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2007-07

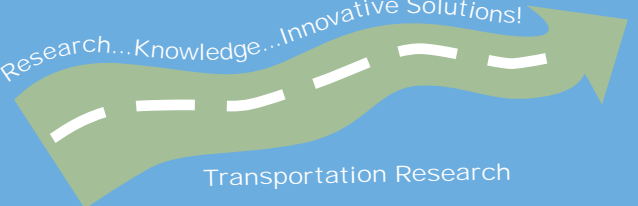
Increasing the Recycling of Manufactured Shingle Scrap in Minnesota: A Market Development Project

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1. Report No. MN/RC-2007-07	2.	3. Recipients Accession No.	
4. Title and Subtitle Increasing the Recycling of Manufactured Shingle Scrap in Minnesota: A Market Development Project		5. Report Date January 2007	
		6.	
7. Author(s) Dan Krivit		8. Performing Organization Report No.	
9. Performing Organization Name and Address Dan Krivit and Associates, 2344 Doswell Ave. St. Paul, MN 55108-1631		10. Project/Task/Work Unit No.	
		11. Contract (C) or Grant (G) No. (c) 81547	
12. Sponsoring Organization Name and Address Minnesota Department of Transportation 395 John Ireland Boulevard Mail Stop 330 St. Paul, Minnesota 55155		13. Type of Report and Period Covered Technical - Through April 2006	
		14. Sponsoring Agency Code	
15. Supplementary Notes http://www.lrrb.org/PDF/200707.pdf			
16. Abstract (Limit: 200 words) This Mn/DOT Shingles Recycling Project was initiated to help accelerate the implementation of the use of manufacturers' shingle scrap into hot mix asphalt (HMA) in Minnesota. The intent was to help increase demand for manufacturers' recycled asphalt shingles in Minnesota through targeted outreach and technology transfer tools by addressing the information needs of private contractors and local agencies. Therefore, A Guide to the Use of Roofing Shingles in Road Construction was produced as part of a larger outreach and education campaign. Through interviews with HMA producers and other private companies, it was concluded that there was already very good acceptance of shingle recycling technology and that lack of adequate demand was not the key barrier to further market development. Rather, the lack of readily available supply of manufacturers' shingle scrap was determined to be the key barrier to further growth in recycling of this material. Most of the manufacturers' shingle scrap was already committed to a few recyclers and therefore did not allow new business entries into the marketplace. Recommendations for continued Mn/DOT market development support activities include additional research and specification development. The future promise of recycling "tear-off" shingle scrap may help address the limited supply of manufacturers' scrap.			
17. Document Analysis/Descriptors Manufacturers' shingle scrap; hot mix asphalt (HMA); asphalt shingle manufacturers; shingle recycling; recycled asphalt shingles (RAS); market development; outreach and technology transfer; information needs; available supply.		18. Availability Statement No restrictions. Document available from: National Technical Information Services, Springfield, Virginia 22161	
19. Security Class (this report) Unclassified	20. Security Class (this page) Unclassified	21. No. of Pages 34	22. Price

Increasing the Recycling of Manufactured Shingle Scrap in Minnesota: A Market Development Project

Final Report

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January 2007

Published by:

Minnesota Department of Transportation
Research Services Section
395 John Ireland Boulevard, MS 330
St. Paul, Minnesota 55155-1899

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The authors and the Minnesota Department of Transportation do not endorse products or manufacturers. Company, trade or manufacturers' names appear herein solely because they are considered essential to this report.

ACKNOWLEDGEMENTS

This Shingles Recycling *Project* for the Minnesota Department of Transportation (Mn/DOT) was produced with the help of many individuals. Special thanks and recognition is due to the following individuals that served on the *Mn/DOT Project* Steering Committee:

- Jim Klessig Project Manager for Mn/DOT Research Services
- Roger Olson Research Operations Engineer for Mn/DOT Office of Materials and Road Research
- Don Kyser Engineer and project manager for the Minnesota Office of Environmental Assistance (OEA)
- Debra S. Haugen Environmental consultant for DKA
- Darlene Gorrill Communications consultant and subcontractor to DKA

Other Mn/DOT and OEA staff helped with other aspects of the *Project* including:

- John Garrity Former Mn/DOT Bituminous Engineer
- Greg Johnson Engineer for Mn/DOT Office of Materials and Road Research
- Tom Heininger Mn/DOT video production unit
- Daneeka Marshall-Oquendo Communications specialist for Mn/DOT
- Micky Ruiz Manager for ORS research implementation
- Wayne Gjerde Market development specialist for OEA
- Glenn Korchinsky-Meyer Communications specialist for OEA

Several private companies provided shingle recycling operations and implementation of end use applications.

- Kent Peterson & staff: Bituminous Roadways
 - Dusty Ordorff
 - Todd Smedshammer
 - Recycling crew

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EXECUTIVE SUMMARY

This *Mn/DOT Shingles Recycling Project* was initiated to help accelerate the implementation of the appropriate use of manufacturers' shingle scrap into hot mix asphalt (HMA) in Minnesota. At the time this *Mn/DOT Project* was initiated, only limited shingle recycling was taking place at two known HMA producers in the state despite the fact that Mn/DOT had adopted a materials specification in 1996 allowing for the use of recycled manufacturers' shingle scrap in HMA.

The intent was to help increase demand for manufacturers' recycled asphalt shingles (RAS) in Minnesota through targeted outreach and technology transfer tools.

One of the key objectives of this *Mn/DOT Project* was to address the information needs of private contractors and local agencies and therefore *A Guide to the Use of Roofing Shingles in Road Construction: It's All Part of the Mix* was produced as part of a larger outreach and education campaign. This *Shingles Recycling Guide* included the following fact sheets:


 [Project Overview](#)

 [Minnesota Research](#)

 [Case Studies](#)

 [Economics](#)

 [Vendors of Shingle-grinding Equipment](#) (updated January 2006)

 [For more information](#)

This *Shingles Recycling Guide* packet was mailed directly to Minnesota county engineers, HMA producers and other practitioners. This *Shingles Recycling Guide* packet was also used at various transportation and recycling conferences / trade shows.

Building upon this *Mn/DOT Project*, subsequent state and national recycling projects continued and expanded the outreach and implementation efforts. This *Mn/DOT Project* recognized the need for such additional research and development of recycling "tear-off," or "post-consumer," shingles. Part of the strategy for this *Mn/DOT Project* was to help develop the end-use market demand for manufacturers' shingle scrap as a means to help lead the way for development of the market for tear-off shingles.

Through interviews with HMA producers and other private companies, it was concluded that the lack of adequate market demand was not the key barrier to further market development. Rather, the lack of readily available supply of manufacturers' shingle scrap was determined to be the key barrier to further growth in recycling of this material. The vast majority of the manufacturers' shingle scrap is already committed in long-term contracts to a few recyclers and therefore did not allow new business entries into the marketplace.

A series of other conclusions and recommendations for further market development activities is included as part of this report. Recommended options for further Mn/DOT efforts to increase the use of recycled asphalt shingles (RAS) include:

- Conduct a new pavement crack survey of all shingle recycling road demonstration projects.

- Finalize and publish its recycled *Shingle Scrap Specification* on file in the Bituminous Office into a memorandum as additional, official technical guidance.
- Continue additional lab and field research leading towards adoption of a new specification for recycling tear-off shingle scrap into HMA.

CHAPTER 1 – INTRODUCTION

The *Mn/DOT Project* was originally intended to produce and disseminate specific outreach and education tools to increase the awareness about manufacturers' shingle recycling opportunities. Key target audiences and outreach strategies were developed. Later, other funding agencies contributed to additional research and development efforts that built upon this original *Mn/DOT Project*.

This project built on previous research and feasibility work conducted by Mn/DOT leading to the adoption of a new materials specification in 1996 to allow up to 5 percent manufacturers' shingles scrap in certain asphalt hot mixes ^[1,2,3,4].

Lack of adequate end-market demand was originally identified in this *Mn/DOT Project* Communication Plan as one of the key barriers to growth of recycling manufactured shingle scrap ^[7]. This inadequate demand was despite publication of several research and demonstration studies that successfully used recycled shingles in bituminous pavement and in other applications ^[2,3,4]. Many of these projects had been completed in Minnesota, plus there are dozens of successful projects using scrap shingles in other states ^[8,9,10,11,12,13,14,15, 16,17, 28]. These past research and demonstration projects had proven the technical and economic advantages and limitations of using manufacturers' shingle as an asphalt supplement. This *Mn/DOT Project* concluded that many state and local agency engineers were not aware of the opportunities to use of shingles in their HMA pavements.

A strategic communications plan was produced at the beginning of this *Mn/DOT Shingles Recycling Project* to establish and verify *Project* priorities ^[7]. Three key strategies were established:

1. Increase awareness of the potential benefits of adding recycled shingles to hot-mix asphalt;
2. Increase the actual use of shingles in hot-mix asphalt; and
3. Develop incentives for using shingles in hot-mix asphalt.

This strategic plan identified five key audiences groups in Minnesota:

1. Hot-mix asphalt producers
2. Private road construction contractors
3. City and county engineers
4. Asphalt shingle manufacturers
5. Other government officials ^[7]

One of the early tactics that was considered as part of this *Mn/DOT Project* was the need to identify and encourage additional recyclers, such as other HMA producers, to enter into this shingle recycling business. The hope was that new company entries into the marketplace, producing a quality processed shingle scrap product, would help make the sale of the recycled shingle-derived HMA and other aggregate products more competitive.

The Mn/DOT shingle recycling specification restricts the source of shingles to material derived directly from shingle manufacturing plants. Therefore, this *Mn/DOT Project* was not intended to promote the recycling of tear-off shingle scrap at this stage. Rather, the promotional materials produced referred to the Mn/DOT specification that limited the material to manufacturers' shingle scrap only.

This *Mn/DOT Project* recognized the need for additional research and development of recycling "tear-off" (or "post-consumer") shingles. This is material derived from on-site re-roofing jobs or construction and demolition debris disposal / recycling facilities. The increased variability and potential contaminants from tear-off shingles requires additional sorting, inspection, and cleaning processes that add cost and risk.

Part of the strategy for this *Mn/DOT Project* was to help develop the end-use market demand for manufacturers' shingle scrap as a means to help lead the way for development of the market for tear-off shingles. It is likely that utilization of tear-off shingle scrap will be found to be technically and economically feasible through continued research and demonstration projects.

ABOUT THE *Mn/DOT PROJECT* TEAM

Mn/DOT retained the services of Dan Krivit and Associates (DKA) to coordinate this *Project*. DKA retained the services of Darlene Gorrill, a communications specialist that has worked with Mn/DOT on other projects.

The *Project* Team consisted of three primary state agency staff. Mn/DOT's Office of Research provided the contract management for this *Project* under the direction of James Klessig. Roger Olson, Mn/DOT Research Project Engineer at the Maplewood Materials Lab, provided the primary technical direction. Mr. Olson also served as the technical liaison to other Mn/DOT materials engineers. Don Kyser, staff engineer, was the primary liaison with the Minnesota Office of Environmental Assistance (now a division of the Minnesota Pollution Control Agency).

This *Mn/DOT Project* maintained a neutral position with respect to competing private vendors and other private interests. Mn/DOT, MOEA, nor its consultants, endorsed or gave preference to any one vendor over another. That being said, the past demonstrations and case studies, by necessity, required the *Project* Team to rely on the information and technical expertise of the few HMA producers that had direct experience with shingles recycling.

OBJECTIVES

A series of specific workplan objectives were established to guide the activities of this *Mn/DOT Project*:

1. Develop an updated set of priorities to guide Mn/DOT and MOEA efforts to improve the market development of using shingle scrap. One element of these priorities will be verification of priority audiences to be targeted and communication tools to be utilized as a part of this implementation project.
2. Implement the communication strategy as the project budget allows.
3. Evaluate the effectiveness of communications and education efforts. Make recommendations for the next phase of work.

This project implemented the basic elements of the final *Project Communication Plan* as developed for Mn/DOT in October 2001 ^[7]. Direct contacts with key audiences provided “one-on-one” technical assistance and input to the *Project* team to guide the development of an updated set of priorities. Interviews were conducted with both HMA producers and local agency engineers to determine their level of information needs and opinions about shingle recycling. The other communication tools (e.g., fact sheets, trade articles, conference presentations) were also implemented and in direct response to the needs assessment interviews.

CHAPTER 2 – RESEARCH HISTORY

There is a rich and deep history of research and development on the emerging technology of using recycled asphalt shingles as a road construction material supplement. The body of published literature extends from the mid 1970's. An extensive bibliography of related research, reports, agency web sites and articles published within trade press media has been compiled as part of this and other related shingles recycling projects. (See Chapter 3: [Other Minnesota Research and Development Efforts](#) for more information on these other projects). An updated literature review and summary is in preparation.^[35] This report includes reference to past Minnesota studies that are most directly relevant to the *Mn/DOT Project* outreach and implementation objectives. The Mn/DOT specifications are also directly relevant

The primary focus of past research has been on the use of manufacturer's shingle scrap for use in hot mix asphalt (HMA). This body of literature covering the economic and technical feasibility of recycling manufactured shingle scrap has been generally positive and optimistic about the potential for growth. This past research has led to over 15 states allowing the use of recycled manufacturers' shingles in HMA and/or other road construction applications.^[19]

MN/DOT SHINGLES RECYCLING RESEARCH AND DEVELOPMENT HISTORY

The following Minnesota studies were part of the original Mn/DOT sponsored research and development program.

Three field demonstrations and a series of related laboratory materials tests were conducted in Minnesota for Mn/DOT as part of the original research and development efforts. This original Minnesota research period has been informally referred to as the *Mn/DOT "Phase One" Research* program. The paving project field demonstrations include:

- Willard Munger Recreation Trail in St. Paul constructed in 1990 as reported by Curtis Turgeon in 1991^[3];
- Trunk Highway (T.H.) 25 in Mayer constructed in 1991 as reported by David Janisch and Curtis Turgeon in 1996^[4]; and
- County State Aid Highway (CSAH) 17 in Scott County also reported by Janisch and Turgeon in their 1996 report^[4].

One of the original laboratory studies on the subject was conducted by David Newcomb for Mn/DOT and published in 1993^[2]. This 1993 Newcomb project was conducted by the University of Minnesota Department of Civil and Mineral Engineering and sponsored in part by the predecessor agency to the Minnesota Office of Environmental Assistance (MOEA). (Note: MOEA is now an office within the Minnesota Pollution Control Agency – MPCA).

Munger Trail Pavement Field Demonstration Project Constructed in 1990 (Turgeon, 1991)

The shingle-only mix met specifications and yielded an economic advantage of decreasing the virgin asphalt cement demand of the mix. ^[3] The shingle-only mix met specification and demonstrated a significantly higher Marshall stability than the control mixture. The angular granules and relatively hard asphalt cement contributed by the shingle scrap are potential sources of this increase in stability. The decrease of 2.0 percent in asphalt demand (from 5.0 percent virgin asphalt in the control to 3.0 percent asphalt in the shingles-only mix) has important potential economic benefits. ^[3]

While the shingle-only mixture also exhibited a relatively open surface texture due to the coarse natural aggregates, it performed satisfactorily. ^[3]

The penetration of the shingle-only mix was lower than the control mix. Stiffer binders can be more susceptible to low temperature cracking. Cracking of the shingle-only mix should be monitored closely. Inplace air voids were higher than expected as well. The stiffness of the asphalt cement may also inhibit compaction. ^[3]

Trunk Highway 25 Field Demonstration Project Constructed in 1991 (Turgeon, 1993; Janisch and Turgeon, 1996)

This project was summarized analyzed as part of the study published by David Janisch and Curtis Turgeon in 1996. ^[5] This demonstration conducted in 1991 was a cooperative effort to continue the successful research resulting from the Munger Trail project during the previous year.

As of observations on December 6, 1995, and again in approximately 2002, the mixtures containing shingle scrap were performing at least as well as the control section. No discernable difference existed between any of the shingle scrap section and the control section. ^[5]

Scott County Highway 17 Field Demonstration Project Constructed in 1991

In 1991, based on Mn/DOT's experience with shingle scrap, Scott County also constructed a test section using shingle-modified HMA as reported by Janisch and Turgeon in 1996. ^[5]

The highway pavement test sections were originally reviewed on November 22, 1995. Roger Olson (Mn/DOT staff) and Deb Haugen (DKA) again reviewed these test sections in approximately 2002. In 1995, both the control and the shingle test sections were in good condition. There were no discernable differences between the control and test sections. The control section is on a long, positive grade while the shingle section is in a flat area.

In 2002, in conjunctions with this *Mn/DOT Project*, Roger Olson arranged for Mn/DOT's pavement survey crew to take core samples from the T.H. Project 25 and CSAH 17 demonstration project. Performance grade (PG) testing was then conducted on the samples (see Table 1 for results summary).

Table 1
Mn/DOT Laboratory Test Results of
T.H. 25 and CSAH 17

<u>Road Project</u>	<u>Percent Shingles</u>	<u>PG Grade</u>
TH 25	0%	73-20
TH 25	5%	75-20
TH 25	7%	79-15
CSAH 17	0%	77-22
CSAH 17	10%	75-24

Source: Presentation by Roger Olson at MAPA’s Annual Contractors’ Workshop on March 4, 2004. ^[25]

University of Minnesota Laboratory Research (Newcomb, 1993)

One of the lab research projects was conducted by the University of Minnesota Department of Civil and Mineral Engineering for Mn/DOT by David Newcomb et. al. and published in 1993 ^[2]. The Newcomb study examined impacts of incorporating RAS into two basic types of HMA: dense-grade asphalt mixtures and stone mastic asphalt (SMA) mixtures. Three types of shingle scrap product were tested: fiberglass backed shingles from a manufacturer, organic felt backed shingles from the same manufacturer, and tear-off shingle scrap from a RAS recycling company (under the trade name ReACT by Re-Claim, Inc.).

Newcomb et. al. found that increasing the content of RAS reduced the HMA requirement for new, virgin asphalt binder. The amount of reduction in demand for virgin asphalt binder is dependent on the type and amount of shingle scrap. E.g., the study found that at five percent fiberglass manufacturers’ shingle scrap; there was a 10 percent reduction in demand for virgin asphalt binder ^[2].

Newcomb presented a revised summary of his earlier findings to the *Second Asphalt Shingle Recycling Forum* in April 2003 held in Bloomington, Minnesota. ^[36] The Newcomb study as sponsored by Mn/DOT and the MOEA included a limited field demonstration in Wright County, Minnesota. The shingles used were manufacturer’s scrap only, again as supplied by CertainTeed Corporation’s Shakopee plant. About 95 percent of the shingle scrap was felt (or paper) backed shingles and 5 percent was fiberglass.

Mn/DOT Research Review and Analysis (Janisch, 1996)

In 1996, Janisch study outlined the history of shingle scrap use in Minnesota, presented laboratory and field performance data, and recommended the original 1996 Mn/DOT

specifications allowing shingle scrap as a salvage material in HMA pavements^[4]. Janisch et. al. concluded from field projects that the use of shingles in HMA could provide excellent performance and result in significant saving by reducing the amount of virgin asphalt binder required in HMA. They also concluded that shingle-modified mixes are as resistant to moisture as are unmodified mixes, and that a slight increase in hardness of binder of the mix, resulting from the binder in the shingles did not have any adverse effect on low temperature properties of the HMA. Based on the results of laboratory and field study, the authors recommended the use of manufacturers' shingle scrap in HMA in the state of Minnesota^[4]. A specification was drafted and included as part of the Janisch report.

BITUMINOUS ROADWAYS, INC. (PETERSON, 2003 AND ORDORFF, 2005)

Bituminous Roadways has had extensive experience with the use of ground shingles for more than ten years.^[32] A large number of private and public local, county and state road projects have been constructed by Bituminous Roadways using RAS in HMA. These include (but are not limited to):

- France Avenue – Hennepin County
- County Road 42/83 – Scott County
- 19th Avenue No. – City of South St. Paul
- Highway 13 – Mn/DOT
- Various residential street reconstruction projects – City of St. Paul

Bituminous Roadways has developed some significant operating conclusions from these experiences:

- Less than 50 percent of the shingle asphalt binder is effectively utilized in the mix
- Use of RAS has not been detrimental to quality, but Bituminous Roadways cannot yet conclusively prove that RAS offers improved quality to the mix
- When selecting a virgin asphalt binder grade, adjust one temperature interval lower. For example, if the mix design calls for a virgin asphalt binder of PG 64-XX, when using shingles adjust the virgin asphalt binder to PG 58-XX.
- Lab tests should be conducted to finalize mix design according to the Mn/DOT specified blending chart including residual AC recovery and PG testing.

Bituminous Roadways has made some specific operation recommendations for the future. Shingles recyclers should develop appropriate means to conduct controlled pre-blending of RAS with sand or RAP to avoid re-agglomeration during extended storage of the RAS. The Mn/DOT State specifications should allow for more use if it can be proven to meet standard QC / QA requirements. The state should continue to research and develop the tear-off shingle recycling technology. And, finally, other non-HMA applications should be developed such as dust control, additive to aggregate base, etc.

CHAPTER 3 - OTHER RECENT AND ONGOING RESEARCH AND DEVELOPMENT EFFORTS

OTHER RECENT SHINGLE RECYCLING PROJECTS

A series of other relevant past and ongoing research and development projects, presented below in chronological order.

MOEA (1991 through 2005)

The Minnesota Office of Environmental Assistance (MOEA) has been a long-term state agency partner with Mn/DOT in this shingles recycling market development effort. MOEA provided matching funding for previous research, including the Newcomb project ^[2].

MOEA also provided a series of two capital assistance grants to Bituminous Roadways, Inc. (BRI) for development, purchase, testing and public reporting of actual shingle recycling operations ^[19,20]. BRI has a shingle recycling operation at their plant in Inver Grove Heights, Minnesota that has been processing scrap material from CertainTeed Corp. since 1995. The material has always been processed and utilized by BRI into its own HMA. In addition, BRI has also worked on research to develop additional end-use applications. Beyond the tradition blending into HMA, BRI explored the use of processed scrap shingles as:

1. Aggregate supplement in Class 7 aggregate as base to assist in dust suppression on gravel roads;
2. Dust control on gravel-surfaced roads; and
3. Lightweight pavement surface in cold-mix combination with RAP.

These additional applications show some indications of promise. Review and analyses of these applications was reported in the final RMRC Project report. ^[19]

CMRA Original Project: www.ShingleRecycling.org

The Construction Materials Recycling Association (CMRA) is the lead sponsor of the Asphalt Shingles Research Assessment Project (ASRAP) an ongoing, long-term development project to improve the market for asphalt shingles. Other co-sponsors currently include the University of Florida (Gainesville, FL) and U.S. EPA. (Region 5, Chicago, IL). The ASRAP project was initiated at the *First Asphalt Shingles Recycling Forum* held in Chicago in November 1999. The project began a survey of state agencies and private recyclers in 2001 and culminated in the publication of the web page www.ShingleRecycling.org a comprehensive clearinghouse of information on the subject. The 2001 survey identified individual state regulations, asbestos sampling data, and other research and development projects being conducted around the country. ^[37]

RMRC Project #13 / #14 (2001 – 2005)

Recycled Materials Resource Center (RMRC) “Development and Preparation of Specifications for Using Recycled Materials in Transportation Applications” (RMRC Project #13 / #14). This

RMRC project resulted in a white paper and the preparation of a draft shingle recycling specification submitted to the American Association of State Highway and Transportation Officials (AASHTO) for consideration and potential adoption. ^[38, 39]

RMRC Project #22 (2002 through 2004)

RMRC Project #22 “Overcoming the Barriers to Asphalt Shingle Recycling” funded a project produced principally by the Minnesota Department of Transportation (Mn/DOT). ^[19, 40] One of the many products from this RMRC Project was the *Second Asphalt Shingles Recycling Forum* as held in Bloomington, Minnesota on April 14, 2003. ^[41]

The Minnesota Office of Environmental Assistance (now a division within the Minnesota Pollution Control Agency) sponsored a series of shingles recycling market development initiatives, including a web page containing the A Guide to the Use of Roofing Shingles in Road Construction: It’s All Part of the Mix information packet. ^[42]

First SWMCB Project – Manufacturers’ Shingle Scrap (2003 through 2004)

The Solid Waste Management Coordinating Board (SWMCB) completed a two-year study and developed recommendations on how to increase the recycling of manufacturer shingle scrap in the SWMCB region. ^[43]

OTHER ONGOING PROJECTS

A series of other, related shingles recycling projects and publications are currently underway:

AASHTO Shingles Recycling Specification

In late 2005, the American Association of State and Highway Transportation Officials (AASHTO) adopted a materials specification that itemizes specific quality assurance / quality control requirements for utilizing recycled asphalt shingle (RAS) in HMA. ^[26] In addition, AASHTO adopted a companion recommended practice to provide additional guidance for designing new HMA which incorporates RAS. ^[27] Specific guidance includes design considerations, how to determine the shingle aggregate gradation, how to determine the virgin performance grade and percentage of the virgin asphalt binder and how to estimate the contribution of the shingle asphalt binder to the final blended binder. Both manufacturers’ and tear-off shingle scrap are allowed in the new AASHTO specification.

MOEA - Funded Lab Analyses

The Minnesota Office of Environmental Assistance (MOEA), via a time sensitive grant through Dan Krivit and Associates (DKA), is funding this Minnesota Lab Study Project. This OEA project directly complements a parallel study sponsored by the Missouri Department of Transportation (MoDOT) and will be published in a consolidated report of the two studies. ^[33] (See [MoDOT project](#) description below).

The goal of this OEA Project is to complete the testing of samples adequate to allow Mn/DOT to determine if enough research is available to recommend changes to the State hot mix asphalt (HMA) pavement specifications that could allow the use of tear-off shingles in HMA as a normal business practice.

MODOT Funded Lab Analyses

The Missouri Department of Transportation (MoDOT) is funding similar lab analyses to further research the performance of HMA supplemented with recycled asphalt shingles (RAS) produced from tear-off shingle scrap. The RAS – derived HMA test samples are being compared to control samples of HMA produced from 20% RAP, 0% RAS mixes. The University of Minnesota, Department of Civil Engineering, is completing a portion of the MoDOT lab analyses. The U of M's Asphalt Lab is using its equipment to measure indirect tensile strength for both the Mn/DOT and MoDOT lab analyses.

The project will result in verification or modification of requirements within the new draft Missouri Department of Transportation (MoDOT) specification on tear-off shingle recycling into HMA. This project will conduct additional empirical lab tests needed by MoDOT engineers in order to confirm requirements within their new draft specification allowing recycled tear-off shingles in HMA.

This Missouri project directly complements the [Minnesota lab project](#) (see project description above) and will be published in a consolidated report of the two studies.^[33]

EPA / CMRA Project

The primary goal of this new U.S. Environmental Protection Agency (EPA) project is to develop and demonstrate recommended best practices that provide for superior quality assurance/ quality control (QA / QC) that can be utilized by profitable shingle recycling operators throughout the nation. The project will be produced by CMRA with key partner support from a wide variety of public and private agencies and companies. This project will build directly on the substantial efforts of other research and development efforts in order to help bring tear-off shingle recycling technology to full-scale implementation.

Second SWMCB Project – Tear-Off Shingle Scrap (2006)

The SWMCB Tear-Off Shingle Scrap Recycling Project is intended to accelerate the development of a new infrastructure for recycling post-consumer asphalt shingles. SWMCB is working to demonstrate adequate government sector demand for end products such as HMA derived from recycled tear-off shingle scrap. This 2006 SWMCB Tear-Off Project will also help expand the market for this emerging recycling opportunity by improving information and technology exchange between key players in the private and government sectors. The SWMCB is utilizing its previous web page to help disseminate information: [SWMCB Shingle Recycling](#) (URL: <http://www.greenguardian.com/business/shinglerecycling.asp>).

CHAPTER 4 – PROJECT RESULTS

OUTREACH TOOLS PRODUCED

A series of communication tools were produced for this *Mn/DOT “Phase Two” Project* that have been used successfully in reaching out to the key audiences to provide accurate, timely information about opportunities in shingle recycling. An information “tool kit” was published, [A Guide to the Use of Roofing Shingles in Road Construction: It’s All Part of the Mix](#), that included the following fact sheets:


 [Project Overview](#)

 [Minnesota Research](#)

 [Case Studies](#)

 [Economics](#)

 [Vendors of Shingle-grinding Equipment](#) (updated February 2004!)

 [For more information](#)

This [Shingles Recycling Guide](#) packet was mailed directly to Minnesota county engineers, HMA producers and other practitioners. This [Shingles Recycling Guide](#) packet was also used at various transportation and recycling conferences / trade shows.

The reader of this report utilizing electronic format may wish to click on the above hyperlinks for the actual fact sheets as posted on the Internet by MOEA. Others may wish to view the MOEA web page, www.moea.state.mn.us/lc/purchasing/shingles.cfm, with the subsequent links to view the individual fact sheets.

This Shingles Recycling Guide packet was originally mailed out under signature of Patrick C. Hughes, Mn/DOT Office of Materials & Road Research, in September 2002 to local engineers, hot-mix asphalt producers, shingle manufacturers, solid waste / recycling officials, and other interested parties. It was subsequently used at related industry conferences, workshops and other forums.

In the Winter 2003 issue of the [Technology Exchange Newsletter](#), the University of Minnesota (U of M), Center for Transportation Studies (CTS), published a *Mn/DOT Project* article written by Darlene Gorrill that summarized some of the success stories about various local governments utilizing shingle-derived HMA ^[20]. The Hennepin County and City of St. Paul case studies were highlighted as a means to demonstrate benefits to other local agencies ^[20].

A series of personal communications were utilized as a part of this *Mn/DOT Project* including: site visits to shingle recycling operations; one-on-one meetings; phone interviews; and conference presentations.

Two of the more effective and frequently requested products were:

1. Bibliography of past studies and web pages on the subject; and
2. Slide presentations

Both of these outreach products were continuously updated and improved as new information became available.

BARRIERS TO MARKET DEVELOPMENT

The *Mn/DOT Project* Team developed the following original list of “barriers” to increased recycling of manufacturers’ shingle scrap. This list is presented in order of importance.

1. The market for recycled asphalt shingle (RAS) is “demand limited”. I.e., supply is more than adequate at this point in time. Increased use of manufacturers’ RAS-derived HMA is needed. Increased research, development and use of RAS for other applications is also needed.

(Note: Since this conclusion was first identified in 2002, it has since been revised based on the reflection that the available supply of manufacturers’ shingle scrap may be a more important limiting barrier. That is, other HMA producers would be willing to consider investments in shingle recycling if they knew they could obtain long-term supply commitments.)

2. Current attitudes of key audience groups are affected by:
 - A. Lack of information about the technical and economic benefits of MASS-derived HMA; and
 - B. Perceptions based on old, outdated shingle scrap recycling equipment and product quality;
3. In the past, there was a lack of good quality RAS. This limited supply of high quality material hampered market development efforts.
4. Prior to 2004, it was stated by one shingle recycler / HMA producer that they could recycle much more RAS if Mn/DOT revised the shingle scrap specification to allow use of shingles unless prohibited by the project engineer. The earlier version of the specification required each project engineer to approve use of recycled shingles prior to its use.

(Note: This specification change was implemented in December 2003 to a more permissive approach. Did help with the increased use of RAS in seasons 2004 and 2005..)

5. A concurrent emphasis on tear-off shingles market development may dilute the collective focus on manufacturers’ shingle scrap. There were more than enough barriers to develop the market for manufacturers’ shingles during the 2001 to 2003 seasons. It was felt that target audiences could be confused by the different manufacturers’ vs. tear-off messages.
6. There is lack of competition in the recycling of shingle scrap and its use in HMA. A more mature infrastructure with multiple recycling service providers will help accelerate State market development efforts.

SHINGLES PROCESSING – RECENT FIELD EXPERIENCES

A large number of road construction projects have been implemented on a commercial basis that utilized recycled manufacturers’ shingle scrap as a supplement to HMA pavement.

Bituminous Roadways' Projects

Bituminous Roadways, Inc. has had extensive experience with the use of ground shingles for more than ten years. ^[32] A large number of private and public local, county and state road projects have been constructed by Bituminous Roadways using RAS in HMA. These include (but are not limited to):

- France Avenue – Hennepin County
- County Road 42/83 – Scott County
- 19th Avenue No. – City of South St. Paul
- Highway 13 – Mn/DOT
- Various residential street reconstruction projects – City of St. Paul

The previous (prior to 2004) provision in the older version Mn/DOT specification that required job specific approval had made it difficult to plan for and inventory feedstocks for recycling shingles. Paving customers were hesitant to approve its use in part because shingle-derived HMA was an unknown. Now that the Mn/DOT specification is as permissive as RAP (allowing the use of shingles unless specifically prohibited), the HMA contractors are able to significantly increase their recycling rates of shingles.

Bituminous Roadways has developed some helpful operating conclusions and recommendations from their extensive shingle recycling experience:

- Shingle scrap must be free from other debris to protect grinder
- It is important to grind at least to ½-inch minus to help optimize the asphalt binder value from the recycled shingles
- Watering the shingle scrap just as its fed into the grinding chamber helps with product cooling and dust control
- Shrouding equipment (e.g., on the grinder's feed hopper and product exit conveyor) further helps with dust controlling
- Ground shingles a fed into the HMA plants through an additional standard recycle bin in conjunction with RAP
- Less than 50 percent of the shingle asphalt binder is effectively utilized in the mix
- Use of RAS has not been detrimental to quality, but Bituminous Roadways cannot yet conclusively prove that RAS offers improved quality to the mix
- When selecting a virgin asphalt binder grade, adjust one temperature interval lower. For example, if the mix design calls for a virgin asphalt binder of PG 64-XX, when using shingles adjust the virgin asphalt binder to PG 58-XX.
- Lab tests should be conducted to finalize mix design according to the Mn/DOT specified blending chart including residual AC recovery and PG testing.

Bituminous Roadways has made some specific operation recommendations for the future. Shingles recyclers should develop appropriate means to conduct controlled pre-blending of RAS with sand or RAP to avoid re-agglomeration during extended storage of the RAS. The Mn/DOT

State specifications should allow for more use if it can be proven to meet standard QC / QA requirements. The state should continue to research and develop the tear-off shingle recycling technology. And, finally, other non-HMA applications should be developed such as dust control, additive to aggregate base, etc.

Hennepin County's France Avenue Demonstration

In July 2002, Hennepin County Department of Public Works conducted a demonstration on the use of manufacturer shingle scrap in HMA as a part of a road maintenance project on France Avenue. Communications and materials lab support were provided in conjunction with this *Mn/DOT Project*. County engineers carefully reviewed the available technical literature and agreed to a side-by-side demonstration of HMA overlay pavement between 80th and 90th streets. The northbound "test" lanes were paved with HMA derived from 5 percent recycled asphalt shingles (RAS) and southbound lanes were paved with traditional HMA without shingles. The overlay test mix utilized about 75 tons on manufacturer's shingle scrap.

Greg Chock, P.E. and Operations Manager for Hennepin County's Department of Public Works, was the principal demonstration project manager. Mr. Chock presented a brief summary and results at two events including the [MAPA 48th Annual Asphalt Contractors' Workshop on March 4, 2004](#) and at the SWMC Board meeting on March 24, 2004.

Mn/DOT conducted extractions on a series of four core samples to measure performance grade (PG) of the in-place binder. The extraction results indicated that there was no substantial difference between the pavement mix with shingles compared to the mix without shingles. The County had specified PG 58 - 28 and core sample extraction results indicated:

On southbound lanes (30 percent RAP, no shingles):

- PG 67.6 - 27.0 (sample #1)
- PG 68.1 - 27.9 (sample #2)

On northbound lanes (25 percent RAP, 5 percent shingles):

- PG 66.5 - 27.9 (sample #3)
- PG 67.6 - 28.4 (sample #4)

The County reported a modest savings in the demonstration project due to a credit back from its HMA supplier. Also, the County's Public Works paving crew reported that it appeared the shingle-derived HMA material on the northbound lanes set-up faster allowing traffic to run on the new overlay surface sooner.

In the past, Hennepin County had always permitted the use of recycled asphalt pavement (RAP), but had not explicitly allowed the use of recycled asphalt shingles. As a result of this France Avenue demonstration, the County's Public Works Department decided to increase the use of shingle-derived asphalt in County projects. To help promote such use, the County also decided to include shingle derived asphalt material as an alternative bid item in our annual bituminous contract.

INDUSTRY OPINIONS

Recycling of five percent manufacturers' shingle scrap in HMA has been included in Mn/DOT's specifications for almost 10 years and the research proving the technical and economic feasibility is well documented. As a result of this Mn/DOT support, this practice is generally known and well accepted. Effective outreach and education tools include: research publications, presentations at industry conferences, technical engineering experts to answer questions at Mn/DOT's materials laboratory, and informal peer-to-peer information exchange. Direct mailings are supportive of these primary outreach tools, but alone not effective in reaching interested parties.

Three HMA producers in Minnesota are known to use manufacturers' shingle scrap today in their mixes on a regular basis. Several other HMA producers have tried or would consider using recycled shingles. These other HMA producers may be interested in considering using RAS if it were available at a competitive price. The knowledge and awareness of the feasibility of shingles recycling is relatively high. However, there is little interest in investing in the new technology if the supply of manufacturers' shingle scrap or finished RAS is not readily available.

Industry practitioners have unanimously concluded that the primary economic driver in this technology is the proven, significant cost savings in partial replacement of virgin asphalt binder. The value of shingles recycling will increase proportionally to any increase in price of virgin asphalt.

Through interviews and personal communications with HMA producers, the original hypothesis of this *Mn/DOT Project* was found to be incorrect. The lack of adequate market demand was not the key barrier to further development of the recycling of manufacturers' shingle scrap. On the contrary, the lack of economically available supply of RAS was determined to be the key barrier.

CHAPTER 5 - CONCLUSIONS

1. There is a rich and deep history of research and development on the emerging technology of using recycled asphalt shingles (RAS) as a road construction material supplement. The body of published literature extends from the mid 1970's. The literature includes both government research publications and private reports or patent applications.
2. The Minnesota Department of Transportation (Mn/DOT) has been a leader in the research and development of RAS as a supplement in hot-mix asphalt (HMA). The Turgeon (1991), Newcomb (1993), and Janisch (1996) studies are some of the oldest, government lab and field research publications on this topic ^[2, 3, 4, and 5]. These laboratory and field investigations, sponsored by Mn/DOT and the Minnesota Office of Environmental Assistance (MOEA), led to the development of a Mn/DOT construction material specification, originally adopted in 1996, for the recycling of manufacturers' shingles scrap into HMA. ^[1]
3. The Mn/DOT – sponsored field demonstrations using manufacturers' RAS in HMA pavements date back to 1990. Informal evaluations conducted as late as 1996 and 2002 indicated that the shingle-derived pavement test sections were performing at least as well as the control sections without shingles. Unless any of these demonstration sites have been unknowingly resurfaced or repaved, there is a unique opportunity to re-evaluate the long-term influence of RAS on the performance of HMA pavements through continued pavement surveys.
4. Today, more than 15 states have material specifications that allow RAS in HMA or other road construction applications. ^[19]
5. As referenced in the Mn/DOT scrap shingle recycling specification, ^[1] Mn/DOT has developed a draft "Recycled Shingle Scrap Specification on File in the Bituminous Office" for purposes of providing additional guidance about the sourcing and technical details of processing manufactured shingle scrap. ^[6]
6. Most of the past research and development efforts have focused primarily on the use of manufacturers' shingle scrap. Recycling of five percent manufacturers' shingle scrap in HMA has been included in Mn/DOT's specifications for almost 10 years and the research proving the technical and economic feasibility is well documented. As a result of this Mn/DOT support, this practice is generally well accepted. Three HMA producers in Minnesota are known to use manufacturers' shingle scrap today in their mixes on a regular basis.
7. Several other HMA producers have tried or would consider using recycled shingles. These other HMA producers may be interested in considering using RAS if it were available at a competitive price. The knowledge and awareness of the feasibility of shingles recycling is relatively high. However, there is little interest in investing in the new technology if the supply of manufacturers' shingle scrap or finished RAS is not readily available.
8. Through interviews and personal communications with HMA producers, the original hypothesis of this *Mn/DOT Project* was found to be incorrect. The lack of adequate

market demand is not the key barrier to further development of the recycling of manufacturers' shingle scrap.

9. The first research project conducted in 2004 by the Solid Waste Management Coordinating Board (SWMCB) identified the lack of readily available supply of manufacturers' shingle scrap as a limiting barrier to further growth in this type of shingle recycling. ^[24] That is, the manufacturers' shingle scrap marketplace is supply limited. The vast majority of the manufacturers' shingle scrap is already committed in long-term contracts to recyclers and therefore did not allow new business entries into the marketplace.
10. Effective outreach and education tools include: research publications, presentations at industry conferences, technical engineering experts to answer questions at Mn/DOT's materials laboratory, and informal peer-to-peer information exchange. Direct mailings are supportive of these primary outreach tools but if used alone are not effective in reaching interested parties.
11. Since the initiation of this *Mn/DOT Project*, there have been numerous additional government and private efforts to expand the research and development for the recycling of tear-off shingle scrap.
12. Use of a consistent set of terms and definitions will help in ongoing research and market development efforts. The new AASHTO specification is a substantial help in this regard to provide a national framework for continued research.
13. The technical engineering and economic feasibility of recycling shingle scrap is dependent on adequate material quality assurance and quality control procedures. These QA / QC procedures are needed throughout the entire recycling system, in each component of the recycling cycle. It is imperative that a high quality RAS product be reliably produced from the shingle recycling operation. Also, the supply of scrap feedstock should come from known, certified sources.
14. The primary economic driver in this technology is the proven, significant cost savings in partial replacement of virgin asphalt binder. The value of shingles recycling will increase proportionally to any increase in price of virgin asphalt.
15. Secondary economic drivers may include the following advantages for using RAS in HMA:
 - Avoided cost of landfill tipping fees
 - Partial replacement of virgin and other traditional aggregates
 - Fiber content
 - Public relations
 - Improved value of final HMA product

The published research on these secondary economic benefits of using RAS is not as extensive as the body of literature on the value of RAS as a partial replacement for virgin asphalt in HMA.

16. Some private companies have begun positioning the use of manufacturers' RAS as an asphalt modifier in their mixes so as to increase the resulting end product HMA grade. This is not a generally accepted practice in the industry.

CHAPTER 6 – RECOMMENDATIONS

1. The State of Minnesota’s market development efforts should be continued, including the following strategies:
 - a. Continue and enhance the collaboration between the various state and local agencies involved with shingle recycling, especially Mn/DOT and MPCA/OEA.
 - b. Officially establish a non-binding policy goal of recycling 100 percent of the manufacturers’ shingle scrap generated in the Minnesota by the end of 2008.
 - c. Examine alternative policy, strategic and implementation options to achieve this goal.
2. Mn/DOT should coordinate, if not conduct, a new pavement crack survey of all controlled, Mn/DOT-sponsored shingle recycling road demonstration projects, including:
 - Willard Munger Recreation Trail in St. Paul constructed in 1990 as reported by Curtis Turgeon in 1991 ^[3];
 - Trunk Highway (T.H.) 25 in Mayer constructed in 1991 as reported by David Janisch and Curtis Turgeon in 1996 ^[4]; and
 - County State Aid Highway (CSAH) 17 in Scott County also reported by Janisch and Turgeon in their 1996 report ^[4].
 - St. Paul residential street “tear-off” demonstration project constructed in 2003 as reported by Dan Krivit and Associates in 2005. ^[19]
 - Dakota County Highway 70 “tear-off” demonstration project constructed in 2005 as part of the ongoing shingles recycling lab analyses project (report in preparation). ^[33]

One objective of this additional cracking survey would be to re-evaluate the long-term influence of manufacturers’ RAS on the performance of HMA pavements. Another objective would be to begin to monitor the initial tear-off demonstrations.

3. Mn/DOT should finalize and publish its recycled *Shingle Scrap Specification* on file in the Bituminous Office into a memorandum that that can be reliably used by the private sector as additional, official technical guidance.
4. Mn/DOT should continue additional lab and field research leading towards adoption of a new specification for recycling tear-off shingle scrap into HMA. As a preceding step towards a formal specification in the “*Mn/DOT Spec Book*”, Mn/DOT could develop a provisional specification for recycling of tear-off shingle scrap into HMA. This provisional specification should be developed as soon as possible to allow for appropriate investments by the private sector.

GLOSSARY, DEFINITIONS AND LIST OF ACRONYMS

As with most new or developing technologies, there are a wide variety of new terms that are used inconsistently. One means of improving communications and understanding of key market development barriers and improvement opportunities is to use a consistent set of well-defined terms and acronyms. This glossary represents the recommended definitions used in this final report.

Construction & Demolition Waste (C&D)

Federal Highway Administration (FHWA).

Final Blended Binder – For the purpose of this specification, shall mean the mixture of virgin asphalt binder and shingle asphalt binder. (As per the AASHTO specification ^[26])

Hot-Mix Asphalt (HMA) is a engineered road construction material used in a variety of paving applications made from liquid asphalt, aggregate, and recycled materials (e.g., RAP and/or asphalt shingles). Mn/DOT specifies standardized HMA designs and quality control procedures for public agencies road construction projects using state or federal highway funds.

Manufacturers’ Shingle Scrap means all forms and type of waste and usable scrap generated from asphalt shingle manufacturing plants. Can include: whole shingles; aggregate (sand or granules); cut-out “tabs” from three-tab asphalt shingles (also known as “slugs”); solidified “globs” of liquid asphalt derived from line clean-outs; and other plant scrap and waste. (See also “Recyclable Manufactured Shingle Scrap” for the preferred types of manufactured shingle scrap.)

(AASHTO - Manufactured Shingle Waste – For the purpose of this specification, shall mean rejected asphalt shingles or shingle tabs that are discarded in the manufacturing process of new asphalt shingles. ^[26])

Minnesota Department of Transportation (Mn/DOT)

Minnesota Office of Environmental Assistance (MOEA)

Minnesota Pollution Control Agency (MPCA)

New Hot Mix Asphalt – For the purpose of this specification shall mean hot mix asphalt manufactured using aggregates, recycled asphalt pavement (if used), virgin asphalt binder, and reclaimed asphalt shingle. (As per the AASHTO specification ^[26])

Recyclable Manufactured Shingle Scrap is a dynamic term that will be defined by each shingle recycling operation. The definition should specify the exact type and form of manufactured shingle scrap accepted for recycling. For example, in the Twin Cities Area, the generally accepted list of recyclable manufactured shingle scrap includes only whole shingles. Tabs, asphalt globs and other manufacturing plant waste are generally prohibited and not accepted due to transportation logistics and processing equipment limitations.

Recyclable Residential Tear-Off Shingle Scrap - Asphalt shingle scrap derived from private, pitched roof, residential re-roofing projects from houses with single family units up to

four-plex structures comprised primarily of shingle scrap with minimum amount of contaminants such as wood, metal, plastic and other trash.

Recycled (or Reclaimed) Asphalt Pavement (RAP) is ground, screened product derived from old bituminous paving surfaces. Alternative sources of RAP can include either: bituminous chunks of pavement (i.e., not milled); and / or millings from on-site grinding / reclamation equipment.

Recycled Asphalt Shingles (RAS) means ground, screened product, generally in a form ready for use in hot-mix asphalt plants. May also be known as “processed shingles”.

(AASHTO’s definition Reclaimed Asphalt Shingle – For the purpose of this specification, shall mean either manufactured shingle waste or post-consumer asphalt shingle that has been processed into a product that meets the requirements of this standard. [26])

Recycled Materials Resource Center (RMRC) is the research institute funded in part by the FHWA located within the University of New Hampshire in Durham.

Roofing Waste - All types and forms of tear-off scrap from residential and commercial re-roofing projects including shingles, rolled roofing materials, other membranes, metal gutters / flashings, wood scrap, and other miscellaneous construction waste (e.g., caulking tubes, shingle wrappers, general trash).

Shingle Asphalt Binder – For the purpose of this specification, shall mean the asphalt binder that is present in the reclaimed asphalt shingle. (As per the AASHTO specification [26])

Shingle Aggregate - For the purpose of this specification, shall mean mineral granules, sand, or other mineral matter present in the reclaimed asphalt shingle, excluding the shingle fiber content. (As per the AASHTO specification [26])

Shingle Fiber – For the purpose of this specification shall mean, glass felt, paper felt, cotton rags, foil, fabrics or films used as the structural basis of asphalt shingle and other asphalt roofing products. (As per the AASHTO specification [26])

Stone Mastic Asphalt (SMA) is a specific type of high-grade HMA intended to produce a rut-resistant pavement surface. The mix design utilizes a high quality, abrasion resistant, coarse aggregate to form a stone skeleton. Also fibrous material and hard asphalt are specified in SMA.

Solid Waste Management Coordinating Board (SWMCB)

Tear-Off Shingle Scrap means shingle scrap derived from re-roofing projects whereby the old shingle layers are removed to prepare the roof surface for new shingles and / or other roofing materials. (See also “Residential Tear-Off Shingle Scrap” for the eligible source of recyclable tear-off shingle scrap.)

(AASHTO’s definition - Post-Consumer Asphalt Shingle – For the purpose of this specification, shall mean asphalt shingles that are removed from the roofs of existing structures when the new roofs are being installed. Post-consumer asphalt shingle is often called “Tear-Off” shingle. [26])

Virgin Aggregate – For the purpose of this specification shall mean coarse and fine aggregate introduced into new hot mix asphalt that is exclusive of the shingle aggregate. (As per the AASHTO specification ^[26])

Virgin Asphalt Binder – For the purposes of this specification, shall mean new performance graded asphalt binder to be used in (actually added in the plant to make) the new hot mix asphalt. (As per the AASHTO specification ^[26])







REFERENCES

REFERENCES CITED

1. Minnesota Department of Transportation Specification for Scrap Asphalt Shingles as part of the “2360 Plant Mixed Asphalt Pavement, Combined 2360/2350 (Gyratory/Marshall design) specification” as originally amended on December 9, 2003 for the 2004 construction season. From the Mn/DOT Bituminous Office web page: http://www.mrr.dot.state.mn.us/pavement/bituminous/specifications/2005/2360-2350-Combined_2005.pdf, refer to sub-item number 2360.2, A., a2h “Scrap Asphalt Shingles”. (Cited December 2006)
2. David Newcomb, Mary Stroup-Gardiner, Brian Weikle, and Andrew Drescher, "Influence of Roofing Shingles on Asphalt Concrete Mixture Properties." Report MN/RC-93/09, University of Minnesota, Minnesota. (June 1993)
3. Curtis M. Turgeon, "Waste Tire & Shingle Scrap/Bituminous Paving Test Sections on the Willard Munger Recreational Trail Gateway Segment (Interim Report #91-06)." Office of Materials and Research, Minnesota Department of Transportation. (February 1991)
4. Curtis M. Turgeon, "Mn/DOT Physical Research Construction and Lab Report: Shingle Scrap in Asphalt Concrete on T.H. 25 south of Mayer (S.P. 1006-20)" as constructed on June 17-21, 1991. (Circa 1993)
5. D. W. Janisch and C.M. Turgeon, “Minnesota's Experience Using Shingle Scrap in Bituminous Pavements.” Minnesota Department of Transportation, Maplewood, MN. Report No. PB-97-132278/XAB MN/PR--96/34. (October 1996)
6. Minnesota Department of Transportation, Office of the Bituminous Engineer, Draft “Scrap Shingle Specifications on file.” (Circa 1998)
7. Darlene Gorrill, “Communication Plan for Making Scrap Shingles a Competitive Source of Asphalt for Bituminous Pavement Material (Draft),” submitted to the Minnesota Department of Transportation. (July 1997)
8. Darlene Gorrill and Dan Krivit, “Communication Plan: Improving Recycling of Manufactured Shingle Scrap into Hot-Mix Asphalt in Minnesota”, submitted to the Minnesota Department of Transportation. (October 2001)
9. G. Paulsen, M. Stroup-Gardiner, and J. Epps, "Recycling Waste Roofing Material in Asphalt Paving Mixtures." Transportation Research Record #1115, Transportation Research Board. (1987)
10. Prithvi S. Kandhal, "Waste Materials in Hot Mix Asphalt - An Overview." National Center for Asphalt Technology, Report No. 92-6. (1992)

11. Ben B. Ross, "An Evaluation of the Use of Hot Mix Asphalt Pavements Containing Roofing Shingle Material in North Carolina." Prepared for the North Carolina Department of Environment, Health and Natural Resources. (Raleigh, NC, 1997)
12. Charles S. Hughes, "Uses of Waste Asphalt Shingles in HMA." Special Report 179, National Asphalt Pavement Association. (Lanham, Maryland, 1997)
13. Donald E. Watson, et al., "Georgia's Experience with Recycled Roofing Shingles in Asphaltic Concrete." TRR 1638, Transportation Research Board. National Research Council. (Washington DC 1998)
14. Federal Highway Administration, "Roofing Shingle Scrap, User Guidelines for Waste and By-Product Materials in Pavement Construction." Publication FHWA RD-97-148. (McLean, Virginia, 1998)
15. Vermont Agency of Natural Resources. "[Recycled Shingles in Road Applications.](#)" (September 1999)
16. National Association of Home Builders (NAHB) Research Center, "From Roofs to Roads...Recycling Asphalt Roofing Shingles into Paving Materials," An information and guidance brochure for builders, remodelers, solid waste planners, and recyclers of construction waste. (Upper Marlboro, MD, 1999)
17. Rajib B. Mallick, Matthew R. Teto, and Walaa S. Mogawer, "[Evaluation of Use of Manufactured Waste Asphalt Shingles in Hot Mix Asphalt.](#)" Technical Report #26, Chelsea Center for Recycling and Economic Development. (2000a). Web page URL (Cited December 2006): <http://www.chelseacenter.org/pdfs/TechReport26.pdf>.
18. Andrew J. Zickell, "[Asbestos Analysis of Post-Consumer Asphalt Shingle Waste.](#)" Technical Report #41, Chelsea Center for Recycling and Economic Development. (2002). Web page URL (Cited December 2006): <http://www.chelseacenter.org/pdfs/TechRept41asbestoshingle.pdf>
19. Dan Krivit, "Overcoming the Barriers to Asphalt Shingle Recycling: Final Report for the RMRC Project 22" Recycled Materials Resource Center, Durham, NH. (January 2005)
20. Bituminous Roadways, Inc. "Bituminous Roadways, Inc. Experience with Shingles Recycling Equipment," the first round of capital assistance grant report to the Minnesota Office of Environmental Assistance." (Circa 1999)
21. Bituminous Roadways, Inc. "Bituminous Roadways, Inc. Experience with Shingles Recycling Equipment," the second round of capital assistance grant report to the Minnesota Office of Environmental Assistance" (August 2004)
22. Darlene Gorrill, "Minnesota's Use of Shingle Byproduct in Paving Projects Increases". Center for Transportation Studies (CTS), Minnesota Technology Transfer (T2), Local Technical Assistance Program, Technology Exchange Newsletter, Winter 2003. As published on the CTS web page site: <http://www.cts.umn.edu/T2/TechExch/2003/winter/shinglebyproduct.html>
23. Recycled Materials Resource Center (RMRC); "Research Project 22: Overcoming the Barriers to Asphalt Shingle Recycling," a research project fact sheet originally published

- by RMRC in February, 2003. As published on the RMRC web site:
<http://www.rmrc.unh.edu/Research/Rprojects/Project22/reports/P22summary.pdf>
24. Dan Krivit, "Manufactured Shingle Scrap Recycling Project" Prepared for Solid Waste Management Coordinating Board (SWMCB). (August 2004)
 25. Roger Olson, "Mn/DOT's Perspective on Shingle Recycling" a presentation to the Minnesota Asphalt Pavement Association's (MAPA) 48th Annual Asphalt Contractors' Workshop on March 4, 2004
 26. Association of American State Highway and Transportation Officials (AASHTO) Use of Reclaimed Asphalt Shingle as an Additive in Hot Mix Asphalt: A Provisional Standard Specification (M2005A-TS-2c) (July 2006)
 27. Association of American State Highway and Transportation Officials (AASHTO) Provisional Standard Recommended Practice for Design Considerations when using Reclaimed Asphalt Shingles in New Hot Mix Asphalt (R2005A-TS-2c) (July 2006)
 28. Ron Sines (The P. J. Keating Company), "Use of Recycled Shingles in HMA Pavements", A presentation to the Northeast Asphalt User/Producer Group", October 31, 2002.
 29. Douglas I. Hanson, Kee Y. Foo; and Todd A. Lynn; Evaluation of Roofing Shingles in HMA for the National Center for Asphalt Technology. (March 1997)
 30. Kee Y. Foo, Douglas I. Hanson, and Todd A. Lynn, "Evaluation of Roofing Shingles in Hot Mix Asphalt." *Journal of Materials in Civil Engineering*, Vol. 11, No. 1, February 1999, pp 15-20.
 31. Bob Ayres (Allied Blacktop, Inc.), *Shingle Recycling: A Paving Contractor's Perspective* A presentation at the Second Asphalt Shingles Recycling *Forum* in Bloomington, MN on April 14, 2003. URL: <http://www.projects.dot.state.mn.us/uofm/shingles/ayres.pdf>.
 32. Dusty Ordorff, "Bituminous Roadways, Inc.: Recycling Shingles Since 1996" Presentation at the March 16, 2005 CONEXPO-CON/AGG: Educational Seminar Program.
 33. Dan Krivit, James McGraw, Mihai Marasteanu, and Joe Schroer, "Lab Analyses of Shingles Scrap in Various Hot Asphalt Mixes". An ongoing project co-funded by the Minnesota Office of Environmental Assistance and the Missouri Department of Transportation. (In preparation.)
 34. Dan Krivit; Darlene Gorrill, Roger Olson, A Guide to the Use of Roofing Shingles in Road Construction: It's All Part of the Mix (including a series of fact sheets) for the Minnesota Department of Transportation and the Minnesota Office of Environmental Assistance, 2001. (Web page URL: www.moea.state.mn.us/lc/purchasing/shingles.cfm.)
 35. Dan Krivit, Shingle Recycling: A Selected Literature Review for the EPA / CMRA Project and the Minnesota / Missouri lab analyses projects (co-funded by MOEA and MoDOT). In preparation.

36. David Newcomb, "Roofing Shingles in Hot Mix Asphalt", A presentation at the Second Asphalt Shingles Recycling *Forum* in Bloomington, MN on April 14, 2003. URL: <http://www.projects.dot.state.mn.us/uofm/shingles/newcomb.pdf>.
37. Construction Materials Recycling Association (CMRA), joint venture web site originally created in collaboration with the U.S. Environmental Protection Agency (EPA) and the University of Florida (Gainesville): www.ShingleRecycling.org.
38. Henry Justus (Chesner Engineering), "Standard Specification for Recycled Asphalt Shingle as an Additive in Hot Mix Asphalt". Prepared for the Recycled Materials Resource Center, University of New Hampshire, Durham, New Hampshire as part of RMRC Project #13/14 (Draft as transmitted October 24, 2003).
39. Henry Justus (Chesner Engineering), "Draft White Paper for Recycled Asphalt Shingle as an Additive in Hot Mix Asphalt". Prepared for the Recycled Materials Resource Center, University of New Hampshire, Durham, New Hampshire as part of RMRC Project #13/14. (Draft as of August 28, 2003).
40. Recycled Materials Research Center (RMRC), research center web page as hosted by the University of New Hampshire (UNH): www.rmrc.unh.edu/Research/Rprojects/Project22/reports/P22summary.pdf.
41. Recycled Materials Resource Center (RMRC) *Second Asphalt Shingles Recycling Forum* as held on April 14, 2003: www.projects.dot.state.mn.us/uofm/shingles.
42. Minnesota Office of Environmental Assistance (MOEA) market development and purchasing assistance web site: www.moea.state.mn.us/lc/purchasing/shingles.cfm. This MOEA web site has posted the *Mn/DOT "Phase Two" Project* information kit entitled A Guide to the Use of Roofing Shingles in Road Construction: It's All Part of the Mix, including the following fact sheets:
 -  [Project Overview](#)
 -  [Minnesota Research](#)
 -  [Case Studies](#)
 -  [Economics](#)
 -  [Vendors of Shingle-grinding Equipment](#) (updated February 2004!)
 -  [For more information](#)
43. Solid Waste Management Coordinating Board (SWMCB) original manufacturers' shingles recycling project (2002 through 2004) produced a series of fact sheets and conference presentations. These products are posted (currently being updated) on the SWMCB web page: www.greenguardian.com/shinglerecycling/.