Committee on Transportation Research Board Resource Conservation and Recovery

2016 Summer Workshop | July 26-29

Committees on Resource Conservation and Recovery (ADC60) and Geo-Environmental Processes (AFP40)

Asheville, North Carolina

Mining Byproducts and Recycled Materials for Better Roads and Road Repairs

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Natural Resources Research Institute (NRRI)
Duluth, MN

Session 4A – Implementation of Sustainability in Transportation Infrastructure
July 27, 2016

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A little background about the NRRI…

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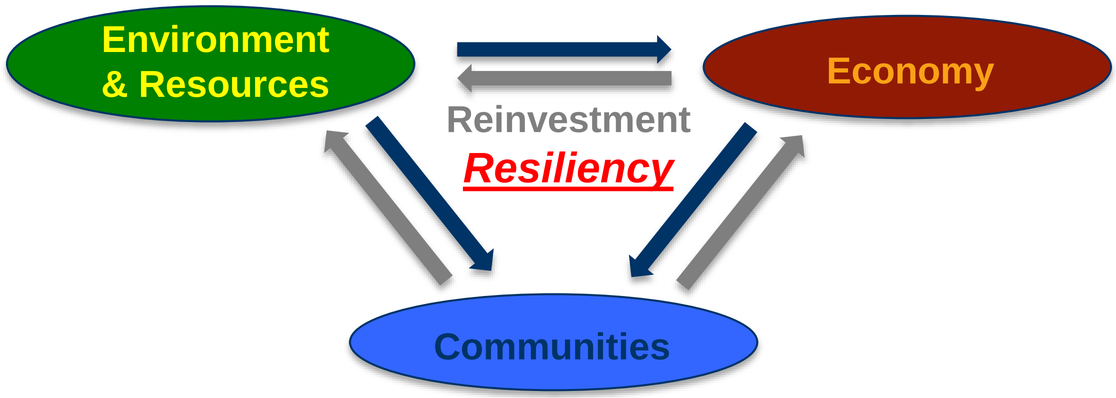
What we do: the NRRI mission



Deliver applied research solutions to balance economy, resources and environment for resilient communities

- ✓ **Broad Engagement**
- ✓ **Collaboration, Consortia**
- ✓ ***Science-Driven***
- ✓ **Future-Focused**

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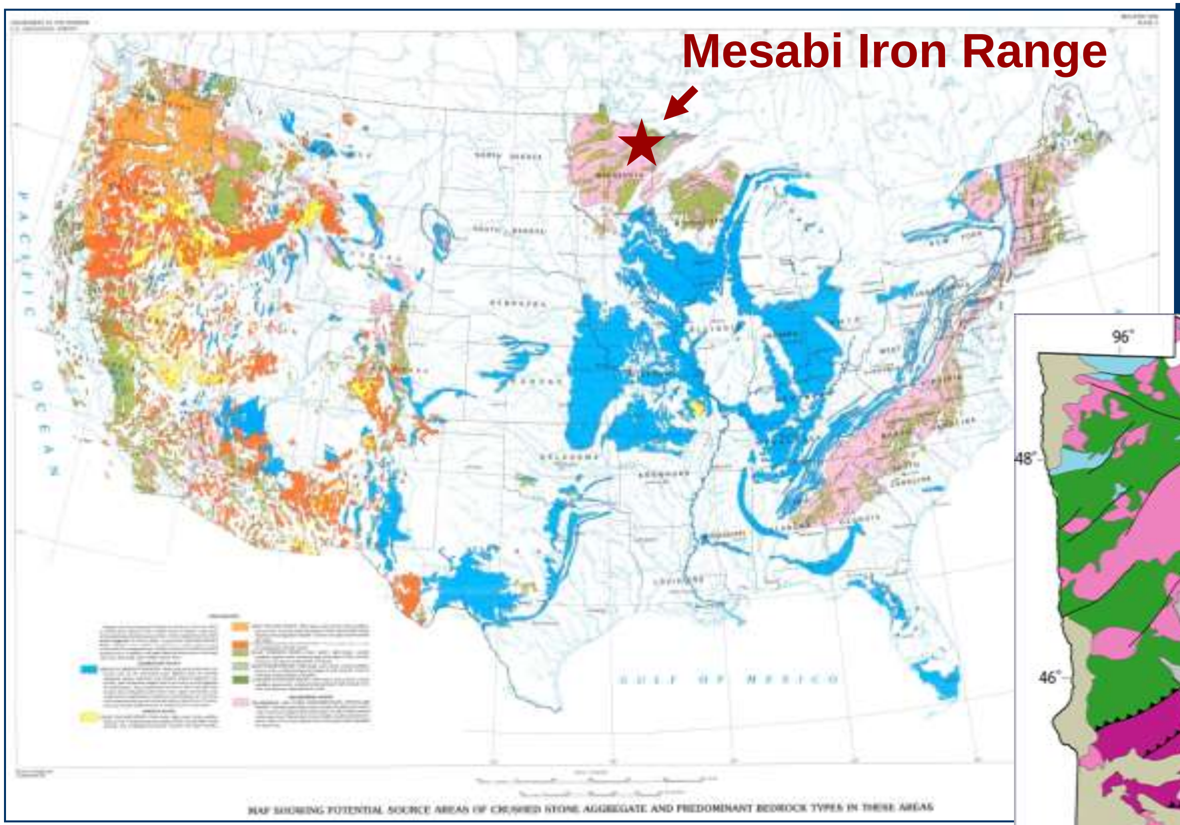
A little background about iron ore (taconite) mining and mining byproducts

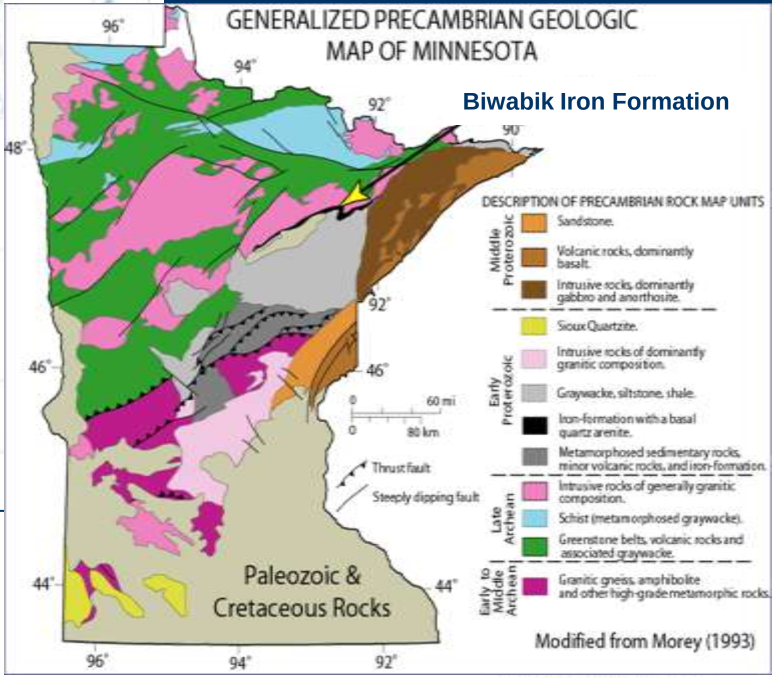
Where?

Geologic setting



Base Map Source: Langer, 1988

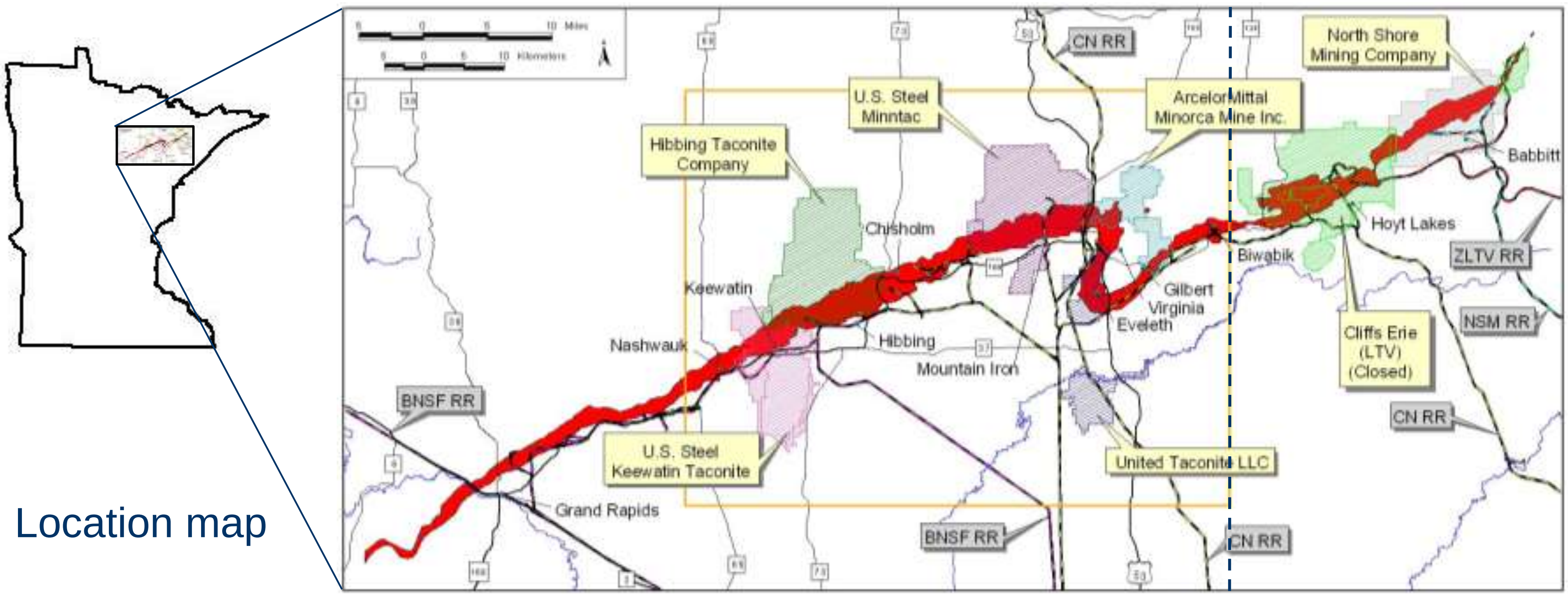
Taconite ore is mined on Minnesota's Mesabi Iron Range from the Biwabik Iron Formation.



Source of byproduct aggregate

Minnesota's taconite* mining industry generates <u>*tens of millions*</u> of tons of byproduct materials every year that could be used as aggregate.

**** Taconite is a hard, dense rock composed largely of an intimate mixture of quartz and magnetite (Fe_3O_4), plus varying amounts of iron oxides, carbonates, and silicates (Davis, 1964)***



West and Central ⟷ East

Byproducts and Use Examples

Decreasing Size

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
- Chipseal
- Railroad Ballast
- Blast Furnace Trim
- Cement making feed stock
- Road Base

Coarse Tailings: -1/4 inch (-6 mm) processing plant byproduct, ready-made fine aggregate equivalent

- Bituminous and PCC Aggregate
- High Friction Surfacing (HFS) Aggregate
- Pavement repair/patching products
- Select Granular
- Filtration Media
- Road Base and Sub-base
- Embankment Fill
- Seal Coat / Slurry Seal
- Cement making feed stock

Taconite-based Repair Methods

- **NRRI has focused on two approaches to all-season pavement repair:**
  1. ***A taconite-based pothole and pavement repair compound***
  2. ***Microwave-based pothole and pavement repair***
- **Both represent value-added niche products and technologies that take advantage of the chemistry and mineralogy of taconite materials**

This is *NOT* an ideal pothole repair solution

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Taconite-based pothole and pavement repair compound

An exothermic reaction occurs between magnetite-bearing components and activator

134°F within ~10 minutes, indicating set: Oct 31, 2012

Condition January 7, 2013

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Condition on December 26, 2014

Field Test: Hwy 169 near Keewatin, MN with MnDOT November 4, 2010

Keewatin patch condition

June 2, 2014

Loss at leading edge

Microwave-based pothole and pavement repair

Microwave

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Microwave Repair Methodology

Combine mobile microwave technology with compounds containing recycled/byproduct materials such as recycled asphalt pavement (RAP)/millings, microwave-absorbing taconite materials (Tac), and recycled asphalt shingles (RAS)

<u>Objective</u>

Repair potholes and damaged pavement in all seasons, especially winter.

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Microwave (left); HeatWurx IR (right)

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Results

- <u>HeatWurx</u>: About 1 hour for pavement to reach ~180°F at a depth of 2 inches; temperature at surface close to 400°F (starting pavement temperature ~35°F)

- <u>Microwave</u>: 5-7 minutes to heat pavement and patch material to >200°F to a depth of 2 to 3 inches; easy to shovel

Typical microwave repair temperature

280° F

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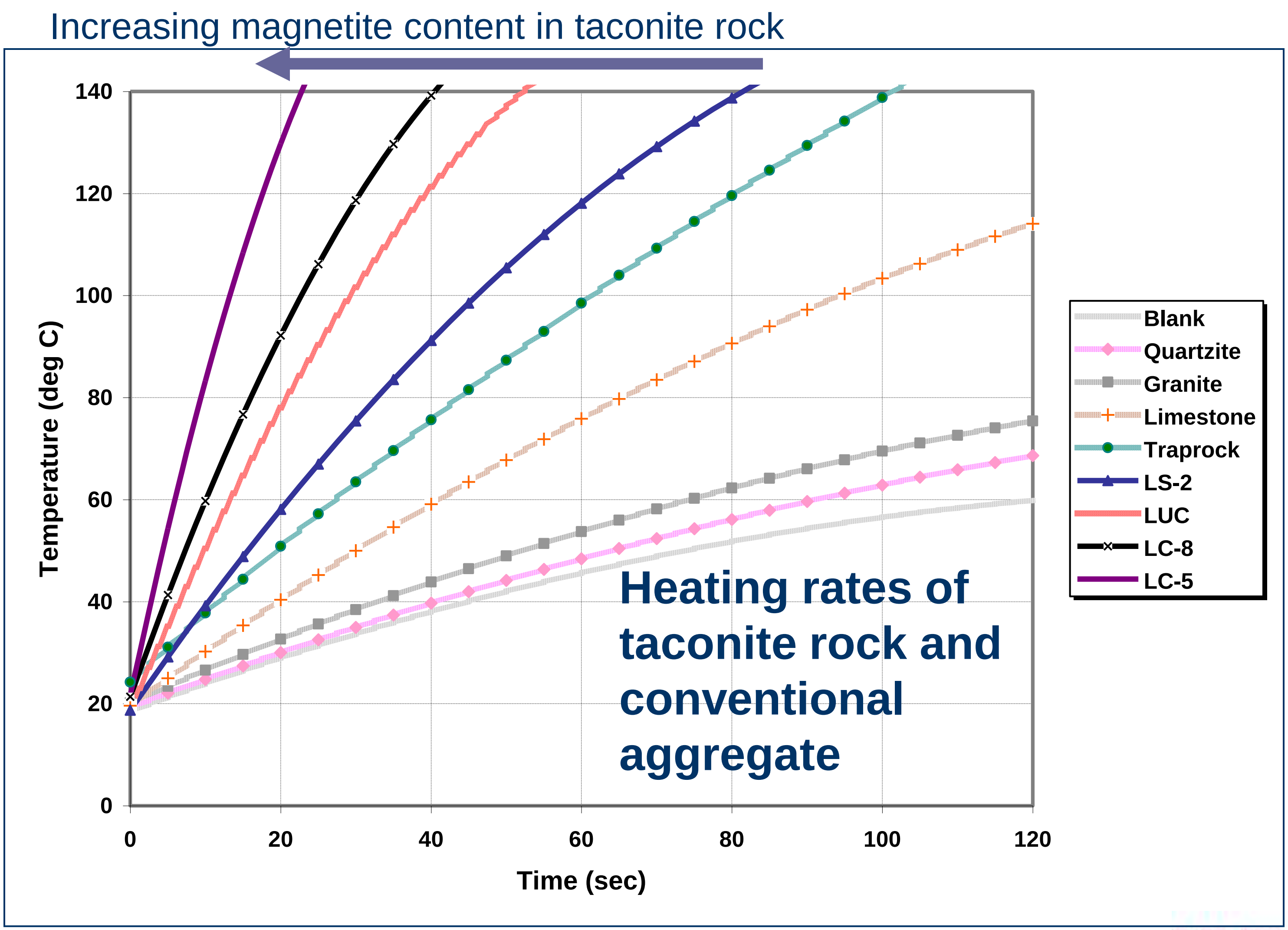
Microwave technology takes advantage of the mineralogy of taconite materials



From: Hopstock and Zanko, 2004

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Media attention

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THE CONVERSATION

Academic rigor, journalistic flair

Microwave repairs might annihilate zombie potholes once and for all

March 9, 2016 6.13am EST

The vehicle-based microwave system, making the streets safe again. Zanko et al., 2016, CC BY-ND

https://theconversation.com/microwave-repairs-might-annihilate-zombie-potholes-once-and-for-all-39160

March 9, 2016 6.13am EST

TECHNOLOGY QUARTERLY: THE FUTURE OF AGRICULTURE

The Economist

JUNE 11TH–17TH 2016

Fixing potholes

The hole story

Instant duck pond

Researchers are inventing new ways to prevent a motoring curse

POTHOLES are a scourge of rich and poor countries alike. The American Automobile Association recently calculated that 16m drivers in the United States suffered pothole damage to their vehicles in the past five years. That damage ranged from punctures, via bent wheels, to broken suspensions. The bill to fix it was about $3 billion a year. In India, meanwhile, the cost of potholes is often paid in a harsher currency than dollars. There, more than 3,000 people a year are killed in accidents involving them. Yet cash-strapped governments often ignore the problem, letting roads deteriorate. In Britain, for example, some £12 billion ($17 billion) would be needed to make all roads pothole-free. Ways of repairing potholes more cheaply and enduringly would thus be welcome. And several groups of researchers are working on it.

The most common cause of potholes is water penetrating cracks in a road's surface

The Economist June 11th 2016

and weakening its foundation. This is a particular problem with asphalt surfaces. These are made from an aggregate of materials bound together by sticky bitumen. The constant pounding of traffic disintegrates the road surface above the weakened area. In cold climates the destruction is aggravated by water in the cracks freezing and thawing. The shattered asphalt then peels away, leaving a pothole.

To make matters worse, any repairs that do happen are usually a lash-up. To save money, the material used for the patch is frequently "worked cold". This means it is not heated with specialist equipment to make the bitumen in it soft enough to flow into the shape required and meld properly with the edges of the pothole. Instead the stuff is simply shovelled off the back of a lorry and pounded down. That can work as a temporary fix until the road can be resurfaced properly, but often as not this job gets delayed almost indefinitely, which results in more cracks appearing around the fill and yet more potholes.

What is needed is a material that can be used as readily as a cold patch, but which works as well as a hot one. Larry Zanko and his colleagues at the University of Minnesota Duluth, think they know what it is. They are mixing asphalt with ground iron ore that contains magnetite—an iron oxide which, as its name suggests, is magnetic. A phenomenon called ferromagnetic resonance means that when magnetite is zapped with microwaves of an appropriate frequency it gets hot.

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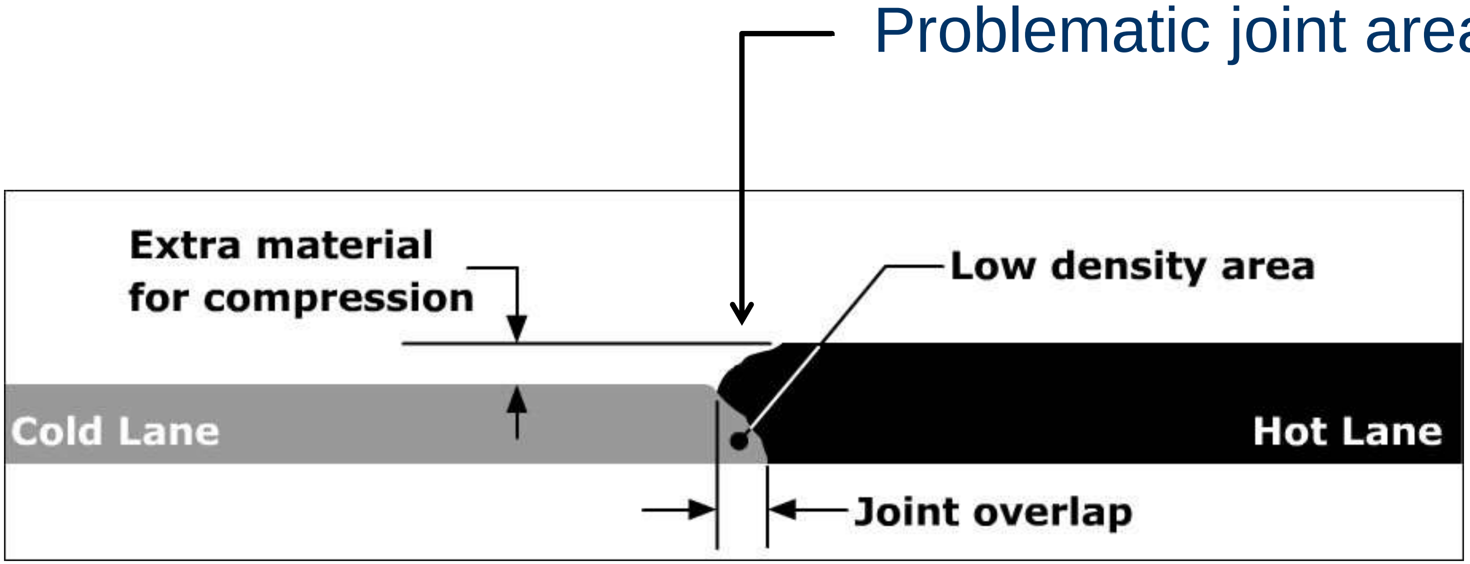
Findings

The two repair alternatives merit further development and consideration, as the field performance of both suggests they have long-term potential for more widespread and alternative use.

For example…

A solution for longitudinal joint failure?

Deteriorating longitudinal joints between adjacent driving lanes and paved shoulders are a major long-term maintenance for DOTs, and a safety problem for the driving and motorcycling public.



http://www.pavementinteractive.org/2010/07/21/why-longitudinal-joints-fail/

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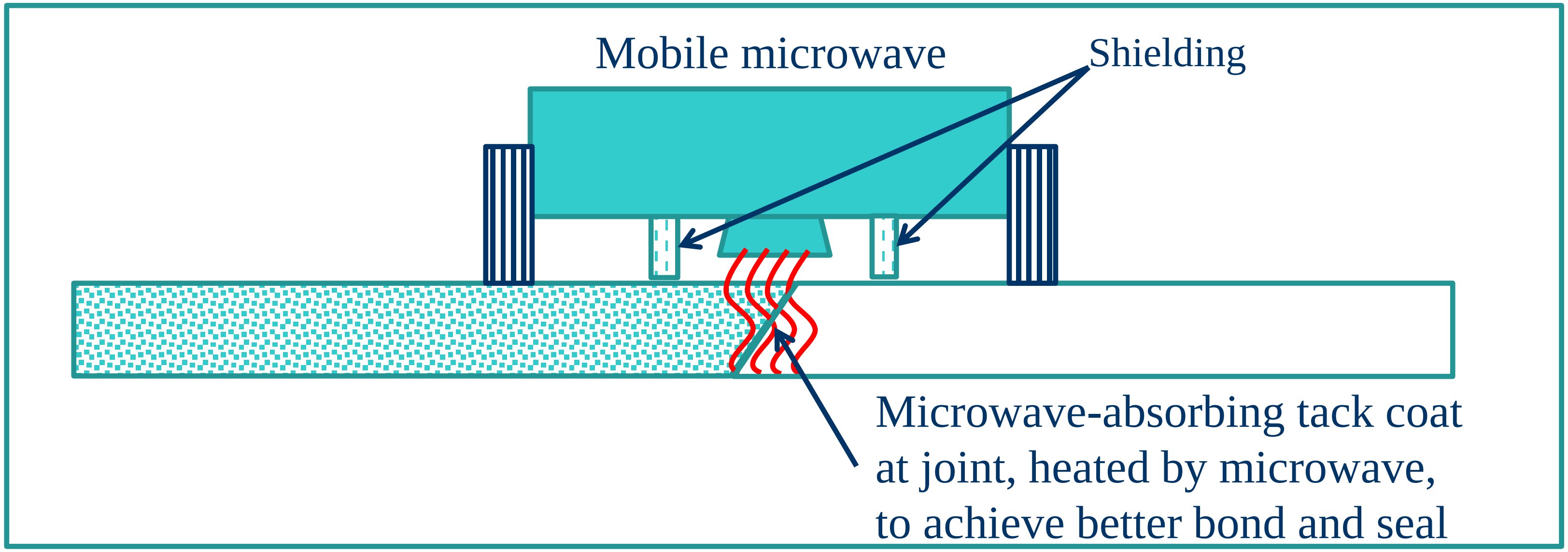
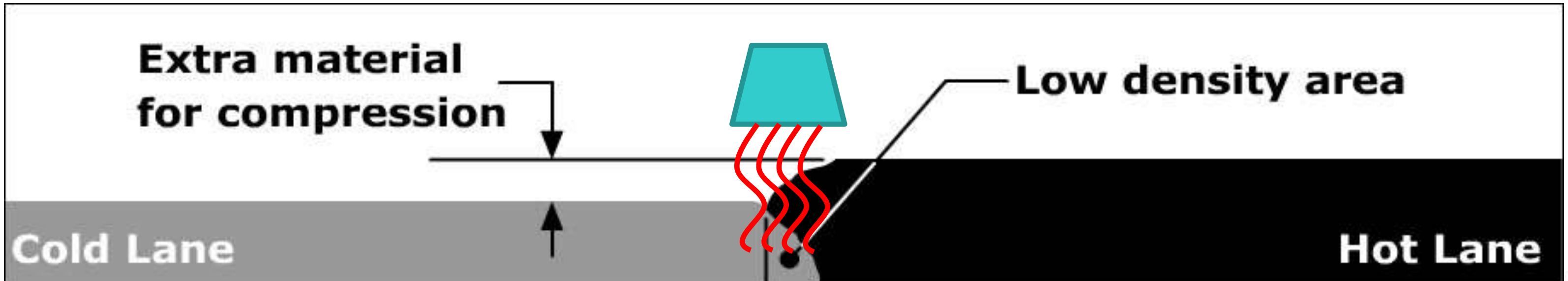
Applications





http://www.pavementinteractive.org/2010/07/21/why-longitudinal-joints-fail/

Conclusions

- Minnesota’s taconite mining byproducts can be a significant source of high-quality construction aggregate material.
- When considered within the context of the critical need for repairing, maintaining, and upgrading the nation’s transportation infrastructure, their potential as a more sustainable alternative to conventional aggregate sources is tremendous.

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Thank you

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