company) at Silver Bay in 1955 and Erie Mining Company (later became LTV Steel Mining Co.; closed in 2001) at Hoyt Lakes in 1957 (Fig. 1). Pilotac, the precursor to Minntac, also began operations in the 1950s. Four more taconite operations came on line in the later 1960s. Pellet production began at Eveleth Taconite Company (now United Taconite LLC), Eveleth, in 1965. These operations were followed in 1967 by U.S. Steel's Minntac plant at Mountain Iron, the National Steel Pellet Company (now Keewatin Taconite) at Keewatin, and Butler Taconite at Nashwauk (closed in 1985; not shown on map). The final two operations, Hibbing Taconite Company, Hibbing, and Inland Steel's Minorca Mine (now ArcelorMittal Minorca Mine Inc.), Virginia, began producing pellets in 1976 and 1977, respectively. A listing of current mining operations on the Mesabi Range can be found in Oreskovich et al., 2007, Appendix A.

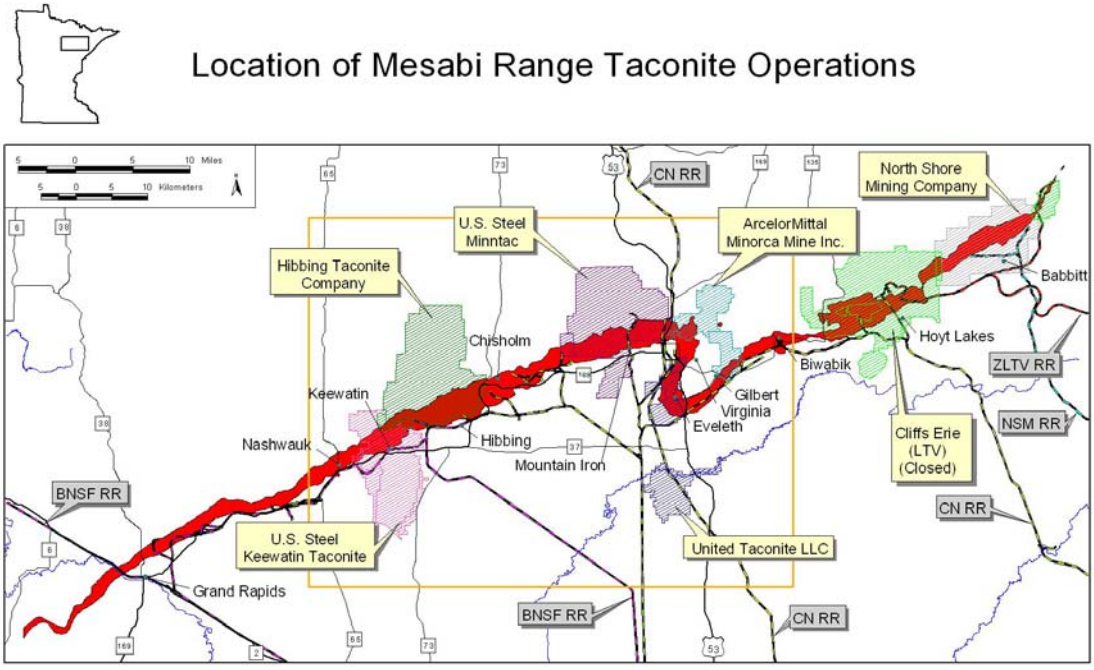

Figure 1. Taconite operations on the Mesabi Range.

1950s AND 1960s – THE EARLY YEARS

Up the North Shore

Reserve Mining and Silver Bay Town Site

Taconite byproducts were used as construction aggregates by 1960 in the town of Silver Bay, Minnesota, located up the north shore of Lake Superior from Duluth (Fig. 2). Silver Bay began as a company town in the 1950s with the construction and opening of Minnesota's (and North America's) first taconite processing plant by Reserve Mining Company. The plant began operating in 1955.

In 1960, when the plant expanded, Reserve Mining Company set up its own concrete batch plant on-site for internal use. The plant expansion and subsequent

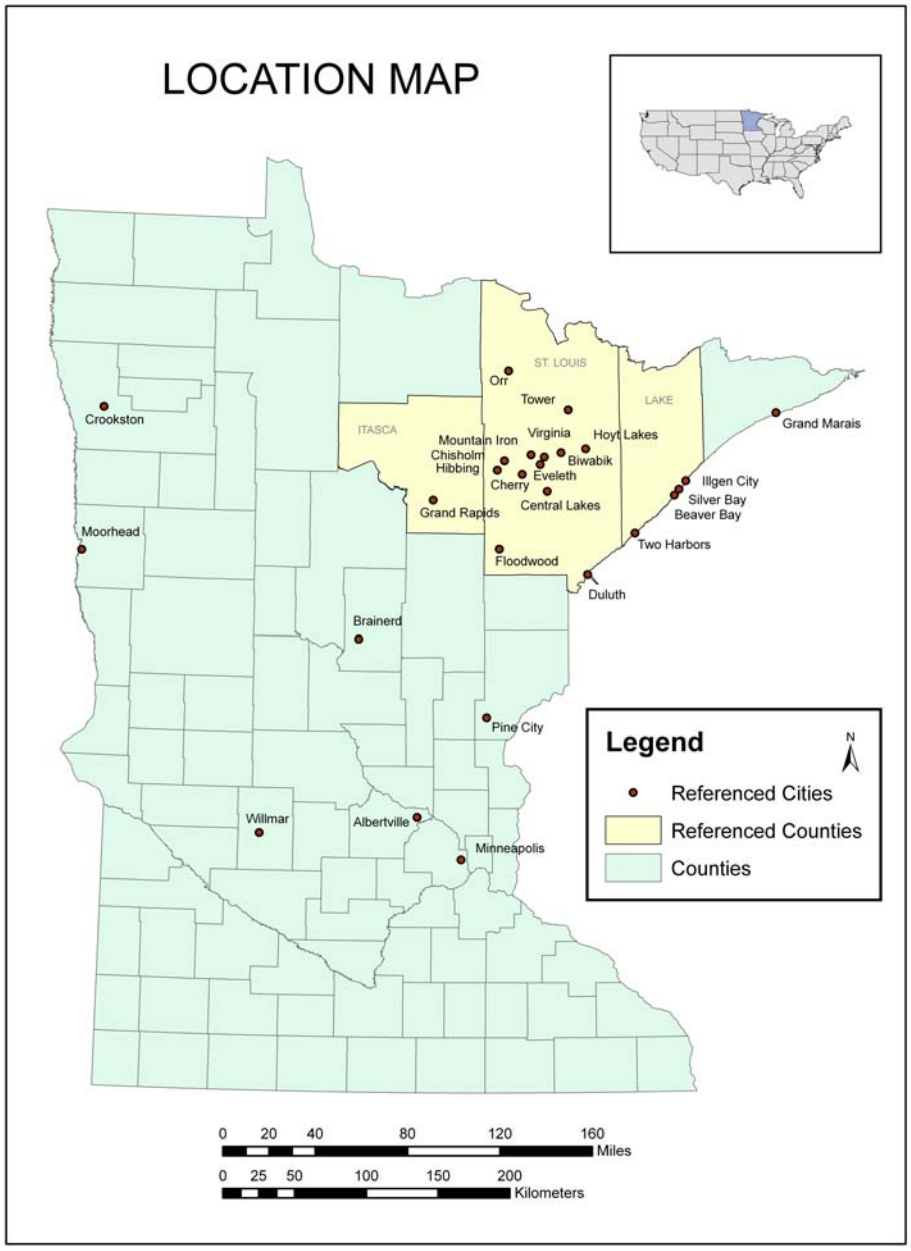

Figure 2. Location of cities and counties referenced in text.

additions to the facility used tailings in concrete mixtures for floor slabs and foundation walls (J. Viola, project engineer for Reserve Mining, pers. comm., 2006). For example, the dry cobber area in the plant has floors made of tailings concrete. Viola estimated that thousands of cubic yards of concrete were produced. Test cylinders of the concrete were taken to Duluth for testing, generally breaking at well over 4,000 psi.

The city of Silver Bay expanded in 1960 to accommodate the growing workforce. Reserve Mining tailings were used as base and sub-base under city streets to an estimated depth of 18 inches (J. Viola, pers. comm., 2006). Reserve Mining Company also provided tailings at no cost to the citizens of Silver Bay. Loaded haul trucks were driven into the city where they were dumped (A. Goodman, Lake County Highway Engineer, pers. comm., 2006). The tailings were mixed with cement to create driveways and slabs. Driveways were constructed with a 1-foot depth of tailings. Tailings were also used as base material under and around foundations (J. Viola, pers. comm., 2006).

Early Highway Use

Tailings were first used in road construction by the Minnesota Highway Department (MHD, precursor to Mn/DOT) in 1958 (A. Schenck, Mn/DOT (retired), pers. com., 2006). Tailings from Reserve Mining Company were used as stabilized bituminous sub-grade under Minnesota Trunk Highway 61 (MN TH61), which runs along the north shore of Lake Superior. By 1961, MHD was using taconite tailings from Reserve Mining as fill and in bituminous pavement on County State Aid Highway 4 (CSAH4) located northwest of Beaver Bay. The base material is still in place (A. Goodman, pers. comm., 2006). During the following construction season, 1962, Reserve Mining tailings were used as base material and in bituminous on MN TH61 in the Split Rock area. The tailings were trucked right off the delta in Lake Superior. For paving, a bituminous plant was set up on the tailings delta to produce hot mix (D. Flemming, Mn/DOT (retired), pers. comm., 2007). Schenck (pers. comm., 2006), an MHD survey crew member at the time, recalled doing a major backfill of at least 40 feet of tailings over a triple box culvert in the Split Rock area.

In 1969 and 1970, MN TH61 was constructed from the state maintenance garage north of Palisade Head to ½ mile north of the junction of MN TH61 and MN TH1, in the area of Illgen City (Fig. 2). Reserve Mining Company tailings were used for the entire road thickness (approximately 4 ft.) (D. Flemming, pers. com., 2007). The road was dug to 3 feet, on average, and tailings were used as sub-cut fill. This fill was capped with a sub-base and base of tailings, and then topped with bituminous pavement made with the tailings. The bituminous was laid in three courses: a base course that used a lower percentage of oil, a middle or "binder" course, and a top "wear" course. The original road is still intact (although it may have been overlaid), and has held up very well (D. Flemming, pers. com., 2007).

This same project also involved the use of tailings for culvert base and fill. Because of the many creeks and ravines in the area, upwards of thirty culverts were laid, averaging every ¼ mile. Ten to twelve of these culverts were large enough to walk through (D. Flemming, pers. com., 2007).

Taconite tailings were used to pave MN TH61 all the way from Two Harbors to Grand Marais (J. Foldesi, Lake County Highway Dept., pers. comm., 2006). This original pavement was probably 5-6 inches thick. Several projects have involved milling this pavement down 2 inches and replacing it with a limestone pavement. The remaining thickness of the original

pavement (3-4 inches) would still be in place (J. Foldesi, pers. comm., 2006).

Virginia

In the city of Virginia, Mn/DOT's first use of coarse taconite tailings came in 1960 as backfill at Mn/DOT's building site on Hoover Road, a low lying area typical of many building sites in the area (D. Hill, Mn/DOT (retired), pers. comm., 2006). Engineered fill would become a very common use for coarse taconite tailings on the Mesabi Range. Because coarse tailings contain a very low percent of fines (< 2.5% -200 mesh in coarse tailings from USX-Minntac, ArcelorMittal Minorca Mine Inc., and United Taconite LLC (Zanko et al., 2003)), there is no capillary action with moisture in the material, and thus no frost heave (D. Hill, pers. comm., 2006).

Construction of the U.S. Trunk Highway 53 (US TH53) beltline around the city of Virginia took place in the late 1960s. Because it was constructed on a swamp, large amounts of coarse taconite tailings were used as fill. Depths of fill ranged to as much as 30 feet on the north end of the project (D. Hill, pers. comm., 2003). Hill related that Mn/DOT learned much about working with tailings during this project. The project was originally designed without Class 5 to contain the tailings before paving. Tack was shot to stabilize the tailings. This made the tailings sticky, causing them to build up on equipment tires. It became obvious that a bituminous working surface had to be built. Today, three inches of Class 5 base are placed on top of coarse taconite tailings in order to stabilize the top (D. Hill, pers. comm., 2006).

1970s - ERA OF TACONITE TAILINGS OVERLAYS

Beyond the Range

The 1970s saw the rise of taconite tailings usage in bituminous overlays. The 2361TT mix was designed for this purpose. From the Mesabi Range to the Twin Cities metropolitan area and beyond, tailings were in demand for ¾- to 1-inch overlays. The dense angular particles imparted strong wear characteristics and excellent skid resistance to road surfaces. Overlays of taconite tailings laid down in the 1970s are still holding up today in locations ranging from Grand Rapids in northern Minnesota to Moorhead in the west and Willmar in the south.

Eleven miles of taconite tailings bituminous overlays were laid down on the city streets of Willmar, located in south central Minnesota, in 1970 (Fig. 3). A map provided by the City of Willmar bears the notations "5/8" MHD (Minnesota Highway Department) Bit. (bituminous) overlay with taconite in the mix." Approximately four city blocks of the original 1970 taconite tailings overlays remain in place today (M. Odens, Director of Public Works, Willmar, pers. comm., 2006).

In 1975, around 60,000 tons of taconite tailings were used throughout Minnesota, including the Duluth and Minneapolis metropolitan areas, for highway and bridge deck resurfacing on state projects (Collins, 1976). They were used on State Highways 36 and 280 in the Twin Cities metro area (W. Murphy, Associated General Contractors (AGC), pers. comm., 2003). That same year, another 23,000 tons of taconite tailings were used on Interstate 35-E and 35-W in the Minneapolis-St. Paul area (Collins, 1976).

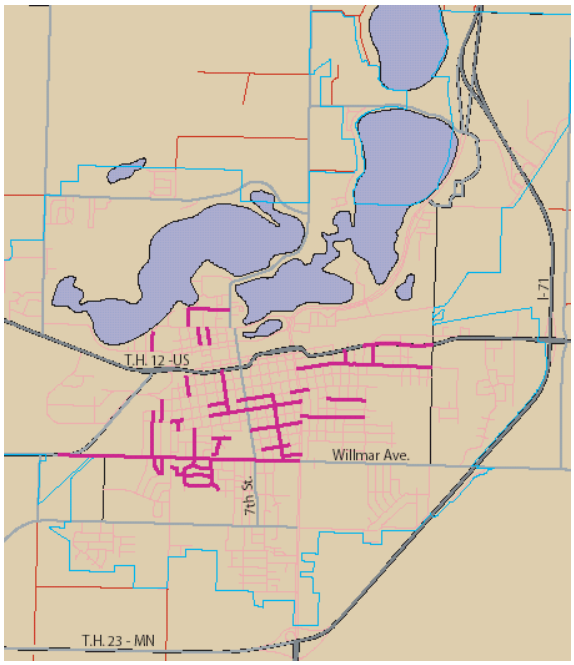

Figure 3. City of Willmar taconite tailings overlays.

A Federal Highway Administration (FHWA) report on mining wastes and their potential for use as highway material (Collins, 1976) cites thin surface overlays as the primary use of taconite tailings. It further states:

> "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."

Other Minnesota uses for taconite tailings listed in the FHWA report were embankment fill, base and sub-base material, and in bituminous mixtures. The report states that lack of cohesiveness is the main difficulty in using the tailings as base and sub-base. However, it goes on to state that this can be rectified by maintaining the tailings in a moist condition and by using an asphalt emulsion to stabilize the top three inches.

South of Eveleth

South of Eveleth, approximately 33 miles of CSAH 7 received a full depth (12" or 16") bituminous pavement with 100% taconite tailings in 1974. Oil content of the mix was 8.5% (R. Young, St. Louis County Public Works Dept., pers. comm., 2006). This 30+ year pavement is still in place. Young reported that the road is scheduled to be redone in the near future.

THE 1980s - BOOM TO BUST

The 1980s saw a major downturn in the demand for Minnesota's iron. Butler Taconite closed for good, reducing the number of mines from 8 to 7. The entire Mesabi Range economy was affected.

The overlay trend of the 1970s continued, although it stayed closer to home. A widely publicized court case regarding Reserve Mining Company dumping tailings into Lake Superior and questions of health issues associated with the mineralogy of the Reserve Mining tailings caused Mn/DOT to shy away from the use of taconite tailings away from the Mesabi Range. Because the geology of the iron-formation changes on the far east end of the Range, Mn/DOT drew a line through the Erie Mining / LTV Steel pit and declared that only taconite materials taken from west of the line could be used on state roads.

Mn/DOT continued to use coarse taconite tailings on major roadways on the Mesabi Range, as did local municipalities. In addition, tailings were now used for surfacing streets in locations as far away as the city of Moorhead, located on the Red River in western Minnesota. From 1985 to 1990, both state projects (SP) and municipal

state aid projects (MSAP) were involved in surfacing Moorhead streets with taconite tailings. These overlays are still in place (R. Brooks, Engineer, City of Moorhead, pers. comm., 2006).

A new application for taconite tailings was developed in the 1980s. A bituminous tailings mix was used for crack and joint repair in areas that were to receive a 1-inch overlay. The material was hand-placed in cracks and joints that had been blown out and sprayed with tack. The patch was compacted by pneumatic roller and subjected to two days of free-rolling traffic to insure total compaction prior to paving the overlay (D. Hill, pers. comm., 2006).

1990s – TACONITE AGGREGATE'S COMING OF AGE

By the 1990s, major road construction contractors from the Mesabi Range to the City of Duluth were using taconite tailings for fill, base, and sub-grade, and incorporating them into bituminous mixes, including Superpave mixes. Coarse tailings provide excellent control of volumetric properties in bituminous mix designs, particularly with regard to void space (D. Gustafson, mix design engineer, Northland Bituminous, pers. comm., 2006). One of the first Superpave jobs in Minnesota was done on an 18-mile stretch of US TH2 either side of Floodwood in the late 1990s (R. Olson, Mn/DOT, pers. comm., 2006). Tailings from EVTAC (now United Taconite) were used in the mix on this job.

In addition to coarse tailings, taconite blast rock was now routinely crushed and sized to specification to produce railroad ballast and coarse aggregate products. The coarse aggregates were incorporated into bituminous mix designs for wear courses on segments of US TH53, US TH169, and MN TH37 in 1996.

In another application, segments of US TH53 northbound from Central Lakes to Half Moon Lake (~6.4 miles) and southbound from the White Face River to Central Lakes (~7 miles) were designed to use coarse crushed taconite for permeable asphalt base (D. Hill, pers. comm., 2006). The specifications called for minus 1.5-inch rock with low -200 fines and 3% asphalt cement. The permeable asphalt base was used to achieve grade strength in moist sub-grade areas without encouraging capillary action (D. Hill, pers. comm., 2006). The material was emplaced in 1995 and 1996, respectively.

2000s – RECONSTRUCTION AND MAJOR NEW CONSTRUCTION

The turn of the century brought with it down times for the Mesabi Range that have since reversed due to the strong demand for steel in developing countries like China. The remaining six taconite operations are currently producing at full capacity.

"Pave the World" – The Summer of 2001

January of 2001 saw the closure of LTV Steel Mining Company's mine and plant in Hoyt Lakes, reducing the number of operating mines to six. In an effort to provide jobs for part of the dislocated workforce, Mn/DOT embarked on a highway resurfacing campaign of such proportions that one Mn/DOT employee described it as "the summer we paved the world." From Cherry to Eveleth, Eveleth to Gilbert, South of Eveleth to north of Virginia, up to Tower and Orr and more, bituminous overlays were paved (Fig. 2). Much of the resurfacing involved the use of coarse taconite tailings in the bituminous mix, as high as 100% of the aggregate content on various stretches. The pavements laid down that summer continue to be an asset to the Mesabi Range, an area that relies heavily on tourism.

A Decade of Reconstruction

In addition to the resurfacing of 2001, the new decade has brought about several major total reconstruction projects. Examples include projects on highways US TH169 and US TH53, as well as municipal roads in the city of Virginia.

US TH169, Mountain Iron to Chisholm

The concrete pavement of US TH169 from Mountain Iron to Chisholm (Fig. 2) was rubblized to form a solid base for bituminous surfacing in 2002. Edge drains were installed using coarse taconite tailings as fine filter aggregate to better drain this stretch of highway that had long been plagued by frost-heaved concrete panels. Coarse tailings were also used for select granular and base on the project, while crushed taconite rock was used for culvert treatments (D. Koski, Mn/DOT, pers. comm., 2002).

Piedmont Avenue (US TH53), Duluth

Major reconstruction took place on Piedmont Avenue (US TH53) in the City of Duluth from 2003 to 2005. Taconite tailings, brought in by train, were used as sub-base and sub-grade in the road bed, as well as for engineered fill behind the retaining walls on the hillside. Coarse crushed taconite, ¾-inch minus, was used for drainage structures on the project (T. Sexton, Resident Engineer, Mn/DOT, 2006).

City of Virginia Projects

Total reconstruction of two major arteries through the city of Virginia took place from 2002 to 2004. The first project, reconstruction of 9th Ave. from 9th St. North to 9th Street South, used 2-12 feet of coarse taconite tailings as common or select granular borrow and roughly 21 inches of ¾-inch minus taconite as Class 3 (sub-base) and Class 5 (base) (B. Hennis, Lead Engineer, Virginia, pers. comm., 2006).

The second project, Second Ave. / 9th Street (MN TH135) from TH 53 at the south entrance of the city to TH 53 at the north end of the Virginia beltline, was reconstructed and then surfaced with concrete. This project utilized 2-4 feet of coarse taconite tailings as select granular borrow and 9-12 inches of coarse-crushed taconite (3/4-inch minus) as Class 3 (sub-base) and Class 5 (base) (B. Hennis, pers. comm., 2006). Both projects were turn-back projects, from St. Louis County and Mn/DOT, respectively. "Turn-back" means that the county and state returned complete responsibility for these road segments to the city of Virginia upon finalization of the projects.

New Construction – US TH53 / MN169 Interchange North of Virginia

The largest single project use of coarse taconite tailings to date occurred over the course of the 2004 and 2005 construction seasons at the site of the newly constructed US TH53 / MN TH169 interchange north of the city of Virginia. Over 1.82 million tons of coarse taconite tailings were used on the project (K. Adolfs, Resident Engineer, Mn/DOT, pers. comm., 2006). Most of it went into embankment fill to support bridges over US TH53 and railroad tracks. Tailings were also used in the roadbed, as well as in the placement and fill of two box culverts set beneath northbound and southbound US TH53 for snowmobile trail use. The bituminous pavement contains 10% taconite tailings in the mix (J. Oswald, Northland Constructors, Inc., pers. comm., 2006).

Location of the interchange allowed for a unique set of circumstances that contributed to this high-volume use. Because the interchange was located just northeast of Minntac's mine property,

Minntac was able to build a haul road directly to the site. Mine trucks were used to haul the tailings from the plant site to a nearby staging area or directly deposit the tailings on the embankment itself.

Specialty Niche – Brainerd International Raceway (BIR)

Coarse taconite tailings entered a specialty niche market in 2003 when used in a resurfacing project on the Brainerd International Raceway's drag strip. The tailings were used as the aggregate in asphalt laid down in the launch pad and run-off areas of the track. The tailings were chosen over regular rock aggregate by Ed Shaughnessy, local drag racer and project manager for C. R. Meyer & Sons, the contractor, because of their durability and density, which is similar to that of concrete (Lovely, L., Construction Equipment Guide, 2004). The tailings imparted traction and a smooth transition to and from the concrete racing surface. Two records (world and national) fell during the first full season of racing following construction (BIR press release, 2003).

BIR's initial success with taconite tailings spurred interest in the racing world from Indianapolis to Florida. However, incorrect mix design led to spalled pavement where service vehicles sat on the hot track, and the taconite tailings asphalt was removed and replaced with regular asphalt after one year (E. Shaughnessy, pers. comm., 2007). BIR General Manager Scott Quick (pers. comm., 2007) has recently expressed interest in revisiting the use of taconite tailings asphalt in the track with a modified mix design.

Test Cell Construction at MNRoad Testing Facility

Two test cells were constructed using taconite aggregates in 2004 at Mn/DOT's MnRoad outdoor pavement testing facility at Albertville, MN (Fig. 2). Both cells are on the internal track, subjected to one controlled 5-axle semi- tractor-trailer that travels the 2.5-mile loop for 8 hours per day. One cell contains taconite as the coarse fraction in bituminous and the other as the coarse fraction in concrete. Test results can be obtained from the Mn/DOT office in Maplewood, MN. Future test cells using taconite aggregates will be constructed in the portion of the facility that is exposed to actual interstate traffic to determine how the aggregates and mixes perform under real time conditions.

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