Overcoming the Barriers to Asphalt Shingle Recycling: Final Report for the RMRC Project 22

Final Report

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EXECUTIVE SUMMARY

This *RMRC Project, Overcoming the Barriers to Asphalt Shingle Recycling* (RMRC Project 22), continued over 14 years of research and development in Minnesota and selected other states on recycling of shingle scrap. This *RMRC Project* focused on field-testing, market development, and technology transfer of tear-off shingle scrap recycling. The end-use road construction applications demonstrated included use of recycled asphalt shingles (RAS) as: (1) a dust control supplement; (2) an unbound aggregate supplement as base; and (3) a 5 percent blend into hot-mix asphalt (HMA). One of the first products was an "Environmental White Paper" documenting the results of a controlled personal air sampling of ambient dust generated from a shingle recycling operation. A major outreach strategy was the April 2003 *Second Asphalt Shingles Recycling Forum* held in Bloomington, MN.

In the past, the additional quality assurance / quality control (QA/QC) challenges of residential tear-off shingle scrap have been barriers to development of this type of asphalt shingle scrap. In Minnesota, there is more demand for recycled manufacturer shingle scrap than available supply. Thus, there was a continued need to develop tear-off shingle recycling as addressed by this *RMRC Project.*

Recycling manufacturer RAS into HMA as the primary application is well developed. There is still a need to develop secondary, non-HMA applications such as blending into unbound aggregate for road base and use as dust control. This is especially true for recycled materials derived from tear-off shingle scrap. Tear-off derived RAS does not yet have as an extensive proven track record as compared to manufacturer shingle scrap. Nor is tear-off scrap allowed in as many state DOT specifications. For example, tear-offs are still prohibited from Mn/DOT's scrap shingle specification. This will go hand-in-hand with the need to continue to develop the tear-off collection and processing infrastructure in order to assure production of high-performance products suitable for road construction materials.

There still is a continued need to improve the understanding and awareness about the technical and economic benefits to use such RAS derived products. For example, many engineers are still skeptical about the engineering properties of shingle-derived HMA and need more information about the quality assurance / quality control practices employed by most reputable shingle recyclers.

There was substantial recycled shingles specification development work recently completed by the RMRC. This other related project sponsored by RMRC was the "Development and Preparation of Specifications for Using Recycled Materials in Transportation Applications" (RMRC Project #13 / #14). Conducted by Chesner Engineering, this related RMRC project resulted in 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.

The Solid Waste Management Coordinating Board (SWMCB) *Manufacturer Shingle Scrap Recycling Project* was conducted mostly in 2004. The *SWMCB Project* and was intended to expand the emerging shingle recycling markets by improving information and technology exchange in the six-county region within the Twin Cities Metropolitan Area. The *SWMCB Project*, together with the other ongoing efforts Mn/DOT and OEA, helped accelerate the

development of this market and served to increase the recycling rate. The Metro Counties' elevated interest in purchasing shingle-modified HMA clearly demonstrated the potential increased end-use demand for manufacturers' shingle scrap and thereby help stimulate the overall shingle recycling market.

This *RMRC Project* has resulted in a wide variety of products, including completed and pending research, publications, presentations at conferences / meetings, a video, photos and other video clips.

This *RMRC Project* included a one-time demonstration in the fall of 2003 of the use of residential tear-off asphalt shingle scrap. Bituminous Roadways, Inc. (BRI) conducted this demonstration. BRI sourced the tear-off shingle scrap from Sella Roofing derived from re-roofing jobs on private, residential homes primarily in St. Paul. Armor Waste hauled the mixed roofing waste via roll-off boxes to its Eagan transfer stations. The results were very encouraging and additional research and specification development plans are in progress.

In November 2001, Bituminous Roadways, Inc. (BRI) and SKB Environmental agreed to a short demonstration on the use of shingles cold-blended together with traditional aggregates as a dust control measure. Mn/DOT released a *Construction of Field Evaluation Sections for the Use of (Manufacturer) Waste Shingles* as conducted at SKB Industrial Waste Landfill in Rosemount, Minnesota. This work indicated such cold-blending, especially the RAS / aggregate mix, is feasible but maybe should be restricted to summer only to take advantage of warmer.

The *RMRC Project* team, including BRI, proposed a field and lab test demonstration on the blending of RAS with traditional unbound aggregate for use as road base. The primary purpose of this proposed demonstration was to observe the quality and performance of this "Class 7-BC" product containing a maximum 10 percent recycled shingles by volume. This RAS / aggregate base demonstration project has not yet been finally completed.

The primary economic driver for asphalt shingle recycling is the virgin asphalt cost savings derived by HMA producers. RAS becomes a partial replacement of the virgin asphalt. BRI realizes savings of approximately $.50 to $1 per ton of final HMA product with the use of five (5) percent RAS. The total, average cost per ton for HMA production and sale is approximately $30 per ton. This is very similar to the savings reported by Allied Blacktop (Eau Claire, WI) at the *Second Asphalt Shingle Recycling Forum* as held in April 2003. Allied reported savings of about $.50 per ton of HMA product. Other studies have indicated a savings of up to $3 per ton of final HMA (NAPA,)

This *RMRC Project* resulted in several recommendations to various specifications including Mn/DOT's and the proposed AASHTO specification. The key strategy in each case was to help promote a larger dialogue with between the state DOT materials engineers responsible for specification development and the private recycling industry. Nine other state DOT's are known to have shingle recycling specifications.

A series of key conclusions and recommendations were developed for this *RMRC Project* final report.

CHAPTER 1 – INTRODUCTION

ABOUT THIS RMRC PROJECT

This *Phase Three* project continued over 14 years of research and development in Minnesota on recycling of shingle scrap. *Phase Three* focused on field-testing, market development, and technology transfer of tear-off shingle scrap recycling. The end-use road construction applications demonstrated included use of recycled asphalt shingles (RAS) as: (1) a dust control supplement; (2) an unbound aggregate supplement as base; and (3) a 5 percent blend into hot-mix asphalt (HMA). One of the first products was an "Environmental White Paper" documenting the results of a controlled personal air sampling of ambient dust generated from a shingle recycling operation. A major outreach strategy was the April 2003 *Second Asphalt Shingles Recycling Forum* held in Bloomington, MN.

Minnesota continues to approach its efforts on improving the recycling of shingle scrap in two parts. First, the State, local governments and private sector operators are addressing the barriers to recycling of manufacturer asphalt shingle scrap. Second, and in sequential order, continued research and development is underway to address the barriers to recycling of tear-off shingle scrap. The technical, economical, environmental and educational challenges are slightly different for each type of shingle scrap. The most successful, overall market and technology development strategy will ultimately be comprehensive and encompass both sources of shingle scrap: manufacturer and tear-off.

There are a few critical barriers holding back the development of recycling of shingle scrap. These barriers are felt nationally, regionally and locally.

Lack of End-Use Demand and Specifications There continues to be a need to develop sufficient end-use demand for shingle-derived products. Recycling manufacturer RAS into HMA as the primary application is well developed. There is still a need to develop secondary, non-HMA applications such as blending into unbound aggregate for road base and use as dust control. This is especially true for recycled materials derived from tear-off shingle scrap. Tear-off derived RAS does not yet have as an extensive proven track record as compared to manufacturer shingle scrap. Nor is tear-off scrap allowed in as many state DOT specifications. For example, tear-offs are still prohibited from Mn/DOT's scrap shingle specification.

Lack of Supply of RAS The use of recycled shingles in HMA is still not widespread and additional supplies of feedstock scrap are needed to promote further market development. The use of 5 percent manufacturer shingle scrap in hot-mix asphalt (HMA) is well proven through multiple studies, authorized by an existing Mn/DOT specification, and generally accepted by the HMA industry. However, only three shingle manufacturers exist in Minnesota and their manufacturers' asphalt shingle scrap is mostly locked up under contract.

Lack of Communications and Outreach There still is a continued need to improve the understanding and awareness about the technical and economic benefits to use such RAS derived products. For example, many engineers are still skeptical about the engineering properties of shingle-derived HMA and need more information about the quality assurance / quality control practices employed by most reputable shingle recyclers.

Lack of Developed Tear-Off Recycling Infrastructure There is a need to continue to develop the tear-off collection and processing infrastructure in order to assure production of high-performance products suitable for road construction materials.

PROJECT GOALS AND OBJECTIVES

This *RMRC Project* was the next in a series of development efforts to address these barriers. This project had seven objectives:

1. Improve awareness and attitudes of product buyers through strategic information / technology transfer and to build further cooperation between the waste management and pavement industries.
2. Improve the understanding about the economic and technical advantages of using shingle scrap in various road construction materials. Demonstrate that the end products derived from RAS perform comparably or better than traditional materials.
3. Assist with the development of more advanced collection and processing systems for tear-off shingle scrap.
4. Identify and develop necessary leadership within both the public and private sectors.
5. Field test the tear-off derived end-product applications leading to recommendations for one or more standard recycled material specification.
6. Develop and implement a tear-off field sampling and lab testing protocol to provide sufficient data to recommend appropriate environmental and safety protections.
7. Institute a technology transfer service that can be sustained over a longer time frame, beyond the period of this *RMRC Project*.

RMRC PROJECT #13 / #14: SPECIFICATION DEVELOPMENT

There was substantial recycled shingles specification development work recently completed by the RMRC. This other related project sponsored by RMRC was the "Development and Preparation of Specifications for Using Recycled Materials in Transportation Applications" (RMRC Project #13 / #14). Conducted by Chesner Engineering, this related RMRC project resulted in 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. (See AASHTO Specification section within Chapter 2 below for more discussion.)

OTHER RESEARCH AND DEVELOPMENT EFFORTS

Minnesota has a rich, deep history of development of the shingles recycling technology and markets. Original research sponsored by the Mn/DOT and the MOEA began as early as 1990.

All research has indicated that the use of five percent shingle scrap in the production of hot-mix asphalt (HMA) can be designed and controlled so as to maintain the bituminous pavement engineering properties. As a result, in 1996, Mn/DOT adopted a material specification allowing up to five percent manufacturers' shingle scrap in HMA. The current version of the Mn/DOT specification allows use of shingle-modified HMA at the private contractor's discretion unless prohibited by the project engineer [4]. The research and specification for recycling of shingle scrap is built upon the successful development of the recycled asphalt pavement (RAP) technology.

Mn/DOT Projects

There is a substantial amount of previous research and feasibility work (informally referred to as *"Phase One"*) conducted for Mn/DOT in the early 1990's. Within *"Phase One",* a series of three studies were sponsored and published by Mn/DOT:

- Turgeon, Curtis M., "Waste Tire & Shingle Scrap Bituminous Paving Test Sections On The Munger Recreational Trail Gateway Segment." Office of Materials and Research, Minnesota Department of Transportation, February, 1991.
- Newcomb, David E., Mary Stroup-Gardiner, Brian M. Weikle, and Andrew Drescher, "Properties of Dense-graded and Stone-mastic Asphalt Mixtures Containing Roofing Shingles." ASTM Special Publication 1193, ASTM, 1993
- Newcomb, David, et al., "Influence of Roofing Shingles on Asphalt Concrete Mixture Properties." Report MN/RC-93/09, University of Minnesota, Minnesota, 1993.
- Janisch, D. W. and C.M. Turgeon, "Minnesota's experience using shingle scrap in bituminous pavements. Final report, 1991-1996." Minnesota Department of Transportation, Maplewood, MN. Report No. PB-97-132278/XAB MN/PR--96/34, October 1996.

These earlier research and development projects lead to the first version of the Mn/DOT materials specification in 1996 to allow up to 5 percent manufacturer scrap shingles in certain asphalt hot mixes.

The *"Phase Two" Mn/DOT Project* (approximately 1997 through 2002) was focused on outreach to expand implementation of manufacturer shingle scrap recycling. The top *Phase Two* priority was to increase utilization into HMA as per the current Mn/DOT specification.

As part of the Mn/DOT *"Phase Two" Project* resulted in an information "tool kit". Mn/DOT published this as, A Guide to the Use of Roofing Shingles in Road Construction: It's All Part of the Mix and included the following fact sheets:

- Project Overview
- Minnesota Research
- Case Studies
- Economics
- Vendors of Shingle-grinding Equipment (updated February 2004)
- For more information

The Minnesota Office of Environmental Assistance (OEA) helped further disseminate this shingles recycling Guide via the OEA web page, www.moea.state.mn.us/lc/purchasing/shingles.cfm, with the subsequent links to view the individual fact sheets.

This 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.

Ongoing Market Development Efforts by the OEA

The Minnesota Office of Environmental Assistance (OEA) has been a full and long-term state agency partner with Mn/DOT in this shingles recycling market development effort. OEA provided matching funding for previous research, including the Newcomb project. OEA also awarded two capital assistance grants to Bituminous Roadways, Inc. (BRI) for development, purchase, testing and public reporting of actual shingle recycling operations. With assistance from the latest OEA grant, BRI bought a new mobile grinding machine for the processing of scrap shingles.

BRI recently completed the last of its reports to MOEA in regards to its experience and lessons learned. This is one of the key indicators of the significant progress that has been made in manufacturer shingle scrap processing.

OEA also has hosted a web page on the environmentally preferable purchasing of recycled shingles: http://www.moea.state.mn.us/lc/purchasing/shingles.cfm. This web page represents the ongoing efforts by MOEA to continue to assist in the development of this viable market for recycled shingles.

Ongoing Efforts by Private Industry

The private sector, especially HMA producers, continues to provide ongoing implementation and field trials of the use of recycled shingle scrap in various mixes of asphalt. Within the State, the Minnesota Asphalt Pavement Association (MAPA) continues to advocate for recycling research and development, especially if the material use can result in reduced production costs and equal or improved product performance, such as with recycled shingle scrap. For example, MAPA was instrumental in advocating for the recent update in the Mn/DOT specification to allow contractors the discretion to use shingles in HMA.

SWMCB Project

The Solid Waste Management Coordinating Board (SWMCB) *Manufacturer Shingle Scrap Recycling Project* was conducted mostly in 2004. The *SWMCB Project* and was intended to expand the emerging shingle recycling markets by improving information and technology exchange in the six-county region within the Twin Cities Metropolitan Area. The *SWMCB Project*, together with the other ongoing efforts Mn/DOT and OEA, helped accelerate the development of this market and served to increase the recycling rate. Also, part of the intent of this *SWMCB Project* was to improve local government purchasing of shingle derived HMA. This involved affirmative county HMA purchasing practices. The Metro Counties' elevated interest in purchasing shingle-modified HMA clearly demonstrated the potential increased end-

use demand for manufacturers' shingle scrap and thereby help stimulate the overall shingle recycling market.

CMRA Project

CMRA and EPA co-sponsored the first *Shingles Recycling Forum* in December 1999 that later resulted in a web page co-sponsored by U.S. EPA, the National Roofing Contractors Association (NRCA), and the University of Florida, http://www.shinglerecycling.org/. The net result was a very high level of outreach, education and implementation efforts. High-quality information is now readily available and many more interested parties are aware of the shingle recycling opportunities.

CHAPTER 2 – PROJECT RESULTS

This *RMRC Project* has resulted in a wide variety of products, including completed and pending research, publications, presentations at conferences / meetings, a video, photos and other video clips.

LITERATURE SEARCH

An extensive annotated bibliography was produced for this *RMRC Project* and contained over 100 shingle recycling references and resources for more information. The final format for publication of this bibliography has not yet been decided.

SHINGLE RECYCLING OPERATIONS

There are four hot-mix asphalt / paving companies that process recyclable scrap generated from Minnesota shingle manufacturers:

- Bituminous Roadways, Inc. (Inver Grove Heights, MN)
- Omann Brothers (St. Michael, MN)
- Allied Blacktop Corp. (Eau Claire, WI)
- Bauerly Companies (St. Cloud, MN)

Each of the four companies has developed its own, unique processing system but they all including grinding and screening components. In each case, their primary end use application is the HMA for their companies' paving operations. A minor portion of the oversized material after screening is being used as an aggregate supplement for road base. All four are currently utilizing manufacturer shingle scrap, but would like to develop additional supplies from tear-off shingles in the future.

Bituminous Roadways, Inc. (BRI) and Omann Brothers have long, individual histories of shingle scrap processing, use, research, development and field application. Omann began recycling shingles approximately in 1991. BRI began recycling shingles in 1995. Numerous studies from Minnesota, including the Mn/DOT *Phase One Project*, have used shingle-modified HMA from both producers.

BRI has a shingle recycling operation at their HMA plant and aggregate pit in Inver Grove Heights, Minnesota. BRI utilizes the Bandit *Beast* model horizontal grinder with a standard trommel screen (see Appendix A for more details). BRI has an exclusive contract to manage the scrap material from CertainTeed Corporation. The material has always been processed and utilized by BRI into its own HMA according to Mn/DOT specifications. In addition, BRI has conducted or participated in multiple research projects to develop alternative end-use

applications. Beyond the traditional blending into HMA, BRI explored the use of processed scrap shingles as:

1. Aggregate supplement in unbound "Class 7" aggregate for base;
2. Dust control on gravel-surfaced roads; and
3. Lightweight pavement surface in cold-mix combination with RAP.

Omann Brothers has been utilizing recycled shingle scrap from CertainTeed Corporation and Owens Corning, Inc. and at its plant near St. Michael, MN. Omann has had success with installing shingle-modified HMA with much higher ratios of recycled shingle scrap (e.g., 20 to 30 percent). This is technically and economically feasible because Omann's market includes both private customers and other local projects that are not required to follow the Mn/DOT specification maximum of 5 percent shingle scrap by weight. Omann designed its own equipment and has two patents on its system.

Another out-of-state company, Allied Blacktop (Eau Claire, Wisconsin), also receives manufacturer shingle scrap from Minnesota for processing and recycling. Allied's shingle-modified HMA products are installed in customers' projects in western Wisconsin. Like BRI, Allied uses the Bandit *Beast* grinding equipment but has different screening and debris management system components. (See Appendix B for a diagram of Allied's shingle recycling system.)

In 2004, Bauerly Companies began its full-scale shingle-recycling program near St. Cloud, MN.

There are several other HMA producers that have used recycled shingle scrap in the past. Some of these companies and others are considering such use in the future if a clean, reliable supply of recyclable shingle scrap is approved and can be economically secured.

DEMONSTRATIONS

Tear-Off Demonstration

This *RMRC Project* included a one-time demonstration in the fall of 2003 of the use of residential tear-off asphalt shingle scrap. Bituminous Roadways, Inc. (BRI) conducted this demonstration. BRI sourced the tear-off shingle scrap from Sella Roofing derived from re-roofing jobs on private, residential homes primarily in St. Paul. Armor Waste hauled the mixed roofing waste via roll-off boxes to its Eagan transfer stations. There, the material was tipped and sorted by Armor Waste crews. Asphalt shingle scrap was sorted via hand and bobcat. Non-shingle debris that was removed included:

- Metal (aluminum flashings, cans, nails and other scrap metal);
- Wood (scrap lumber, pallets, and other scrap wood);
- Plastics (film plastic such as stretch wrap, shingle manufacturer bundle wraps, caulk tubes, and other scrap plastic); and
- Other trash and non-shingle debris (yard waste, "lunch trash").

Armor Waste normally sorts materials in this fashion in part due to lower tipping fees at certain landfills. Therefore, the above sourcing, tipping, and sorting operations are normal procedure for loads of mixed roofing waste. The final asphalt shingles loads sent to Bituminous Roadways, Inc. (BRI) were very clean, without any significant contamination. However, some minor amount of nails and roofing felt remained in the product shipped to BRI.

BRI received approximately 200 tons of certified, residential tear-off asphalt shingle scrap from Armor at its Inver Grove Heights, MN pit and asphalt plant. BRI stockpiled the tear-off scrap separately from its manufacturer shingle scrap. Once a final HMA job was identified and approved by the City of St. Paul, BRI processed the tear-off scrap by using multiple passes through its grinding and screening equipment to remove all nails and produce a high-quality recycled asphalt shingle (RAS) product (ground / screened). The tear-off RAS product was stockpiled separately from the manufacturer RAS product.

BRI reported that the tear-off scrap was relatively easier to grind compared to manufacturer scrap and thus the tear-off scrap could be processed at a higher production rate. This may be due to the tear-off product being more brittle in part because it is more oxidized. The additional passes through the Bandit Beast – model grinder was costly but necessary to assure that all the debris, primarily nails and staples had been removed. In the future, if tear-offs are processed on a regular, commercial-scale basis, at least one additional magnet should be added to the processing line to provide for adequate removal of metal contaminants (e.g., nails, stables) with "one pass".

Finally, the tear-off RAS was incorporated it into HMA at BRI's Inver Grove Heights asphalt plant. The tear-off shingle-derived HMA was used in the first, asphalt base lift of a residential road reconstruction project in St. Paul (on the four blocks of Westminster Street immediately south of York Avenue East) at approximately two (2) inches thick. Only the northbound lanes, base course utilized tear-off derived HMA. Southbound lanes utilized manufacturer derived HMA with all other mix design and QA / QC parameters remaining the same. Only the base lift of these northbound utilized tear-off derived HMA. The final wear course was installed in the spring of 2004 and included manufacturer derived HMA only, no tear-offs shingle scrap was incorporated into the wear course.

BRI reported that, although there were no differences in HMA production, there was approximately one (1) percent more asphalt cement (AC) recovered in the tear-off derived HMA. This somewhat explains the lower air voids in the tear-off derived HMA observed at BRI lab and the higher density in the field as shown in core results. This is as expected given that tear-offs typically have AC content around 30 to 40 percent as compared to manufacturer product which is around 20 percent AC. BRI also reported that there were no differences in paving operations other than the BRI crew's higher awareness of possible debris. No debris was detected.

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 was provided by the *Mn/DOT "Phase Two" Shingles Recycling Project.* County engineers carefully reviewed the available technical literature and agreed to a side-by-side demonstration of HMA overlay pavement using shingles on northbound lanes and traditional HMA without shingles in the southbound lanes.

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.

Dust Control at SKB

In November 2001, Bituminous Roadways, Inc. (BRI) and SKB Environmental agreed to a short demonstration on the use of shingles cold-blended together with traditional aggregates as a dust control measure. Mn/DOT released a *Construction of Field Evaluation Sections for the Use of (Manufacturer) Waste Shingles* as conducted at SKB Industrial Waste Landfill in Rosemount, Minnesota. Greg Johnson, P.E. at Mn/DOT's Office of Materials and Road Research, works on aggregate road surfaces and prepared a Power Point presentation based on his observations on November 7, 2001.

The first 30 x 100 foot section involved blade mixing the existing aggregate base with 5 tons of manufacturer RAS scrap (ground, screened to approximately ½-inch minus). This was done by a visual approximation of equal volumes. The existing base aggregate was a mix of gravel, crushed concrete, clay, and sand. The existing road surface was firm and very compacted. The grader made a series of passes with the blade tipped on edge cut into the surface as a method of scarifying. Equal volumes of shingles and base aggregate were thoroughly mixed together (50:50) and then bladed out to a smooth surface. The surface was then watered three times to aid in compaction. A steel-wheel vibratory roller was used to compact the surface (four roller

passes). Appropriate density was achieved at a final thickness of about 1.5 inches. There was no segregation apparent and the RAS was difficult to detect visually.

The next 30 x 100 foot section involved blade mixing 10 tons of RAS with 20 tons of RAP (2:1). Both products were ground to 1/2 inch minus. The shingles and RAP were blade-mixed thoroughly on top of the existing aggregate surface left intact as a base. The RAS / RAP mix was then leveled out. This section was also compacted with the vibratory steel-wheel roller in a manner similar to the first, RAS / base aggregate section described above. The final mat thickness was approximately 2.5 inches. The surface never did compact adequately. This was due to late season of construction. The weather was not warm enough to get the asphalt in the RAP and shingles to adhere to each other or the aggregate. Additional watering and passes with the roller improved the density only minimally. The mix proved to both difficult to blend and to achieve density, at least at colder temperatures.

Supplement to Unbound Aggregate by BRI

The *RMRC Project* team, including BRI, proposed a field and lab test demonstration on the blending of RAS with traditional unbound aggregate for use as road base. While the project has not yet been finally completed, the primary purpose of this proposed demonstration was to observe the quality and performance of this "Class 7-BC" product containing a maximum 10 percent recycled shingles by volume. The objectives included:

- Field test the performance an aggregate road base comprised of a Class 7-BC supplemented with 10 percent RAS as compared to a control strip without shingles.
- If successful, determine the material quality and product performance data needed by Mn/DOT to develop a new specification to allow use of shingles in aggregate as base.

Bituminous Roadways, Inc.'s (BRI's) traditional, Class 7–BC aggregate is comprised of approximately (rough estimates):

- 70 percent crushed concrete
- 10 percent rubble asphalt
- 20 percent virgin sand and other aggregates

Note that these three materials are not blended but the relative composition is a rough approximation derived from visual volume estimates. The composition varies and is due to the incidental mixtures as delivered to BRI's plant.

BRI's recycled shingle product proposed for this demonstration is known as screened "overs" not passing the trommel screen ½-inch mesh. All proposed RAS were proposed to be from manufactured, asphalt shingle scrap from CertainTeed Corporation's Shakopee, MN plant. No tear-off shingle scrap was proposed. BRI produced about 5,000 tons of Class 7-BC with 10 percent shingles at its Inver Grove Heights plant in 2003. The product was produced using its normal recycled aggregate processing operations via subcontractor. The RAS screened "overs" product was derived from the existing BRI stockpile and blended into the Class 7-BC during the crushing operations. A maximum blending ratio of 10 percent was estimated using bucket front-end loader.

BRI proposed to install the Class 7-BC products on a selected road construction project in 2004 accompanied by field and lab testing of the following parameters:

- Gradation
- Proctor (moisture / density)
- Resilient modulus
- Dynamic cone penetrometer (DCP)

BRI proposed to conduct the lab and field testing using an independent materials lab contractor. It was proposed that Mn/DOT conduct additional, duplicate testing at its discretion if necessary. The demonstration project has not yet been completed but is still under development.

ECONOMIC ANALYSIS

On August 9, 2004, Bituminous Roadways, Inc. (BRI) submitted its final report to the Minnesota Office of Environmental Assistance (OEA) as part of its state grant obligations. This report as submitted by Kent Peterson, President of BRI, is entitled: *A Project to Improve a System for Processing Shingle Scrap and to Increase the Market for Processed Shingles*. This BRI report to OEA provided extensive discussion about the cost of research, development and operations. The report stated that the use of manufacturer shingle scrap has become standard practice at BRI with a large percentage of the HMA production incorporating recycled asphalt shingles (RAS) in the same manner as recycled asphalt pavement (RAP) and other materials are incorporated.

The primary economic driver for asphalt shingle recycling is the virgin asphalt cost savings derived by HMA producers. RAS becomes a partial replacement of the virgin asphalt. BRI realizes savings of approximately $.50 to $1 per ton of final HMA product with the use of five (5) percent RAS. The total, average cost per ton for HMA production and sale is approximately $30 per ton. This is very similar to the savings reported by Allied Blacktop (Eau Claire, WI) at the *Second Asphalt Shingle Recycling Forum* as held in April 2003. Allied reported savings of about $.50 per ton of HMA product. Other studies have indicated a savings of up to $3 per ton of final HMA (NAPA,)

BRI notes that any entity interested in recycling (shingles) must budget for extensive modifications (e.g., dust shroud installation), repair, and maintenance (e.g., hard surfacing of grinding / wear parts). Asphalt shingles will always be extremely abrasive given the hard, ceramic mineral granules used in the shingle design and manufacturing process.

BRI also notes that stockpiling of the finished product is difficult, as the material tends to re-agglomerate in storage. It may be feasible to blend the material with RAP or sand to help alleviate the stockpiling problem. This practice of pre-blending feed stocks is currently not permitted by Mn/DOT's HMA bituminous specifications. E.g., RAP and RAS must be blended at the time they are incorporated into the HMA plant.

BRI's experience has indicated that any grinding operation will probably require two operators to safely staff a shingles grinding crew. From a mechanical point of view it may be possible to design a machine with enough controls to allow one person to operate it. However, safety concerns with this and any grinding operation make it desirable, if not necessary, to have two operators.

Given the high cost of transportation, the grinding operation should ideally be located as close to the supply of the feedstock and as close to the HMA plant as possible.

BRI notes that a water source is necessary to provide for watering of the feedstock as it enters the grinding chamber.

Other external economic factors must also be considered. For example, the Twin Cities metropolitan area generates and sends an estimated 400,000 tons of residential roofing waste to area construction and demolition (C & D) landfills. Most of this mixed roofing waste is comprised of recyclable asphalt shingles. Current C & D disposal tip fees are up to $35 to $40 per ton. Recycling of shingle waste will preserve valuable landfill space. The reduction in landfill capacity use could be expected to be several hundred thousand cubic yards annually.

Transportation of shingle waste to demolition landfills is time consuming and expensive with primary landfill demolition landfills being located 25 to 40 miles from the inner cities of Minneapolis and St. Paul. If clean, residential shingle scrap can be stored, shipped and processed at more close-in facilities, trucking costs will be reduced.

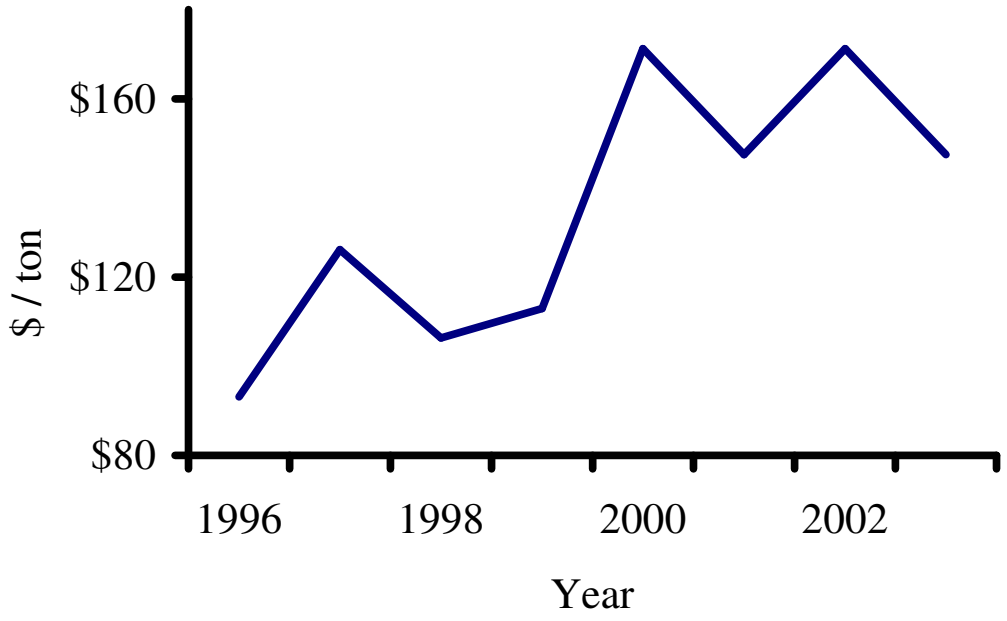
As stated above, use of RAS in HMA adds value to the final product by reducing production costs. Ground organic (cellulose) backed shingles are about 30 to 35% asphalt. Fiberglass shingles are about 20% asphalt. When added to a typical HMA mix design of about six (6) percent asphalt content, five (5) percent RAS by weight of total aggregate will reduce the virgin asphalt content to five and a half (5.5) percent. This reduction in virgin asphalt costs makes use of the RAS worthwhile to HMA producers considering that virgin asphalt now costs approximately $145 per ton (as of August 2004).

Asphalt shingles also contribute a small amount of high quality aggregate in the form of fine, mineral granules. Also, the fiber content (fiberglass or cellulose shingles) also is a positive contribution to the mix, although the added value has not been quantified.

The future of virgin asphalt costs is expected to continue to increase given the trends from available data shown in the next three figures.

Figure 1
City of St. Paul Hot-Mix Asphalt Plant:
Raw Material (Virgin) Asphalt Prices

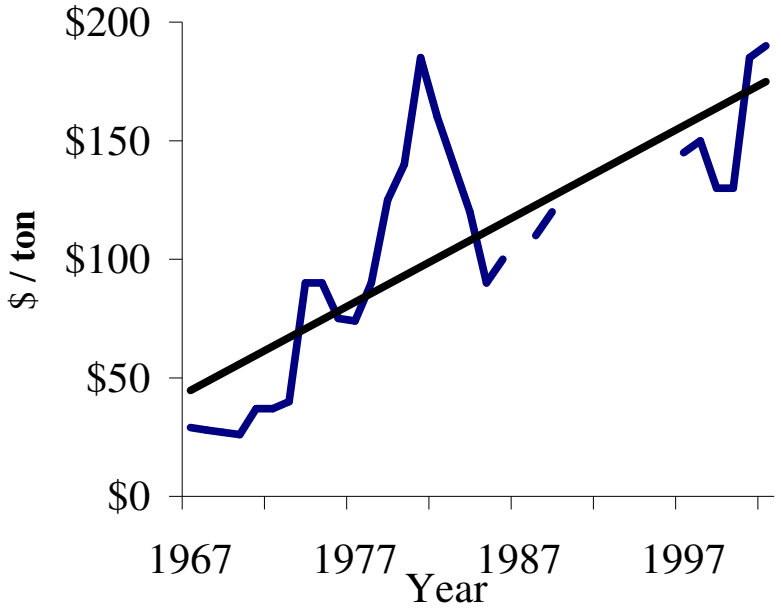
(PG 84 - 22)



Source: City of St. Paul, personal communications. 2003

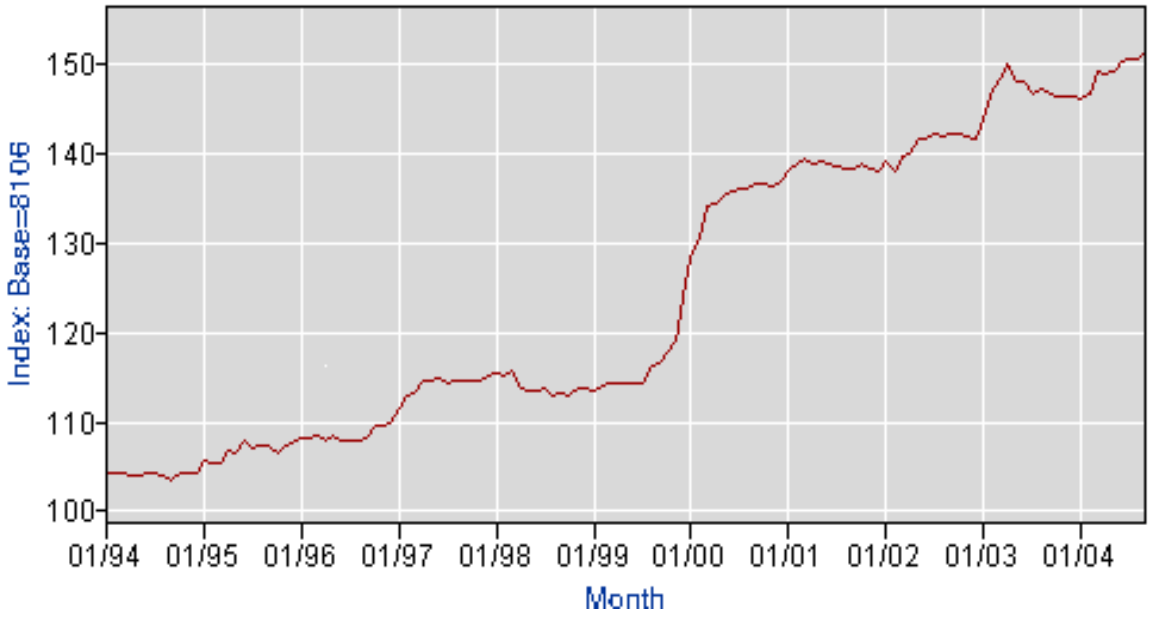
Figure 2
Minnesota Asphalt Cement Prices

(As per Mn/DOT Bids)



Source: Minnesota Asphalt Paving Association (MAPA), 2004

Figure 3
National Asphalt Price Trend



Source: U.S. Dept. of Labor: Bureau of Labor Statistics

SPECIFICATION DEVELOPMENT

This *RMRC Project* resulted in several recommendations to various specifications including Mn/DOT's and the proposed AASHTO specification. The key strategy in each case was to help promote a larger dialogue with between the state DOT materials engineers responsible for specification development and the private recycling industry.

Mn/DOT

Like most states, Mn/DOT construction materials specifications are the industry standard and are required on any State Aid Road Project. Other government and private paving standards are not bound by Mn/DOT specifications but the majority of paving professionals choose to defer to Mn/DOT materials and design specifications as the industry standard. Therefore, these Mn/DOT specifications play a very significant role in the commercial expansion and economic implementation of such recycled commodity development.

Shingle Scrap Specification

Mn/DOT's shingle scrap specification (see section 2360.2 Materials: A2h Scrap Asphalt Shingles) has remained largely unchanged since its original promulgation in 1995. Three recent changes have been made, or are in progress, to this specification.

The first change, made in the fall of 2002 within Mn/DOT's annual bituminous specification amendments for the 2003 construction season, was to delete the qualifying approval step. The original specification allowed the use of manufacturer shingle scrap "…when approved by the project engineer". Thus, using manufacturer shingle scrap was prohibited unless actively approved by the local engineer on the agency project (e.g., city or county engineer). The current specification allows using manufacturers' shingle scrap in HMA at the discretion of the HMA producer unless specifically prohibited by the project engineer. This current version now treats approval of the use of recycled shingle scrap similar to the approval of recycled asphalt pavement (RAP) whereby it is allowed by Mn/DOT specification unless actively prohibited by the local engineer.

It has been reported that this change, sometimes described as positioning the specified use of shingles as "permissive", has resulted in significant increased use of recycled asphalt shingles in HMA. Previous to this change, each job had to be approved by the project engineer. Also, many local engineers wanted the mix design to be approved by the Mn/DOT bituminous office. Now, the HMA producer is able to use RAP and/or RAS at its discretion depending on the paving project, customer preferences, and recycled material availability. Such discretion allows RAS to be used on an ongoing basis without the previously required prior approvals. Yet, all Mn/DOT-specified QA/QC requirements for the production of HMA and pavement construction must still be followed.

Specification on File in the Mn/DOT Bituminous Office

Mn/DOT also 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. This draft "…specification on file…" includes the following provisions:

- All scrap shingle materials shall be obtained from shingle manufacturers. No tear off or re-roof material is allowed.
- After processing (i.e., grinding and screening), the recycled scrap shingle material shall be sized so that 100 percent (by weight) passes through a ¾-inch square sieve, and at least 95 percent shall pass through a #4 sieve.
- The HMA producer must submit written certification by both the shingle manufacturer and the shingle scrap processor as to the content and source of the material. Certification forms are available from the Bituminous Office.
- Scrap shingles shall be stockpiled separate from other salvaged material (e.g. RAP). (Pre-) blending of scrap shingle material in a stockpile with other salvaged material is prohibited.

Mn/DOT Bituminous Office staff are in the process of finalizing and publishing this recycled scrap shingle specification on file so that it can be reliably used by the private sector.

Other States

Nine other state DOT's are known to have shingle recycling specifications. Tables 1 and 2 below were compiled to help begin to identify the current status of such state DOT specifications and beneficial use determination (BUD) licensing procedures by state environmental agencies. This information was presented to the Northeast States' Materials Engineers Association (NESMEA) at their annual meeting on October 20, 2004. The information was derived from a brochure published by the National Association of Home Builders (NAHB), the RMRC Project #13 "White Paper" by Henry Justus of Chesner Engineering, and direct phone interviews. These lists are presented as a sampling of known specifications and BUD procedures and are not an exhaustive summary of all states' specifications.

Table 1
Northeastern States Specifications and BUD Licenses

Recycled Asphalt Shingles in the Northeastern States DOT Specs and State Beneficial Use Determination (BUD) Licenses (Draft summary as of 10-19-04)		
State	**State DOT Specs**	**State BUD License**
CT		Draft BUD License (M, T) CT Dept. of Environmental Protection
FL	Under development	
ME		ME BUD License (M, T) ME Dept. of Environmental Protection
MA	Pilot underway	BUD License (M, T), MA Dept. of Environmental Protection
NH		BUD License (M, T)
NJ	NJDOT Spec (901.10) 5% manufacturer scrap only	
PA	PADOT spec 5% manufacturer scrap, Draft spec for tear-off scrap	
VT		BUD license, VT Agency of Natural Resources

Table 2
Others States Specifications and BUD Licenses

Recycled Asphalt Shingles in Other States DOT Specs and State Beneficial Use Determination (BUD) Licenses (Draft summary as of 10-19-04)		
State	**State DOT Specs**	**State BUD License**
FL	Tear-off spec under development	
GA	5% manufacturer or tear-off scrap	
IN	5% manufacturer scrap	
MI	50% recycled content[(1)]	
MN	5% manufacturer scrap only	BUD permit by rule for both M and T
NC	5% manufacturer scrap only	
OH	"certain percentage of recycled material"	
TX	manufacturer or tear-off scrap	

AASHTO Specification

The American Association of State Highway and Transportation Officials (AASHTO) is in the middle of a thorough process to develop a new shingles recycling materials specification for use in HMA. One objective of this new AASHTO spec is to address the needs for quality assurance / quality control (QA/QC) during the processing and utilization of recycled asphalt shingles in HMA. Under sponsorship of the RMRC Project (#13 / #14), Chesner Engineering submitted a draft shingle recycling specification to the AASHTO Subcommittee on Materials (SOM). At the August 2004 annual AASHTO meeting in Nashville, the draft spec was reviewed, discussed and referred back to the Technical Section (2c) of the SOM for further improvements. It is anticipated this revised draft specification will be balloted by the SOM at its August 2005 meeting.

The Chesner report to RMRC, *Draft White Paper for Recycled Asphalt Shingle as an Additive in Hot Mix Asphalt* (April 15, 2003), included a proposed AASHTO specification. See the RMRC web page link:

http://www.rmrc.unh.edu/Research/Rprojects/Project13/Specs/RASAC/p13RASAC.asp

and click on the link via the recycling symbol icon hyperlink.

The *White Paper* and proposed specification covered a wide variety of technical shingle recycling issues including:

- Types, definitions, sources, and sampling
- Gradation of RAS
- Addition rates of RAS into HMA
- Deleterious substances
- Methods of sampling and testing

CHAPTER 3 – CONCLUSIONS

1. **Mn/DOT's Research and Development Efforts** provided essential and substantial background and preliminary implementation outreach in preparation for this *RMRC Project*. The body of literature on recycling shingle scrap into suitable materials for road construction that has been sponsored by the Minnesota Department of Transportation (Mn/DOT) and the Minnesota Office of Environmental Assistance (OEA) is not only substantial but nearly continuous over the past 15 years. These Mn/DOT and OEA publications, together with other research, published literature and information resources, clearly indicate the technical and economic feasibility of using recycled asphalt shingles as a supplement in hot-mix asphalt (HMA).
2. **Outreach, education, implementation** - This *RMRC Project* was a culmination of several other related shingle recycling market development projects including the *Mn/DOT Projects* (*"Phase One" and "Phase Two"* as outlined above), the *SWMCB Project*, and the Construction Materials Recycling Association (CMRA) *Project*.
3. **Economic analysis and outreach** - The primary driving force behind the accelerated development of this new technology is the favorable economics of substituting recycled asphalt shingles for a portion of virgin asphalt oil, aggregate and manufactured fiber.
4. ***Second Asphalt Shingles Recycling Forum*** - This *RMRC Project* sponsored the *Second Asphalt Shingles Recycling Forum* on April 13 – 14, 2003. This *Forum* provided a two-day opportunity to discuss, in-depth, the engineering, environmental and public relations issues surrounding this rapidly developing technology. (See the web page http://www.projects.dot.state.mn.us/uofm/shingles/ for an agenda and speaker presentations.) The *Forum* provided clear indication of areas of consensus and difference of opinion. A wide variety of government agencies and private companies presented their market development strategies. All parties, including *Forum* participants, expressed keen interest in the future of shingle recycling.
5. **SWMCB – sponsored panel session at MAPA Annual Workshop** - The related *SWMCB Project* sponsored an informative panel session at the 48th Annual Contractors' Workshop of the Minnesota Asphalt Paving Association (MAPA) on March 4, 2004 in Brooklyn Center, MN. One of the key indications of the growing success of these collective research and development efforts was the announcement and acknowledgement of multiple HMA producers recycling shingle scrap generated from Minnesota.
6. **NESMEA presentation on results of the *RMRC Project*** - RMRC sponsored a panel presentation by Dan Krivit (Owner, DKA) at the NorthEast States Materials Engineers Association (NESMEA) on October 20, 2004 in Portsmouth, NH. Several key project conclusions were presented. Key questions that require further research were identified and framed for ongoing discussions. Directly related research on recycled asphalt pavement (RAP), also sponsored by RMRC, was presented by Dr. Jo Daniels,

7. **Shingle-derived HMA performance** - Hot-mix asphalt (HMA) modified with recycled asphalt shingles can perform at least as well as paving mixes without shingles. Multiple research studies have shown that the composition of asphalt shingles closely mirrors that of hot mix. Recycled shingles can improve the performance of (HMA) by increasing the pavement's resistance to wear and moisture, decreasing deformation and rutting, and decreasing thermal fatigue and cracking.
8. **State HMA specifications** - Based on this large body of research, nine state departments of transportation, including Minnesota, are known to have adopted material specifications that allow the use of recycled asphalt shingles in HMA (see Tables 1 and 2).
9. **AASHTO specification** - Under sponsorship of the RMRC Project #13 / #14, the American Association of State Highway and Transportation Organization (AASHTO) has initiated the development of a new scrap shingle materials specification for use in HMA. This proposed AASHTO specification will help address the needs for quality assurance / quality control (QA/QC) during the processing and utilization of recycled asphalt shingles in HMA.
10. **Residential, tear-off shingle scrap** - While most state specifications allow the use of manufacturer shingle scrap only, only two are known to explicitly allow tear-off shingle scrap. Several states are in the process of developing a tear-off specification and are currently in pilot studies or other specification development stages.
11. **Specifications for use of RAS as an unbound aggregate as road base** - The research on the use of RAS as a supplement to traditional, unbound aggregates for use of road base is not as developed as use of RAS for HMA. Mn/DOT does not yet have a specification for this road construction application and one demonstration project testing this use is still under development.
12. **Health and environmental impacts** - This *RMRC Project* closely examined the potential health and environmental impacts of recycling asphalt shingles. A sub-group of state and federal officials was convened to examine past data and direct environmental testing as part of this *RMRC Project.* A separate "Environmental White Paper" was produced. Key conclusions included:

    - The data from previous sampling and lab analyses indicated negligible to no asbestos in residential tear-off asphalt roofing shingles.
    - Previous studies indicate that any asbestos containing material are more likely from commercial buildings or contamination of the asphalt shingles from the mastic, caulk or felt.
    - The air sampling conducted as part of this *RMRC Project* indicated that permissible exposure limit for asbestos would not be exceeded even in the worst case. This worst case scenario assumed asbestos would be 100 percent of total fibers released by the shingle grinding operation and measured by the project environmental consultant and laboratory. It is highly unlikely that asbestos will ever comprise the total composition of "fibers" during shingle recycling operations because of the presence of fiberglass, cellulose and / or other fibers.
    - Shingle recycling operators can help reduce employee risk to dust and fiber exposure by developing and implementing a dust management plan. This plan can include regulated

requirements and common sense tactics to avoid unhealthy employee exposure to any fugitive dust that may be generated during recycling operations.

- Use of a particulate respirator by the grinder operator is probably not necessary given the measured "total fiber" and "total dust" samples. Furthermore, use of any such respirator may limit visibility and maneuverability thus increasing other operational hazards.

13. **Leadership** - There is a wide variety of federal, state and local agencies and private interests that are working on shingles recycling research and development efforts. Leadership and coordination will be needed to maximize the efficiency of these sometimes disconnected efforts.
14. **Technology transfer** - Continued efforts to transfer known information about shingles recycling is needed.

CHAPTER 4 – RECOMMENDATIONS

1. **RMRC** should continue to support shingles recycling market development through publication and outreach of the products from this *RMRC Project (#22)*, including the following:
   - This Executive Summary
   - The "Tear-Off Demonstration" video tour and still pictures
   - The "Environmental White Paper"
   - The "Bibliography of References, Web Sites and Other Resources"
   - Other selected photographs and video clips
2. **RMRC** should provide virtual and other links to related research web sites including the *SWMCB Project*, *Mn/DOT Project*, Minnesota Office of Environmental Assistance, and CMRA's ShingleRecycling.org.
3. **RMRC** should continue to monitor and comment on, as appropriate, the development and adoption of the AASHTO shingle recycling specification originally drafted as part of the *RMRC Project #13 / #14.*
4. **RMRC** should advocate for state and local governments to use "affirmative, environmentally preferable procurement" policies when purchasing HMA to include recycled asphalt shingle scrap when it meets appropriate QA/QC standards.
5. **RMRC** should support proposed EPA funding of the next phase of research and development that could lead to a national tear-off feedstock sampling and testing protocol.
6. **RMRC** should leverage its extensive network of engineering and other recycling professionals to continue to assist in the development of the shingle recycling technology and end markets for RAS-derived product. New and expanded partnerships should be developed with EPA, state environmental agencies, and private recycling / HMA operators to further the application of best practices in the field.
7. **Materials engineers within state departments of transportation** should continue to develop their specifications for the use of high-quality, recycled asphalt shingles into hot-mix asphalt. States that do not have such DOT materials specifications should consider adopting one. States with such specifications should consider the best approach to allowing and regulating the processing and use of residential, tear-off shingles.
8. **Mn/DOT** should continue its notable research and development efforts and pursue the lab research on the effect of tear-off shingles vs. manufacturer shingle scrap in HMA.
9. **Other Minnesota state agencies, together with the counties and private asphalt companies**, should continue to work with Mn/DOT to develop a new HMA material specification that allows use of tear-off shingle scrap. Any new Mn/DOT specification should include stringent sourcing, processing and blending QA/QC standards.

10. **Shingle recycling operators** that utilize tear-off shingle should aggressively manage the asbestos issue using the following techniques:
    - Strongly consider restricting their supply to private, residential homes only (per the federal EPA rules in NESHAP). Shingles from commercial or institutional buildings or other "regulated facilities" as defined by NESHAP should not be accepted.
    - Develop, communicate and enforce strict supply specification for "clean, asphalt shingle only" loads.
    - Certify suppliers such as roofing companies (e.g., require written certification that the loads contain asphalt shingles only without any known hazardous material and are derived from private, residential homes that are not defined as "regulated facilities" by the EPA rules in NESHAP).
    - The roofing company and hauler should certify in writing that the used roofing shingles are asphalt shingles only (such as three-tab shingles) and are free of prohibited materials, including:
        - cementitious shingles;
        - other non-shingle debris (e.g., transite siding, etc.); and
        - other trash or hazardous waste.
    - Inspect each load by personnel trained to visually detect likely asbestos containing materials. Operators should invest in state-certified training courses for their management and site personnel.
11. **All shingle recycling operators** should maximize protection of their employee health and safety:
    - Develop a comprehensive employee hazard prevention program.
    - Provide accurate information as part of a full employee education program
    - Water scrap shingles as they are fed into the grinding chamber.
    - Develop dust management program including optional techniques such as:
        - installing shrouds around the grinder feed hopper and exit conveyor;
        - enclosed, air-conditioned cabs for front end loaders; and
        - personal particulate respirators for grinder operators if deemed necessary and prudent (e.g., for clean-out procedures or other especially dusty conditions)
12. **Shingle recycling operators** should guarantee their product quality. The ground, recycled asphalt shingles (RAS) should be guaranteed to be:
    - Asbestos free.
    - Nail free.
    - ½ - inch minus or finer.
    - Controlled mix ratios when preparing a final product (e.g., HMA or aggregate blends).

- Meet or exceed state QA/QC requirements for traditional HMA

13. **Shingle grinding equipment manufacturers** should consider design and testing of shrouding and other dust and debris control devices (e.g., pneumatic air separation systems) to be sold as optional equipment components. The two primary design objectives should be:
    - Employee health / safety (e.g., reduce exposure to fugitive dust); and
    - Elimination of blowing litter.
14. **Shingle recycling operators** should continue to complete research started on the use of RAS as an aggregate supplement for road base.

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- "Less than 50% of the asphalt in the shingles is effective in the mix
- "Use of ground shingles has not been detrimental to quality à Cannot yet prove that ground shingles offers improved quality to our mix
- "When selecting a virgin binder grade, adjust (1) temperature interval lower. I.E. PG 64-XX provides a PG 58-XX virgin binder. Blending chart and residual AC recovery PG testing should be performed."

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FOR MORE INFORMATION

The following references for additional sources of information are derived from earlier, related outreach and implementation projects conducted by other parties to improve communications about asphalt shingles recycling.

For more information about the this *Project, Overcoming the Barriers to Recycling Asphalt Shingles* (*"Phase Three"*), funded by the Recycled Materials Resource Center (RMRC):

Dr. Jeffrey S. Melton, RMRC
603-862-2107
jeff.melton@rmrc.unh.edu
http://www.rmrc.unh.edu/Research/Rprojects/Project22/Project22.asp
www.projects.dot.state.mn.us/uofm/shingles
www.moea.state.mn.us/lc/purchaing/shingles.cfm

For more information about the project *Improving Recycling of Shingles in Minnesota* (*"Phase Two"*) funded by the Minnesota Department of Transportation (Mn/DOT):

James Klessig, Mn/DOT Office of Research Services
651-282-2472
jim.klessig@dot.state.mn.us

Authors note: *"In memory of Jim Klessig, we would like to recognize his contribution and support to the success of this research and development"*

For technical questions about mix-design approvals involving recycled asphalt shingles in Minnesota:

Roger Olson, Mn/DOT Office of Materials and Road Research
651-779-5517
roger.olson@dot.state.mn.us

For more information about the recycled asphalt shingle market development efforts by the Minnesota Office of Environmental Assistance (OEA):

Don Kyser, OEA
651-215-0191
Don.Kyser@moea.state.mn.us
http://www.moea.state.mn.us/lc/purchasing/shingles.cfm

For questions about the project *Manufacturer Shingle Scrap Project* funded by the Solid Waste Management Coordinating Board contact:

Michael Reed, Ramsey County, Minnesota
651-773-4443
michael.reed@co.ramsey.mn.us
http://www.greenguardian.com/business/shinglerecycling.asp
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For information about national market development efforts as funded in part by the U.S. EPA Region V (Chicago, IL), with assistance from the University of Florida, National Roofing Contractors' Association:

Bill Turley, Construction Materials Recycling Association (CMRA)
630-585-7530
www.ShingleRecycling.org
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For a copy of the *Roofs to Roads: Recycling Asphalt Roofing Shingles into Paving Materials* brochure published by the National Association of Housing Builders (NAHB) Research Center:

800-638-8556; 301-249-4000
www.nahbrc.org

For copies of the reports: *Special Report 179: Use of Waste Asphalt Shingles in HMA: State-of-the-Art Practice* and *Special Report 187: Recycling Practices for HMA* published by the National Asphalt Pavement Association (NAPA):

888-468-6499; 301-731-4748
www.hotmix.org

Asphalt Roofing Shingles Recycling, California Integrated Waste Management Board

916-255-2326
www.ciwmb.ca.gov

For more information about North Carolina's recycled shingle study, *Recycling Asphalt Shingles Into Hot Mix Asphalt Pavement*, published by the North Carolina Division of Pollution Prevention and Environmental Assistance:

919-715-6500; 800-763-0136
nowaste@owr.ehnr.state.nc.us
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APPENDIX A –
DESCRIPTION OF BRI'S SHINGLE RECYCLING SYSTEM

At Bituminous Roadways, Inc. Plant in
Inver Grove Heights, MN

Bituminous Roadways, Inc. (BRI) has been recycling asphalt shingles from CertainTeed Corp. (Shakopee, MN) for over six years. BRI has a long-term contract with CertainTeed, an asphalt shingle manufacturer. BRI processes as much of the shingle byproduct as possible. The balance of the CertainTeed shingle byproduct that is not recycled is diverted to a nearby demolition landfill.

BRI is on their third generation of grinders. They currently use the Bandit Industries, Inc. horizontal grinder "Model 3680 Beast Recycler" funded in part by a capital grant from the Minnesota Office of Environmental Assistance. The stockpiled shingle byproduct is loaded into the grinder's feed hopper via front-end bucket loader. The feed hopper has a floor conveyor to present the shingle byproduct into the grinding chamber. Water is sprinkled onto the material just before the grinding chamber. (See Figures 4 and 5)

The Beast is a low-speed, high-torque shredder equipped with a series of milling teeth mounted on the cylinder head. The milling chamber has a bottom grate or grinding screen with 5/8-inch holes. The product particle size out of the grinder is dependent on the size of holes in chamber grate. BRI is able to produce a ¾-inch-minus product (95% passing the ½-inch screen) directly from the Beast without further screening.

In general, the product exits from the grinder via the attached discharge conveyor and is fed directly into a trommel screen for further sizing as necessary depending on the final product application (e.g., Hot Mix Asphalt – HMA, aggregate base, etc.). If the trommel screen is utilized, the under sized fraction is ½-inch minus and the over sized fraction are about ¾-inch minus down to ½-inch. The "unders" are utilized occasionally in BRI's own HMA on site, according to Mn/DOT specifications, on a job-demand basis. As a means to help control blowing litter, primarily plastic cellophane from the whole shingles, BRI installed additional windscreen hoods around the grinder and discharge conveyor.

The recycling operation requires two operators: one in the loader to feed the grinder with shingle byproduct and to stockpile finished products; and the second to operate the Beast utilizing a radio remote control. Therefore, the loader operator is enclosed in the front-end loader cab. The grinder operator is free to walk anywhere around and near the machine.

At this time, BRI uses the recycled asphalt shingles almost entirely in HMA as the primary end use for RAS derived from shingle byproduct. Other end uses have been tested and are under development and include: dust control and supplement to unbound aggregate as base.

Figure 4
Process Flow Diagram

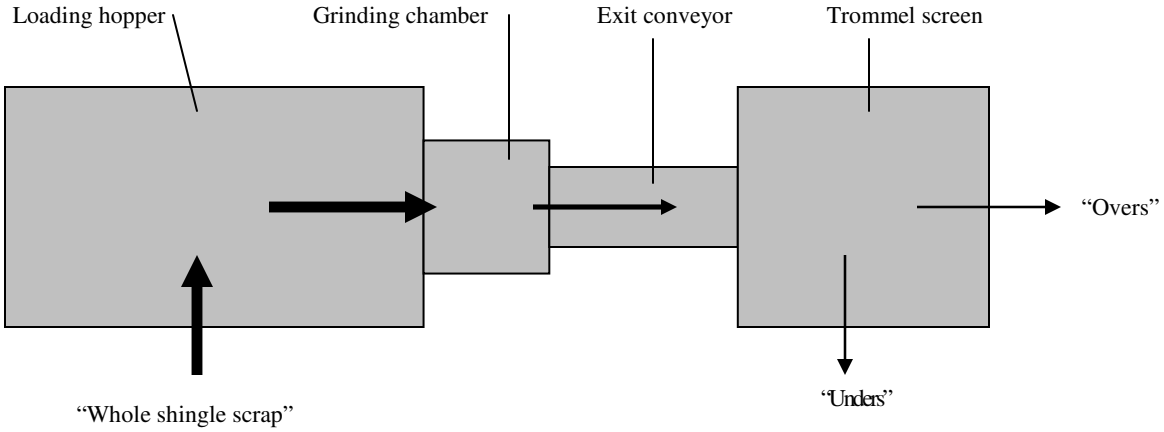

Figure 5
Photograph of Shingle Processing Plant

APPENDIX B – DESCRIPTION OF ALLIED'S SHINGLE RECYCLING SYSTEM

At Allied Blacktop Corporation's Plant in
Eau Claire, WI