

2008 CD&I Recycling Project:
“Shingles Recycling White Paper”

**As Presented to the Waste Streams Policy Committee on
May 12, 2008**

Final Report

Prepared for the:
Solid Waste Management Coordinating Board
and the
Minnesota Pollution Control Agency

By:
Dan Krivit and Associates (DKA)
And
Foth Infrastructure and Environment, LLC

Draft Table of Contents

	<u>Page</u>
Executive Summary	1
1 Introduction and Summary of Relevant Previous Studies.....	5
1.1 2007 CD&I Study (Phase One).....	5
1.2 About this <i>White Paper</i>	6
1.3 Previous SWMCB Manufacturers’ Shingle Scrap Recycling Project in 2004.....	6
1.4 Previous Mn/DOT Projects.....	7
1.4.1 <i>Mn/DOT (Phase One) Period of Research (1990 – 1998)</i>	7
1.4.2 Mn/DOT’s Specification Development (1995 through 2007)	8
1.4.3 <i>Mn/DOT (Phase Two) Outreach Project</i>	10
1.4.4 <i>RMRC (Phase Three) Project</i> Co-sponsored by Mn/DOT (2001 – 2005)	11
1.4.5 Other Projects Co-Sponsored by Mn/DOT.....	13
1.5 Previous MPCA Projects	13
1.6 Local Government Agency Projects	14
1.6.1 <i>St. Paul / Bituminous Roadways (2003)</i>	14
1.6.2 <i>Dakota County / MOEA Lab Analyses Project (2005 – 2006)</i>	15
1.6.3 <i>Hassan / Omann Project (2006)</i>	17
1.6.4 Ramsey County <i>Lower Afton Trail (2007)</i>	19
1.6.5 Dakota County <i>Workshop</i> on December 4, 2007.....	19
1.7 Other Previous Shingles Recycling Projects.....	21
1.7.1 CMRA Projects.....	21
1.7.2 Other States Specifications	21
2 Characterization of Potential Shingle Scrap Supply	23
2.1 Types and Sources of Shingle Scrap.....	23
3 Recycling Targets.....	25
4 Potential Markets.....	27
4.1 HMA	27
4.2 Unbound Aggregate	29

5	Preliminary Economic Analysis	30
5.1	Pace Construction (St. Louis, MO).....	30
5.2	BRI Economics comments.....	30
5.3	Generic Shingle Recycling Expense Items	30
5.4	Economic Data from NAPA	31
5.5	“Typical” Recycling System Designs as per Astec Industries.....	32
5.6	Economic Trends	35
5.6.1	Virgin Asphalt Prices	35
5.6.2	Landfill tipping fees from <i>2007 CD&I (Phase One) Study</i>	36
5.7	Economic Analysis Worksheet.....	Error! Bookmark not defined.
6	Environmental Benefits: Preliminary Analysis	38
6.1	Energy Savings	38
6.2	Green House Gas Emissions.....	38
6.2.1	Preliminary Analysis from U.S. EPA	38
6.2.2	Analysis from Natural Resources Canada	39
7	Market Development Options	40
7.1	Inventory of All Options.....	40
7.2	Analysis of Market Development Priorities	44
8	Conclusions	48
9	Recommendations	51
	References Cited	53
	Appendix A: Definitions.....	56
	Appendix B: Shingles Composition Data From <i>CD&I Phase I (2007) Project Report</i>	58

Executive Summary

The State of Minnesota, together with Minnesota Counties, have continued to improve and expand comprehensive solid waste management programs. The Solid Waste Management Coordinating Board (SWMCB), the Minnesota Pollution Control Agency (MPCA), and the Minnesota Department of Transportation (Mn/DOT) are continuing their initiatives to enhance waste reduction, recycling and recovery of construction, demolition and industrial (CD&I) materials.

This *Shingles Recycling White Paper* is the first in a series of four commodity-specific reports as part of the overall SWMCB / MPCA project on *CD&I Recycling ("Phase Two")* to be completed in 2008. The SWMCB contracted with the consulting team of Foth Infrastructure and Environment / Dan Krivit and Associates to complete this report on shingles recycling and on biomass derived from C&D materials.

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 in hot mix asphalt (HMA). The body of published literature extends from the mid 1970's. The literature includes both government research publications and private reports or patent applications.

Mn/DOT has been one of the leaders in the research and development of RAS as a supplement in HMA. With the help of a variety of research organizations, Mn/DOT has a long list of shingles recycling research studies. Yet only manufacturers' shingle scrap is allowed as per the current Mn/DOT scrap shingle specification. This type of enabling specification that allows the use of the materials at the discretion of the contractor is referred to in the highway construction industry as a "permissive" specification. The broad consensus is that a similar permissive specification is also needed for tear-off shingles when used in HMA.

The *2007 CD&I Study (Phase One)* identified asphalt shingles as a high priority commodity that could potentially be recovered from the CD&I waste stream that is currently being disposed in Minnesota's landfills. Asphalt roofing shingles are a significant portion of a C&D waste stream. The composition analysis for the indicated that roofing made up 15.2% of the total C&D waste as disposed in landfills. Most of this material could be readily sorted for recycling and recovery.

Recycling and other recovery of tear-off asphalt shingles in Minnesota has great potential in the near future to divert significant tonnage from landfills. Using a moderately aggressive estimate, this *White Paper* recommends the following goals:

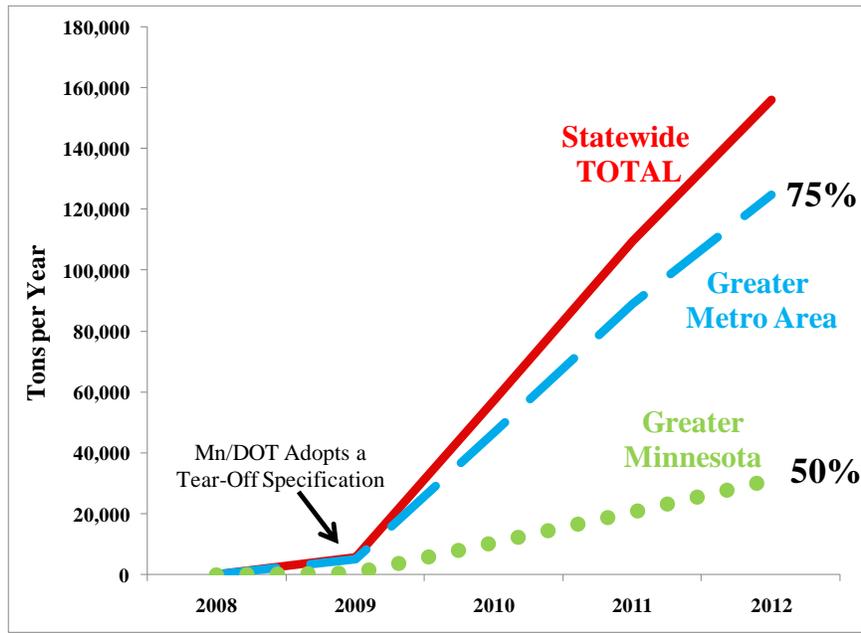
Greater Metropolitan Area*: adopt a 75% recovery goal for available tear-off shingle scrap =	125,000 tons per year
Greater Minnesota: adopt a recovery goal of 50% for available tear-off shingle scrap =	<u>31,000 tons per year</u>
STATEWIDE TOTAL RECOVERY GOAL=	156,000 tons per year

(* Greater Metropolitan Area: Defined by the U.S. Census Bureau as the larger metropolitan statistical area and includes 11 Minnesota counties around Minneapolis / St. Paul.)

This Statewide recovery total of 156,000 tons per year should be the "target" goal for market and policy development planning purposes. This target can serve as a benchmark for MPCA and the

Counties to assess if adequate additional recovery progress is being made. Figure ES-1 displays a hypothetical forecast of annual recovery rates to attain this “target” goal.

Figure ES - 1
Tear-Off Asphalt Shingles Recovery Targets
(Tons per Year)



The analysis and recommended strategies within this *White Paper* are, in general, intended to be applicable Statewide and address the needs of all Minnesota Counties and other local governments to find markets for tear-off shingles. However, all of manufacturers’ shingle scrap is generated in the Twin Cities Metropolitan Area. Plus the vast majority of tear-off shingle scrap is also generated in the Greater Metro Area and other larger urbanized regions of Minnesota (e.g., Duluth, Rochester, St. Cloud) where there is a higher rate of re-roofing jobs. Finally, there are more and larger HMA producers in these same urbanized regions of the state correlated with the amount of pavement construction. Therefore, this *White Paper* provides an initial consideration of both the economies of scale of shingle scrap availability and the transportation logistics and costs to get finished RAS product to potential markets.

One of the key barriers to the development of this new market is the exclusion of tear-off shingle scrap from HMA in the current Mn/DOT specification. Minnesota Counties and MPCA should work closely with Mn/DOT towards adoption of a new state materials specification providing for the appropriate use of tear-off recycled asphalt shingles in hot mix asphalt (HMA).

Counties and other local governments also have an important role to play in the development of the market for recycled tear-off shingles. Minnesota Counties should issue request for bids to purchase hot-mix asphalt and bituminous paving services that include “alternate bid” options and “bid advisories” that state a non-binding policy preference for shingle-modified hot-mix asphalt.

One objective of this *White Paper* is to provide a bridge between the technical research and development efforts and the larger policy options to help continue to expand the market for recycled asphalt shingles. Therefore, as part of this *White Paper*, an exhaustive series of market development “options” were analyzed by the consultant team. Criteria such as cost –

effectiveness, overall feasibility, impact on private industry, and likely political acceptance, were considered. The consultant team's judgments on each of these criteria were intended to be an initial and preliminary step in a longer-term discussion.

Following this preliminary analysis of all available options, this *White Paper* forwarded a number of key policy and technical recommendations for accelerating the development of a strong market for tear-off shingles.

The *White Paper* recommendations and action steps state:

1. The MPCA and SWMCB should encourage Mn/DOT to continue to provide special, provisional project specifications for use of tear-off shingles in HMA that can be used by local governments and contractors on a job-by-job basis.
2. The MPCA and SWMCB should encourage Mn/DOT to continue with its plans to adopt a "permissive" specification for use of tear-offs based on results of a new 2008 – 2009 lab study such that contractors can use tear-off RAS unless explicitly prohibited by the local project engineer. It is further recommended that adoption of this permissive specification is adopted by the end of 2009.
3. The Minnesota Shingles Recycling *Technical Working Group (TWG)* should continue to convene to help coordinate related market development initiatives by State and local government agencies.
4. As a temporary means to help demonstrate the feasibility of use of tear-off RAS into HMA, willing SWMCB County departments of transportation should consider a designing **selected** 2008 and 2009 construction demonstration projects that specify the use tear-off derived HMA. Beginning in about 2010, (assuming that Mn/DOT has adopted a permissive tear-off specification in 2009) Counties should use regular purchasing procedures (e.g., "...may use tear-off shingles...").
5. All SWMCB member Counties should announce their individual plans for using tear-off shingles in HMA construction projects in 2008 and 2009. Each SWMCB County should consider which affirmative procurement policy method they will use for their respective project specifications.
6. MPCA should develop a dedicated tear-off shingles recycling market development grant program for 2009 through 2012. This "dedicated, targeted" tear-off shingles grant approach should be sunset in 2012 or when the tear-off market is self-sustaining (whichever comes first).
7. MPCA should develop a sustainable building technical memo (e.g., for use by LEED™ – type of programs) specific to recycling of tear-off shingles that includes requirements for:
 - a. Standard definitions and terminology
 - b. Standard measurement methods
 - c. Recommended means to develop independent certification of recycling
 - d. Recommendations for funding such certification
8. SWMCB and MPCA should develop tear-off shingles recycling technical assistance tools such as brochures and web page information. Such tools should be used, as appropriate, when State and local regulators conduct on-site, pre-demolition inspections.

9. If there is not reasonable and steady progress towards the proposed targets for recovery of tear-off shingles by the end of 2009, MPCA should evaluate legislative options which may include authority and funding to further promote the market development for tear-off shingles.
10. SWMCB and MPCA should develop a model C&D recycling program, including specific provisions for tear-off shingles recycling requirements. Such a model program should include options for:
 - a. Required bid advisories (i.e., voluntary preferences for purchase of tear-off derived HMA).
 - b. Required bid alternatives (i.e., explicit itemization of the price difference for tear-off derived HMA pavement)
 - c. Other voluntary affirmative procurement methods (“...may use tear-off shingles in HMA...”) such as would be provided by Mn/DOT’s proposed new permissive specification for tear-off shingles.

1 Introduction and Summary of Relevant Previous Studies

The Solid Waste Management Coordinating Board (SWMCB) and the Minnesota Pollution Control Agency (MPCA) are continuing their initiatives to enhance waste reduction, recycling and recovery of construction, demolition and industrial (CD&I) materials. This *Shingles Recycling White Paper* is the first in a series of four commodity – specific reports as part of the overall SWMCB / MPCA project on *CD&I Recycling Project (“Phase Two”)* to be completed in 2008.

The next three commodities that will be covered by white papers as a part of the larger *Project* will include wallboard, biomass from C&D materials, and residual glass from recycling facilities [MR 2-7]. This *Shingles Recycling White Paper*, however, is not representative of the level of detail to be expected within future white papers. The amount of research and market development on recycled shingles far exceeds the efforts to-date on these other three commodities.

1.1 2007 CD&I (Phase One) Study

Together, SWMCB and MPCA collaborated on an extensive *CD&I (“Phase One”) Study* in 2007 including waste composition analyses, literature reviews, surveys of Minnesota companies involved in all aspects of operations, policy deliberations and recommendations for next steps. This *CD&I Study* resulted in the report Minnesota Construction, Demolition, and Industrial Waste Study authored by the project consultant team of Foth Infrastructure & Environment, LLC and Dan Krivit and Associates (DKA). The goal of this *CD&I Study* was to provide information for use by the Project Partners and other stakeholders in evaluating CD&I that can potentially be recovered for reuse, recycling, or creation of energy or compost. After an extensive public participation process, the final *CD&I Study* report (Foth, 2007) was accepted by the Waste Streams Policy Committee overseeing the project and then the SWMCB. The final report was then posted on the SWMCB web page:

<http://www.swmcb.org/files/CD&I%20Waste%20Study.pdf> along with a longer series of report appendices as posted on the SWMCB “non municipal solid waste (MSW)” web page: http://www.swmcb.org/resources/studies_policy_reports/non_municipal_solid_waste.

The *2007 CD&I Study* identified asphalt shingles as a high priority commodity that could potentially be recovered from the CD&I waste stream that is currently being disposed in Minnesota’s landfills. Asphalt shingles are the most common type of roofing material used in new home construction and re-roofing projects. Asphalt roofing shingles are a significant portion of a C&D waste stream. The composition analysis for the *CD&I Study* indicated that roofing (including shingles and tear off) made up 15.2% of the total C&D waste sorted (Foth, 2007). Recyclable asphalt shingles are generated as post-industrial (i.e., “manufacturers’ shingle scrap”) and post-consumer primarily from re-roofing projects (i.e., “tear-offs shingle scrap”) and full building demolition projects. In addition, a relatively minor amount of shingle scrap is generated from new building construction, primarily residential homes.

In 2007, SWMCB had a separate, but related ongoing tear-off shingle market development project. In 2008, SWMCB consolidated its shingles recycling efforts into this comprehensive *CD&I Recycling (“Phase Two”) Project*. One of the key SWMCB strategies is to continue to

coordinate a Minnesota shingles recycling *Technical Working Group (TWG)* in collaboration with the Minnesota Department of Transportation (Mn/DOT) and MPCA. The *2007 CD&I (Phase One) Study* recommended that the principal parties should:

“Continue and expand County – Mn/DOT-MPCA collaboration towards adoption of a new state materials specification providing for the appropriate use of tear-off recycled asphalt shingles in hot mix asphalt (HMA).”

1.2 About this White Paper

The background data, analyses and policy initiatives referenced within this *Shingles Recycling White Paper* are based primarily on previous research and development projects. Recently, there has been an acceleration of government and private initiatives to improve the market for recycled asphalt shingles (RAS). The references cited within this *White Paper* are itemized in the last section of the body of this report. Many other resources are also available on the topic of shingles recycling via the web site www.ShingleRecycling.org, which is a subsidiary program of the Construction Materials Recycling Association.

1.3 Previous SWMCB Manufacturers’ Shingle Scrap Recycling Project in 2004

In 2004, the SWMCB completed its original market development initiative and published the final report, *Manufacturer Shingle Scrap Recycling Project* (DKA, August 2004). This 2004 project was intended to expand the market by improving information and technology exchange. Part of the intent of the 2004 SWMCB project was to coordinate a purchasing position to use in approaching the private marketplace. This involved affirmative county hot-mix asphalt (HMA) purchasing practices. The SWMCB Counties’ elevated interest in purchasing shingle-modified HMA has helped to clearly demonstrate potential increased end-use demand for shingle scrap and thereby help stimulate the market.

The 2004 SWMCB *Manufacturers’ Shingle Scrap Project* report included the following recommendations:

- The SWMCB should encourage each of its member Counties to issue request for bids to purchase hot-mix asphalt and bituminous paving services that include “alternate bid” options and “bid advisories” that state a non-binding policy preference for shingle-modified hot-mix asphalt. This information should also be shared and promoted with Greater Metro Area municipalities.
- The SWMCB should encourage Mn/DOT and the Minnesota Department of Natural Resources to use a similar approach for State purchases of HMA in the Metropolitan Area where the recycled scrap shingle marketplace is more mature.
- The SWMCB County Engineers and Environmental staff should continue to coordinate and collaborate with Mn/DOT, MOEA and MPCA on initiatives to accelerate continued development of the shingle recycling industry by the private sector.
- The SWMCB should encourage Mn/DOT to finalize its draft recycled scrap shingle specification on file in the Bituminous Office into a specification that that can be reliably used by the private sector.

- The SWMCB should encourage Mn/DOT to continue its research and development of a new materials specification that could allow “tear-off” shingles to be recycled into hot-mix asphalt.
- SWMCB staff should develop additional policy recommendations, including a legislative initiative review, to be presented back to the SWMCB for its consideration in September 2004.

The final report was accepted by SWMCB and posted on its “*Green Guardian*” web page:

- **Krivit, Dan** (Dan Krivit and Associates). (**August 27, 2004**) “Driving Change: Solid Waste Management Coordinating Board (SWMCB) *Manufacturer Shingle Scrap Recycling Project*: Final Report.”

Link to the report on the SWMCB / Green Guardian web page PDF file:

http://www.greenguardian.com/pdf/ManufacturedShingleScrap_final.pdf

1.4 Previous Mn/DOT Projects

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 in hot mix asphalt (HMA). The body of published literature extends from the mid 1970’s. The literature includes both government research publications and private reports or patent applications.

This research and development of materials specifications on use of RAS in HMA parallels and is preceded by similar R&D on the use of recycled asphalt pavement (RAP) in HMA. Use of RAP in HMA to partially replace virgin asphalt cement and virgin aggregates has become a standard industry practice. The ongoing RAP research questions are directly relevant to the similar ongoing questions about the use of RAS in HMA (e.g., percent effectiveness of the asphalt content in RAP or RAS once introduced into the HMA plant; relative improvements in asphalt utilization by further RAP or RAS gradation and fractionating into multiple size fractions).

1.4.1 Mn/DOT (Phase One) Period of Research (1990 – 1998)

Similar to its role in the development of RAP recycling, Mn/DOT has been one of the leaders in the research and development of RAS as a supplement in HMA. With the help of a variety of research organizations, Mn/DOT has a long list of shingles recycling research studies. The original lab and field study by Newcomb (2003) was supported by grant funding from OEA with the Turgeon (1991) project beginning as early as 1990. The first RAS specifications were adopted in 1996 and with additional guidelines developed approximately in 1998. This timeframe is sometimes referred to as the original Mn/DOT *Phase One* period of research and specifications development to reflect the extensive nature of the following research studies:

- **Turgeon, Curtis M.** (**February, 1991**) “Waste Tire & Shingle Scrap Bituminous Paving Test Sections On The Munger Recreational Trail Gateway Segment.” Office of Materials and Research, Minnesota Department of Transportation.
- **Turgeon, Curtis M.** (**1993 circa**) “Mn/DOT Physical Research Construction Report, T.H. 25 Shingle Scrap Project (S.P. 1006-20).” Minnesota Department of Transportation, [Constructed on June 17-21, 1991.] .

- **Newcomb**, David; Mary Stroup-Gardiner; Brian M. Weikle; and Andrew Drescher. **(June 1993)** "Influence of Roofing Shingles on Asphalt Concrete Mixture Properties." Report MN/RC-93/09, University of Minnesota, Minnesota.

Summary and abstract at the link on the Minnesota Office of Environmental Assistance (OEA) *Environmentally Preferable Purchasing* web page:

<http://www.pca.state.mn.us/oea/market/resources/newcomb-summary.pdf>

Full report at the Mn/DOT web page (108 pages, 9Mb):

http://www.mrr.dot.state.mn.us/research/MnROAD_Project/MnRoadOnlineReports/93-09.pdf

- **Newcomb**, David E.; Mary Stroup-Gardiner; Brian M. Weikle; and Andrew Drescher. **(1993)** "Properties of Dense-graded and Stone-mastic Asphalt Mixtures Containing Roofing Shingles." ASTM Special Publication 1193, ASTM.
- **Janisch**, David W. and Curtis M. Turgeon. **(October 1996)** "Minnesota's Experience Using Shingle Scrap in Bituminous Pavements (Final Report #96-34). Minnesota Department of Transportation, Maplewood, MN. Report No. PB-97-132278/XAB MN/PR--96/34.

Link to Mn/DOT web page for PDF file:

http://mnroad.dot.state.mn.us/research/MnROAD_Project/MnRoadOnlineReports/96-34.pdf

These laboratory and field investigations were sponsored by Mn/DOT often with the financial assistance of the Minnesota Office of Environmental Assistance (now an office within the Minnesota Pollution Control Agency). This body of research led in 1996 to the development and adoption of a Mn/DOT construction material specification for the recycling of **manufacturers'** shingles scrap into HMA. The Mn/DOT shingle specifications package now contains:

Minnesota Department of Transportation Standard Construction Materials Specifications, Excerpt from the combined 2360/2350 bituminous (Gyratory/Marshall) mix. [Mn/DOT's shingle scrap specification](#) is found within section 2360.2 Materials: A2h Scrap Asphalt Shingles.

And the companion document "on file" at the office of the Mn/DOT Bituminous Engineer that was drafted in approximately 1998 (circa):

Mn/DOT's Draft Scrap Shingles (Guidelines) on file in the Mn/DOT Bituminous Office: (http://shinglerecycling.org/images/stories/shingle_PDF/mndot%20draft%20spec%202382.pdf)

1.4.2 Mn/DOT's Specification Development (1995 through 2007)

In 1995, Mn/DOT confirmed that asphalt pavement mix containing shingle by-products performed at least as well or better as those mixes without shingle by-product and in 1996 adopted its first materials specification allowing the use of manufacturers' shingle scrap in HMA. Table 1 displays the step-by-step history of Mn/DOT's shingles specifications development over the past 17 years:

**Table 1
History of Mn/DOT’s Shingle Scrap Recycling
Specification Development**

Approximate Date	Description of Specification Developed
1990 – 1996	Mn/DOT conducts original phase one research projects (see subsection 1.5.1 within this White Paper)
1996	Mn/DOT adopts its first manufacturers’ shingle scrap materials specification on a more “restrictive” permission basis (job-by-job approval by the project engineer required).
1998 (circa)	Mn/DOT develops a draft “guideline” kept on file” in the office of the Bituminous Engineer.
2003	Mn/DOT amends specification to allow HMA producers the discretion to use manufacturers’ shingle scrap by removing the requirement for job-by-job approval by the project engineer. This more “permissive”, blanket approval basis allows the use of the manufacturers’ shingles scrap unless explicitly prohibited by the project engineer.
2006	Mn/DOT amends specification to require a minimum of 70% new (virgin) asphalt cement (AC) as a percent of the total AC within the higher volume highways.
2007	Mn/DOT develops a special provision, mix design specification for the Ramsey County <i>Lower Afton Trail (LAT) Project</i> that allowed the required use of tear-off RAS in the HMA according to project QA/QC specifications.

The first version Mn/DOT specification required job specific approval 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. Once Mn/DOT amended its specification 2003 to a more “permissive” basis for approval (allowing the use of manufacturers’ shingles unless specifically prohibited), the HMA contractors are able to significantly increase their recycling rates of shingles. This current “permissive” approach to approval of the use of manufacturers’ RAS is similar to the Mn/DOT specification requirements for RAP.

The following specification amendment was made by Mn/DOT in the fall of 2006 in response to continued field experience and increased use of manufacturers’ RAS in HMA mixes. An additional provision was added to the Mn/DOT specification that now reads:

“2360.3 Mixture Design

Table 2360.3-B2a – “Mixture Aggregate Requirements”, footnote (3) referring to traffic levels 4 and 5:

“When shingles are included as part of the allowable RAP percentage the ratio of added new asphalt binder to total asphalt binder shall be 70% or greater ((added binder/total binder) x 100 >= 70).”

Mn/DOT amended its specification in 2006 due, in part, to one case study that resulted in premature cracking. The U.S. Highway 10 project (north of St. Cloud) was overlaid with HMA in 2005 and 2006. The HMA producer / paving contractor was relatively new to shingles recycling in large – scale, Super Pave types of HMA construction projects. The contractor may have overcompensated for the assumed, actual effective asphalt cement (AC) contribution from manufacturers’ RAS in the mix. In any case, the end results was that not enough new asphalt binder was used in the final mix as produced. The lack of adequate amounts of total AC in the final mix may have been a primary cause of premature cracking as observed in certain sections the Hwy. 10 project. In least in part as a result of this experience, Mn/DOT amended their HMA specification at the end of 2006 to require the higher volume highways must have a minimum of 70% new asphalt binder in the mix.

1.4.3 Mn/DOT (Phase Two) Outreach Project

Mn/DOT retained DKA in 2000 to help evaluate alternative means to expand the use of manufacturers’ shingle scrap in Minnesota. This *Mn/DOT Shingles Recycling Project* (also known as the *Mn/DOT Phase Two 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 Phase Two 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* (Mn/DOT and OEA, 2002) 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* was a joint production of Mn/DOT and the Minnesota Office of Environmental Assistance (OEA, now an office of MPCA). The *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 (Phase Two) 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 was 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.

The final *Mn/DOT (Phase Two) Project* report was published by Mn/DOT in conjunction with the Minnesota Local Road Research Board (LRRB) and the Minnesota Center for Transportation Studies (CTS):

- **Krivit, Dan** (Dan Krivit and Associates). (**January 8, 2007**) “Increasing the Recycling of Manufactured Shingle Scrap in Minnesota: A Market Development Project”. Prepared for the Minnesota Department of Transportation. Mn/DOT report number: MN/RC-2007-07. <http://www.lrrb.org/PDF/200707.pdf>

1.4.4 RMRC (Phase Three) Project Co-sponsored by Mn/DOT (2001 – 2005)

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 (Phase Three) 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.
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.

- **Krivit, Dan** (DKA). (**October 2002**) “An Environmental White Paper Report as Part of the RMRC Project Overcoming the Barriers to Asphalt Shingle Recycling”. Prepared for

the Minnesota Department of Transportation and the Recycled Materials Resource Center. Link:

http://shinglerecycling.org/images/stories/shingle_Word/environmental%20white%20paper%20dk%204-10-03.doc

A major outreach strategy was the April 2003 *Second Asphalt Shingles Recycling Forum* held in Bloomington, MN. Presentations from this [Second Asphalt Shingle Recycling Forum](#) are posted on www.ShingleRecycling.org at:

http://shinglerecycling.org/index.php?option=com_content&task=view&id=145&Itemid=221

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 manufacturers' shingle scrap than available supply. Thus, there was a continued need to develop tear-off shingle recycling as addressed by this *RMRC Project*.

It was determined that recycling manufacturers' RAS into HMA as the primary application was already well developed. However, there was 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 did not yet have as an extensive proven track record as compared to manufacturers' shingle scrap. Also, tear-off scrap is not allowed in as many state DOT specifications as is manufacturers' RAS. For example, tear-offs are still prohibited from Mn/DOT's scrap shingle specification. The *RMRC Project* identified 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 was 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 were still skeptical about the engineering properties of shingle-derived HMA and needed more information about the QA/QC 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.

This *RMRC Project* 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 the *City of St. Paul / Bituminous Roadways* field demonstration constructed in the fall of 2003 (see subsection 1.7.1 for more discussion).

In November 2001, 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) was feasible. However, one

recommendation was to restrict such application to summer months only to take advantage of warmer air temperatures to assist with asphalt binding properties. (Johnson, November 2001)

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 proposed RAS / aggregate base project was not fully completed to the point of controlled, documented field demonstration.

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.

The final report of *RMRC (Phase Three) Project* was finally published by RMRC in 2005.

- **Krivit, Dan (DKA). (January 3, 2005)** Overcoming the Barriers to Asphalt Shingle Recycling: Final Report for the Recycled Materials Resource Center (RMRC) Project 22.:

Summary: <http://www.rmrc.unh.edu/Research/past/P22/P22summary.pdf>

Final report: <http://www.rmrc.unh.edu/Research/past/P22/P22final.pdf>

1.4.5 Other Projects Co-Sponsored by Mn/DOT

Mn/DOT has also been directly involved with four more recent shingles recycling demonstration projects that have tested the feasibility of tear-off shingles:

- City of St. Paul / Bituminous Roadways (2002 – 2003)
- *Dakota County / MOEA Lab Study* (2004 – 2006)
- *Hassan / Omann Study* (2006 – 2007)
- Ramsey County *Lower Afton Trail (LAT) Project* (2007)

See subsection 1.6 Local Government Agency Projects below for more discussion on these other projects conducted in collaboration with Mn/DOT.

MPCA and Mn/DOT recently executed an inter-agency grant agreement for the next phase of research, including emphasis on overcoming technical barriers to the use of **tear-off** RAS in HMA. The *TWG* will help review results from this new Mn/DOT project as funded by MPCA.

1.5 Previous MPCA Projects

The Minnesota Office of Environmental Assistance (formerly known as OEA or MOEA) is now an office of the MPCA. MPCA, and OEA in its previous structure, have been full and long-term state agency partners with Mn/DOT in this shingles recycling market development effort. OEA provided matching funding for previous research, including the Newcomb (2003) project within the Mn/DOT *Phase One* period of research. 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 completed the last of its reports to OEA in regards to its experience and lessons learned (Peterson, April 2003; and Peterson, August 2004). This work and positive experiences of BRI as funded in part by OEA is one of the key indicators of the significant progress that has been made in manufacturers' shingle scrap processing.

OEA also hosted a web page on the environmentally preferable purchasing of recycled shingles:

<http://www.pca.state.mn.us/oea/market/shingles.cfm>

This web page represents the ongoing efforts by MPCA to continue to assist in the development of this viable market for recycled shingles. Details on this MPCA / OEA web page include the Mn/DOT and OEA *Shingles Recycling Guide* (2003). The SWMCB 2004 project built directly upon the recent shingle recycling technical assistance efforts by OEA, now an office of the MPCA).

1.6 Local Government Agency Projects

1.6.1 St. Paul / Bituminous Roadways (2003)

This *City of St. Paul / Bituminous Roadways Project* was the first in Minnesota to demonstrate the controlled, documented use of residential tear-off asphalt shingle scrap. This was one task within the larger *RMRC Project*. Bituminous Roadways, Inc. (BRI) initiated a field test within the City of St. Paul in the fall of 2003. BRI conducted this demonstration including shingle processing, HMA production and paving operations. 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. 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 Banditt 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, staples) 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. As one task within the larger *RMRC Project*, Bituminous Roadways, Inc. (BRI) initiated a field test within the City of St. Paul in the fall of 2003 to demonstrate the use residential tear-off asphalt shingle scrap.

1.6.2 *Dakota County / MOEA Lab Analyses Project (2005 – 2006)*

Dakota County: Hwy 70 (Inver Grove Heights) as presented by Todd Howard on December 4, 2007.

The *Dakota County / MOEA Lab Analyses Project* was funded by the Minnesota Office of Environmental Assistance (MOEA). This project directly complemented a parallel study sponsored by the Missouri Department of Transportation (MoDOT). (See MoDOT project description below.)

Dan Krivit and Associates (DKA) was able to secure the participation of Dem-Con Landfill and Resource Recovery in Shakopee, Minnesota to help source and sort the loads of mixed roofing waste into approximately 50 tons of clean, sorted tear-off shingles only. During the week of July 21, 2004, Dem-Con staff identified eligible loads of mixed roofing waste that contained a higher percentage of tear-off shingles from private, residential homes. These loads were redirected to a transfer station tipping area inside an enclosed building. Using a Bob-Cat type of skid-steer loader with a grapple bucket, Dem-Con staff then re-tipped the mixed roofing waste onto the tip floor. Then, Dem-Con staff hand picked out the non-shingle debris such as metal, plastic, wood and other waste. The clean, shingles only material was re-piled, loaded and then shipped to the

Bituminous Roadways, Inc. (BRI) shingle recycling plant / aggregate pit / hot-mix asphalt facility in Inver Grove Heights.

BRI ground and screened the clean, tear-off shingles into a recycled asphalt shingles (RAS) product on Wednesday, September 21. Dakota County ordered the hot-mix asphalt (HMA) for the CSAH 26 project base course. About 40 tons of the tear-off RAS was incorporated into the specified mix.

The tear-off and manufacturer base courses were installed on Monday, October 3, 2005 on County Hwy 26 (70th Street E), east of MN Hwy 52 towards Cahill Ave. The specified, full westbound lanes of base course were installed as “test” pavement strips containing tear-off derived HMA. The “control” pavement strips were installed with normal HMA (derived from manufacturer RAS) according to Mn/DOT specifications. County staff in cooperation with BRI selected the exact “test” and “control” pavement strips, all in the full westbound lanes.

The tear-off derived hot-mix asphalt (HMA) for the base course test strip was laid down first, beginning approximately 11 a.m. Then, once all of the 600 tons (approximately) of tear-off derived HMA was utilized, traditional manufacturer shingle scrap HMA (with 15% RAP) was installed also as base course for a “side-by-side” control strip immediately west of the tear off test strip. BRI also produced a small amount of HMA without any shingles (i.e., no tear-off or manufacturer shingle scrap, 20% RAP), but otherwise with the same mix design, for purposes of the added control samples of HMA needed for this lab study.

The binder courses (with traditional, standard mix) was installed on top of these two test strips on beginning Thursday, October 6. The “control” with no shingles (20% RAP) test strip was also installed on about October 6.

BRI collected four (4) random HMA loose samples from each of the three types of test mixes: “control”, “manufacturer” and “tear-off”. Samples were deemed to be representative and “typical” of normal product. The samples were not aged in the lab before shipping to Mn/DOT or preparing gyratory cylinder “pucks”.

BRI sampled and shipped corresponding loose HMA samples (approximately 2,000 grams) from each mix type to the Mn/DOT Materials Lab in Maplewood. From these loose samples, BRI prepared five (5) compacted samples in the form of gyratory “puck” cylinders from each of the three mix types as per specifications from the U of M Civil Engineering lab (e.g., 5½ inches thick). Air voids in the HMA “puck” samples were prepared with five (5) percent air voids. Four of these HMA “puck” samples from each mix type will be shipped to the U of M Civil Engineering lab. BRI will keep at least one set of “puck” samples. The gyratory “puck” cylinder samples were prepared and delivered to the U of M / Civil Engineering on a separate schedule (to be determined later).

Dakota County staff collected their normal quality control samples from each test strip as per standard QA / QC procedures under agreement with Mn/DOT. Each test strip was defined as a separate “lot” or highway segment to keep the samples separated and identified for this demonstration.

Mn/DOT conducted a series of lab analyses on recycled aggregate products (tear-off RAS; manufacturer’s RAS; and RAP) and HMA samples. Mn/DOT procedures on recycled aggregate samples included: gradations, deleterious, and PG grading. Mn/DOT procedures on HMA samples included: extractions and PG grading. Please refer to the separate Jim McGraw report (in preparation) and presentation (July 12, 2006) for more details on these methods.

The U of M lab conducted stiffness, strength and indirect tensile strength (IDT) tests on prepared specimens cut from HMA gyratory "pucks". Please refer to the Marasteanu / Zofka report (April 6, 2006) for more details on these methods and results. The U of M lab also conducted similar IDT tests on extracted binder supplied by Mn/DOT. Please refer to Marasteanu / Zofka presentation (July 12, 2006) for more details on results from IDT tests on extracted binder.

A final project "wrap-up" meeting was held on July 12, 2006. Held at the Mn/DOT Materials Lab "training room", the scope of the meeting included results from the parallel Missouri DOT shingles recycling lab project. The purposes of this meeting were also expanded to include workshop training (i.e., technology exchange) and discussion of additional field results from other private contractors using recycled asphalt shingles in their asphalt pavement mixtures.

The pavement test sections were constructed in the fall of 2005 with tear-off RAS used in the base course only (i.e., no shingles were used in the surface wearing course). The tear-off pavement test sections show no observable difference compared to the control pavement sections with manufacturers' RAS and no shingles (RAP only). Lab results were reported by Mihai Marasteanu (July 12, 2006) and Jim McGraw (July 12, 2006). In summary, the impacts on mix design due to addition of tear-offs RAS showed little to no significant difference compared to the manufacturers' RAS. The principal concern was the potential for negative impact of tear-off RAS on the low temperature cracking as reported by Marasteanu.

The following links offer further details on the *Dakota County / MOEA Lab Analyses Project*:

- **Krivit**, Dan, "[Shingles Recycling: Co-Sponsors Who's Who](#)", Meeting/Workshop, July 12, 2006.
- **Marasteanu**, Mihai; Zofka, Adam, "[Summary of Shingle Work at the University of Minnesota](#)", University of Minnesota, Civil Engineering Department, July 12, 2006.
- **McGraw**, Jim, "[Mn/DOT Shingle Study](#)", Minnesota Department of Transportation, Materials Research Lab, July 12, 2006.
- **Schroer**, P.E. Joe, "[Asphalt Shingles in HMA Missouri DOT Experience](#)", Missouri Department of Transportation, Construction and Materials Division, March 30, 2005.
- **Schroer**, Joe (Missouri Department of Transportation). (**January 10, 2007**) "[Asphalt Shingles in HMA: Missouri DOT Experience](#)" A presentation to the North Central Asphalt Users and Producers Group (NCAUPG) Conference in Minneapolis, MN.
- **Marasteanu**, Mihai and Adam Zofka. (**July 12, 2006**) Power Point presentation at a shingles recycling workshop. "[Summary of Shingle Work at the University of Minnesota](#)", University of Minnesota, Civil Engineering Department. **McGraw**, Jim; Adam Zofka; Dan Krivit; Joe Schroer; Roger Olson; and Mihai Marasteanu. (**March 14, 2007**) "Recycled Asphalt Shingles in Hot Mix Asphalt". A technical paper and presentation at the Association of Asphalt Paving Technologists (AAPT) annual meeting in San Antonio, Texas.

1.6.3 *Hassan / Omann Project (2006)*

The *Hassan / Omann Project* used both manufacturers' and tear-off recycled asphalt shingles (RAS) at 5% and 10% of the total mix. No recycled asphalt pavement (RAP) was included. The demonstration included RAS in both the wear and base course. All but one of the test mixes used the "standard" virgin asphalt binder performance grade (PG) of PG 58-28. In one of the

mixes, the virgin binder asphalt cement (AC) was adjusted to one grade softer to PG 52-34. The pavement test strips were constructed in August 2006 and visual inspections conducted since then indicate no performance differences to-date. The lab results are extensive, although yet unpublished, and include the following selected, tentative conclusions:

- It is difficult to interpret results to the point of firm conclusions because of limited number of samples and complex, multiple variables affecting HMA performance.
- The impacts of adding RAS, including the interactions with virgin aggregate and virgin binder, is still not well understood.
- Low temperature and fatigue cracking is most likely the property that will control the performance of HMA amended with tear-off RAS.
- The relative impacts of tear-off vs. manufacturers' RAS on the PG grade were about the same at the 5% RAS level.
- The high temperature critical performance of the HMA samples increased (i.e., improved) with the increasing amount of RAS in the mix and more so with tear-offs compared to manufacturers' shingles. The low temperature critical performance of the HMA samples increased (i.e., worsened) with the increasing amount of RAS in the mix and more so with tear-offs compared to manufacturers' shingles. The impacts of tear-off RAS on the PG grade at the 10% RAS level was about:
 - High temperature = 2 ½ grades
 - Low temperature = ½ grade
- Adjusting the virgin asphalt binder to the softer, PG 52-34, decreased both the high temperature and low temperature by ½ grade. The resulting final mix, with the adjusted, softer virgin binder, was close to original, targeted mix design PG 58-28.
- The amount of deleterious material (using the AASHTO method) varied considerably from one sample to the next. The material was primarily plastic and paper. The results ranged from about 0.03% to 0.21% with no readily apparent trend.

The following links offer further details on the *Hassan / Omann Project*:

- **McGraw, Jim** (Minnesota Department of Transportation, Materials Research Lab). (July 11, 2007) Power Point presentation at the *Hassan / Omann Project* luncheon meeting.
http://shinglerecycling.org/images/stories/shingle_PDF/hassan%20twp%20shingle%20study%20jm%2007.07.pdf
- **Marasteanu, Mihai**, University of Minnesota, Department of Civil Engineering. (July 11, 2007) Power Point presentation at the *Hassan / Omann Project* luncheon meeting.
http://shinglerecycling.org/images/stories/shingle_PDF/hennepin-07.07-shingles%20mm.pdf
- **Haugen, Debra (DKA)**. (May 31, 2007) “Recycled Tear-off Shingles Road Construction Demonstration in the Town of Hassan” Final report to the Minnesota Local Road Research Board:
http://shinglerecycling.org/images/stories/shingle_PDF/final%20lrrb-opera%20report%20hassan-omann%20demonstration%205-31-07.pdf

- **McGraw, Jim**, Mn/DOT (July 11, 2007) Power Point presentation at the *Hassan / Omann Project* luncheon meeting.
http://shinglerecycling.org/images/stories/shingle_PDF/hassan%20twp%20shingle%20study%20jm%2007.07.pdf
- **Marasteanu, Mihai**, University of Minnesota, Department of Civil Engineering, (July 11, 2007) Power Point presentation at the *Hassan / Omann Project* luncheon meeting.
http://shinglerecycling.org/images/stories/shingle_PDF/hennepin-07.07-shingles%20mm.pdf

1.6.4 Ramsey County Lower Afton Trail (2007)

Constructed in the fall of 2007, the Ramsey County *Lower Afton Road Trail (LAT) Project* incorporated a number of environmental design parameters and served as a visible demonstration of sustainable design on full-scale public works construction project. The *LAT Project* ribbon cutting ceremony was held on November 15, 2007. The intent of Ramsey County, City of Maplewood and State of Minnesota was to create a showcase of environmentally friendly design into this trail construction project. The trail was designed to utilize market available recycled products and new cutting edge materials that have not necessarily been used on other publicly bid projects. At the end of this project Ramsey County will document the areas where we have utilized recycled post consumer / post manufacturing products and products that were used in this project that could be recycled / recovered in the future.

The construction specifications governing the *LAT Project* included requirements to use the following recycled products:

- Tear-off recycled asphalt shingles in the production of hot mix asphalt for the bituminous paving mixture.
- Recycled plastic lumber timbers for use in construction of retaining walls.
- Recycled aggregate (Class 7) for use as pavement base.
- Recycled plastic for use in the storm pipe.
- Recycled waste wood for use as mulch.
- Recycled plastic for construction of park benches.
- Recycled plastic/rubber tires for construction of patio pavers.

Jerry Auge, Jr. (project engineer for Ramsey County), presented on the *LAT Project* at the December 4th Dakota County shingles recycling *Workshop*. To review Jerry's presentation, link to "[Recycled Tear-off Shingles in Bituminous Pavement for Lower Afton Trail Project](http://shinglerecycling.org/images/stories/shingle_Word/rc%20lat%20spec%20ras%206-07.doc)". The *LAT Project* specifications excerpts relevant to RAS use in HMA are available on-line at: http://shinglerecycling.org/images/stories/shingle_Word/rc%20lat%20spec%20ras%206-07.doc

1.6.5 Dakota County Workshop on December 4, 2007

As part of its larger 2006 – 2007 shingles recycling project, Dakota County produced a Shingles Recycling Workshop on December 4, 2007 as held at the County's Western Service Center in Apple Valley. The title of the *Workshop* was "Diverting Tear-off Shingles from the Landfill".

The purpose of the *Workshop* was to reach key audiences that could potentially be involved in new shingles recycling operation and provide a short, structured opportunity to learn more about Minnesota's experience in the use and applications of recycled asphalt shingles (RAS) and the advancements in technology and market development of the use of tear-off shingles. The intent was to share the most recent information, experience and expertise in the use of RAS.

The goals of this Dakota County Workshop were to:

- Increase awareness and understanding of this new technology.
- Provide updates on state progress and projects using tear-off RAS.
- Promote conversations between all interested parties in Dakota County about how best to divert tear-off shingles from landfills.
- Discuss potential Dakota County projects for 2008 that could use tear-off recycled asphalt shingles (RAS).
- To encourage entrepreneurial ventures into the development of tear-off shingles recycling.
- To discuss existing and new market applications for RAS.
- To broaden the base of expertise on the tear-off RAS specifications.

The Dakota County shingles recycling *Workshop* brought together over 40 participants which included county, city and state officials along with representatives from the roofing, hot-mix asphalt (HMA), and disposal industries. Speakers are listed below including links to respective Power Point presentations:

- Rolland Meillier, Dakota County Environmental Management and SWMCB Shingle Recycling Coordinator
- Roger Olson, Minnesota Department of Transportation (Mn/DOT):
["Minnesota's Experience in Implementing the Use of Shingles"](#)
- Todd Howard, Dakota County:
["Dakota County CSAH 26 Shingle Tear-offs"](#)
- Jerry Auge, Jr., Ramsey County:
["Recycled Tear-off Shingles in Bituminous Pavement for Lower Afton Trail Project"](#) *
* Jerry handed out the *LAT Project* specifications excerpts relevant to RAS use in HMA by Ramsey County Department of Public Works (in conjunction with Mn/DOT) available online at:
http://shinglerecycling.org/images/stories/shingle_Word/rc%20lat%20spec%20ras%2006-07.doc
- Dan Krivit for Bill Boettner, Town of Hassan:
["Hassan / Omann Shingle Recycling Demonstration"](#)

An open discussion was held for the second half of the workshop. The County demonstration projects have been very successful and the county representatives expressed an interest in looking at using shingles in future projects.

Presently, there are three [shingle recycling operations](#) in Minnesota, Bituminous Roadways Inc., Knife River (Bauerly Brothers), and Omann Brothers, Inc. Two facilities are currently using

manufacturers recycled asphalt shingles (RAS) in their HMA mixes. Tear-off shingles have been used in the demonstration projects only. There was discussion about how best to plan for and develop the future tear-off shingle recycling infrastructure in Minnesota. It was also pointed out that larger demonstration projects using tear-off shingles would be more attractive to getting more involvement from the private sector. Future discussions and research are needed in the areas of quality control and quality assurance (QA/QC) of the final ground product (RAS) and the amount of asphalt binder available.

1.7 Other Previous Shingles Recycling Projects

1.7.1 CMRA Projects

Several projects by the Construction Materials Recycling Association (CMRA), in collaboration with the U.S. Environmental Protection Agency (U.S. EPA), were recently completed to help develop the market for recycling of asphalt shingles. One of the CMRA projects was funded in part by a grant from the U.S. EPA's Office of Solid Waste and Emergency Response (OSWER) Innovations Workgroup. The primary goal of this project was to develop, demonstrate and document best practices that can be utilized by shingle recycling operators.

Dan Krivit and Associates authored a *Best Practices Guide* as one of three CMRA products. A second report, titled *Environmental Issues Associated with Asphalt Shingle Recycling*, was written by Innovative Waste Consulting Services, LLC and produced by CMRA. The Web page, www.ShingleRecycling.org, is an ongoing project of the CMRA and posts these additional shingles recycling publications as a result of the 3rd *Asphalt Shingles Recycling Forum* held in Chicago on November 1 – 2, 2007:

[Recycling Tear-off Asphalt Shingles – Best Practices Guide](#) (PDF)

[Environmental Issues Associated with Asphalt Shingle Recycling](#) (PDF)

These two new publications are available on the ShingleRecycling.org [Home Page](#) under NEWS, on the [Forum home](#) web-page and under the presentations from Jon Powell (Environment & Worker Health & Safety) and Dan Krivit (Closing Plenary) on the [Speaker Presentations](#) web-page.

1.7.2 Other States Specifications

Numerous studies have documented the strong market potential for asphalt shingles in HMA. (Visit www.ShingleRecycling.org for more details.) The practice of using recycled asphalt shingles (RAS) is now accepted in 15 states that are known to have either DOT materials specifications or beneficial use determinations (BUDs) issued by the environmental agencies (see Table 2). Eleven states' departments of transportation are known have adopted specifications allowing RAS in HMA. Manufacturers' RAS is allowed in 10 of these states. Tear-off shingles are allowed in four of these states. Six states are known to have BUDs that allow tear-off shingles in HMA or other specified construction applications. BUDs are a regulatory tool used by state environmental agencies to help guide the approval process for proposed reuse, recycling and recovery projects.

Several other states are in the process of developing a tear-off specification and/or are currently conducting pilot field studies. Many of these are available on line and can be found via the shinglerecycling.org web site.

Table 2
Other States' Shingles Recycling HMA Materials Specifications and
Beneficial Use Determinations

State	State DOT Specs	RAS Type	State BUD Approvals	RAS Type
<i>Only Manufacturer Scrap Allowed</i>				
DE			BUD for M scrap	M
IN	5% M scrap only	M		
MD	5% M scrap only			
NC	5% M scrap only	M		
NJ	5% M scrap only	M		
OH	Project Approval by DOT Engineer	M		
PA	Provisional Spec P—c04031A	M		
TX	M scrap only	M		
VA	Special provision	M		
<i>Tear-off Scrap Allowed</i>				
AL	5% M scrap or 3% T scrap	M,T		
CT			General BUD permit for recycling and storage of tear-off scrap	T
GA	5% M or T scrap	M, T		
MA	5% M scrap	M	MA BUD for M or T scrap	M, T
ME			BUD for T scrap	M, T
MN	5% M scrap only	M	BUD permit by rule for both M and T	M, T
MO	5% M or T scrap	M, T		
NY			BUDs	M, T
SC	3-8% T scrap	T		
WI			"Approval for Exemption from Solid Waste Processing Rules for Recycling Asphalt Shingles in Hot Mix Asphalt Concrete"	M,T

Key to type of shingle scrap allowed:

- M: Manufacturers' shingle scrap is allowed / recycled*
- T: Tear-off shingle scrap is allowed / recycled*

Recently, a series of structured research and development projects have been conducted in the Twin Cities area that clearly demonstrate the viability of recycling tear-off asphalt roofing shingles into HMA used for road pavement. The final shingle-derived HMA product has been tested in numerous controlled field and lab experiments. The high-grade asphalt, the fiber content, and mineral granules contained within the recycled roofing shingles are valuable components of traditional hot-mix asphalt, and the process is economically sound.

2 Characterization of Potential Shingle Scrap Supply

2.1 Types and Sources of Shingle Scrap

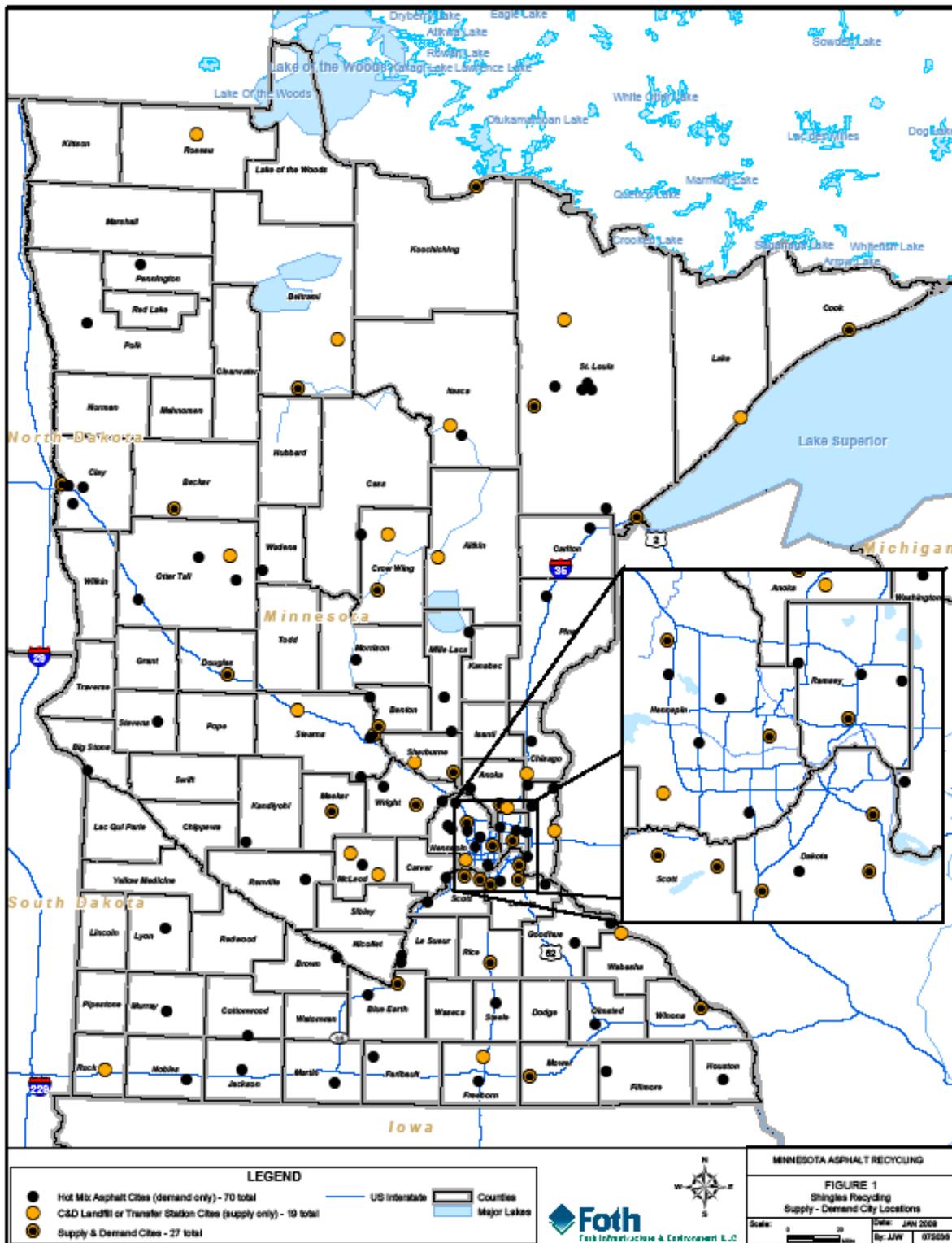
Asphalt shingles are the most common type of roofing material used in new home construction and re-roofing projects. Asphalt roofing shingles are a significant portion of a C&D waste stream. The 2006 composition analysis conducted as part of the *2007 CD&I (Phase One) Study* indicated that roofing (including shingles and tear off) made up 15.2% of the total C&D waste sorted. Recyclable asphalt shingles are generated as post-industrial (i.e., “manufacturers’ shingle scrap”) and post-consumer primarily from re-roofing projects (i.e., “tear-offs shingle scrap”) and full building demolition projects. In addition, a relatively minor amount of shingle scrap is generated from new building construction, primarily residential homes.

Approximately 70,000 tons per year of manufacturers’ shingle scrap is generated in Minnesota from three different plants. About 40,000 to 60,000 tons per year is currently recycled into HMA.

The *2007 CD&I (Phase One) Study* waste characterization indicates that about 227,000 of tear-off asphalt roofing shingles are landfilled statewide in Minnesota each year. In the seven county Metro Area, about 166,000 tons per year are landfilled. These estimates are substantially lower than previous estimates based on earlier studies that relied on national roofing waste assumptions.

Figure 1 is a map of the C&D landfills, transfer stations and HMA plants in Minnesota. The distribution of the C&D facilities indicates the current management of most tear-off shingles. The cursory analysis derived from this map implies that there is generally good distribution of potential markets (i.e., HMA plants) compared to the supply as indicated by C&D landfill and transfer station facilities. Some of these facilities are located in the same cities that have HMA plants (“supply and demand” cities). Thus, the geography is generally favorable for this potential market if the technology can be cost-effectively developed for recycling tear-off shingles into a marketable RAS product for use by HMA plants.

Figure 1
 Map of C&D Landfills, Transfer Stations and HMA Plants in Minnesota



3 Recovery Targets

The following recovery targets are proposed for tear-off asphalt shingles (see Figure 2 and the source data in Table 3). These preliminary targets are based on the key assumptions that the Greater Metro Area can attain a 75 percent recovery rate by 2012 and the rest of Greater Minnesota can attain a recovery rate of 50% by 2012. The projections are based on a starting point of zero tons in 2008.

Figure 2
Tear-Off Asphalt Shingles Recycling Targets
 (Tons per Year)

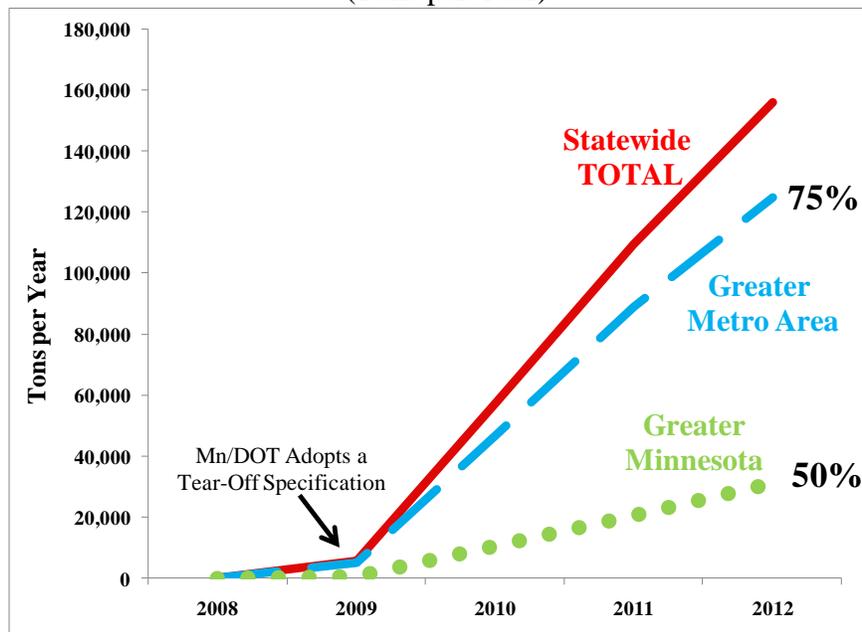


Table 3
Tear-Off Asphalt Shingles Recycling Targets:
75% Recycling in the Greater Metro Area By 2012;
50% in Greater Minnesota

Year	Statewide TOTAL	Greater Metro Area	Greater Minnesota
2008	0	0	0
2009	5,500	5,000	500
2010	57,500	47,000	10,500
2011	109,500	89,000	20,500
2012	156,000	125,000	31,000

The term used in this *White Paper*, “Greater Metro Area”, is the Minnesota portion of the metropolitan statistical area (MSA) as defined by the U.S. Census Bureau. This Minneapolis – St. Paul – Bloomington MSA includes the following 11 Minnesota counties: Anoka, Carver, Chisago, Dakota, Hennepin, Isanti, Ramsey, Scott, Sherburne, Washington and Wright.

SWMCB and Mn/DOT could work with shingles generators, recyclers and HMA producers to help develop a reporting procedure to help the agencies measure progress toward such recycling target goals. The design of this new reporting should be administratively simple, fair, and equitable. Only necessary data should be collected. Summary tonnage data could be reported to allow statewide measurement of the amount of asphalt shingles generated and recycled. Procedures could be established to help protect the rights of private companies to confidential and proprietary information while still giving the counties and State the bottom line generation and recovery data needed to track recycling progress. This voluntary data gathering and progress measurement procedure should be further developed as a separate document later in 2008.

It is likely that LEEDTM – types of sustainable building programs will continue to improve their individual requirements for reporting and certification of waste and recycling tonnages for building and other construction projects. SWMCB and MPCA should continue to engage these sustainable building initiatives to coordinate collaborative measurement schemes.

4 Potential Markets

There are a number of potential end-uses for asphalt roofing waste including:

- Hot mix asphalt (HMA);
- Fuel supplement for cement kilns;
- Energy recovery in industrial boilers;
- Aggregate supplement for road base (unbound as “gravel”) and other construction applications;
- Aggregate use as a part of new shingles; and
- Cold mix pavement applications (e.g., repair patch material, etc.).

This *White Paper* is focused on the two most well developed markets: HMA and unbound aggregate for road base.

4.1 HMA

The use of asphalt shingles in HMA is the most well documented and proven end use application. The other high-value applications (i.e., cement kilns and energy recovery) that utilize the asphaltic, bitumen content are showing strong, but relatively newer promise. Figure 3 displays the locations of HMA plants in Minnesota.

Asphalt roofing shingles are approximately 20% to 35% asphalt, while HMA is approximately 6% asphalt, so a small percentage of shingles (5% by weight of aggregate) can displace a large percentage of asphalt binder. Asphalt shingles are typically ground and screened to produce ½-inch-minus size pieces. The ground shingles are usually fed into the HMA plants along with recycled asphalt pavement (RAP).

MPCA has determined that “manufactured shingle scrap and ground tear-off shingle scrap when used in asphalt pavement...” has a standing beneficial use determination. This means that the generator of the shingle scrap or end user of RAS can recycle this material as HMA pavement in accordance with applicable rules without contacting the MPCA. (MPCA, February 2008)

However, generators, processors and/or markets will need to follow State and local storage requirements and limits. The goal of MPCA’s solid waste storage standards (Minnesota Rules, Chapter 7035.2855) is to prevent contaminants from migrating into ground or surface waters and prevent nuisance conditions from occurring at the storage facility. (MPCA, October 2005; and MPCA September 2006).

Figure 3
 Map of Hot Mix Asphalt (HMA) Plants in Minnesota



4.2 Unbound Aggregate

A typical roadway section is built in several layers. The pavement is the surface layer, and is made of concrete or asphalt. The base supports the pavement and is made of a layer of aggregate base (AB) and sometimes a layer of constructed aggregate subbase (ASB). The ASB material has a more tolerant allowance for maximum levels of sand, silt, and clay. This ASB has less strength than the aggregate base, but this lower grade material is used because it is more economical than AB when bringing the road up to grade. (California Integrated Waste Management Board, 2007)

Less controlled research has been conducted and published on these two road construction , applications, AB and ASB. Nonetheless, RAS has been used successfully as part of the unbound aggregate or gravel base for road construction. Some shingle recyclers have been successfully blending tear-off RAS into aggregate for road construction for many years.

Processed shingles may be blended with recycled asphalt pavement and concrete as long as the overall bitumen content does not exceed state-specified maximums. Materials engineers and shingle recyclers have speculated that the addition of RAS may improve the compaction of the sub-base, but the high AC and fiber content of RAS may impede precipitation drainage within the aggregate base.

Some states do not have a specification for this application, and various demonstration projects and testing are under development. There is a need to empirically demonstrate the quality and performance of this RAS-derived aggregate product. One example of a blended aggregate product could contain a maximum 10 percent recycled shingles by volume. This ratio would help limit the amount of AC content from the shingles to help mitigate any potential negative impacts on infiltration within the AB.

The use of a larger sized RAS product (e.g., from screened “overs” not passing the trommel screen ½-inch mesh) for aggregate as base is a known practice.

MPCA has determined that “manufactured shingle scrap and ground tear-off shingle scrap when used in . . . or road subbases” has a standing beneficial use determination. This means that the generator of the shingle scrap or end user of RAS can recycle this material as an aggregate supplement for road base construction in accordance with applicable rules without contacting the MPCA. (MPCA, February 2008)

5 Preliminary Economic Analysis

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.

Currently there are three shingle recycling operations processing manufacturers' scrap shingles on a regular basis. Manufacturers' shingle scrap is cleaner and more uniform than tear-off shingles. Plus, manufacturer shingle scrap is available from one single source and therefore quality control of supply is easier for recyclers to manage. Tear-off shingle scrap is sourced from a wider variety of roofing companies and hauler suppliers.

In Minnesota, there is more demand for recycled manufacturers' shingle scrap than available supply. Thus, there was a continued need to develop tear-off shingle recycling

5.1 Pace Construction (St. Louis, MO)

Roger Brown gave a presentation at Dakota County / OEA Project close-out meeting on July 12, 2006. Pace Construction Company has been using tear-off recycled asphalt shingles (RAS) since 2001 with great results and success. Pace receives processed RAS from Peerless Resource Recovery, Inc., a local landfill and recycling company in St. Louis, MO. Pace has ten plants, three of which are using RAS. At this time the Missouri Department of Transportation (Mo/DOT) allows 2% tear-off RAS in their hot mix asphalt using the performance grade virgin binder of PG 64 - 22. Roger Brown stated that Pace Construction attains 77% effectiveness of the total RAS binder in the in the final HMA. The ASSHTO Spec has a procedure to calculate or estimate the needed virgin binder mixture. Roger's spreadsheet as handed out at the meeting gave a breakdown of the effective asphalt content in RAP and RAS and the cost savings in using both RAP only mixes and RAP with RAS mixes.

5.2 BRI Economics comments

Bituminous Roadways, Inc. (BRI) has 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) is incorporated (Peterson, August 2004). BRI realizes savings of approximately \$.50 to \$1 per ton of final HMA product with the use of five percent RAS. The total, average cost per ton for HMA production and sale was approximately \$30 per ton in 2003 (Peterson, 2004). This is very similar to the savings reported by Allied Blacktop based in Eau Claire, WI. Allied reported savings of about \$.50 per ton of HMA product (Ayers, April 2003). Other studies have indicated a savings of up to \$3 per ton of final HMA (NAPA, 2000).

5.3 Generic Shingle Recycling Expense Items

Shingle recyclers must budget for extensive modifications (e.g., dust shroud installation), repair, and maintenance (e.g., hard surfacing of grinding / wear parts) to the grinding machine(s). Asphalt shingles will always be extremely abrasive given the hard, ceramic mineral granules used in the shingle design and manufacturing process.

Stockpiling of the finished RAS product is difficult with a very little "shelf life" of fresh material that can be directly loaded into the HMA plant without further processing. Shingle recyclers

universally note that the finished RAS material tends to re-agglomerate in storage, especially during the warmer summer months and especially if stacked in tall aggregate piles. Means to extend the shelf-life of the fresh RAS include:

- Blend the RAS material with RAP.
- Blending the RAS material with virgin sand (i.e., “bituminous aggregate”)

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 incorporated via separate cold feed bins at the time they are incorporated into the HMA plant.

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 landfills essentially all of the 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.

5.4 Economic Data from NAPA

NAPA has issued a fact sheet on how to reduce costs at HMA plants (Newcomb, 2006). 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). (Newcomb, 2006)

In a recent NAPA factsheet, Dave Newcomb states that “...roofing shingles ... have many of the same ingredients as hot-mix asphalt. This includes high quality asphalt binder, hard fine aggregate, mineral filler, polymers, and fibers. With an asphalt binder content of 20 percent, the use of five percent shingles in your mix could reduce the HMA binder content by one percent.for instance, instead of adding 5.5 percent liquid asphalt, you would add only 4.5 percent. For each 10,000 tons of mix, this would save 100 tons of liquid asphalt and at \$250 per ton, this would save about \$25,000 on mix cost.” (Newcomb, 2006)

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 Figure 5.

5.5 “Typical” Recycling System Designs as per Astec Industries

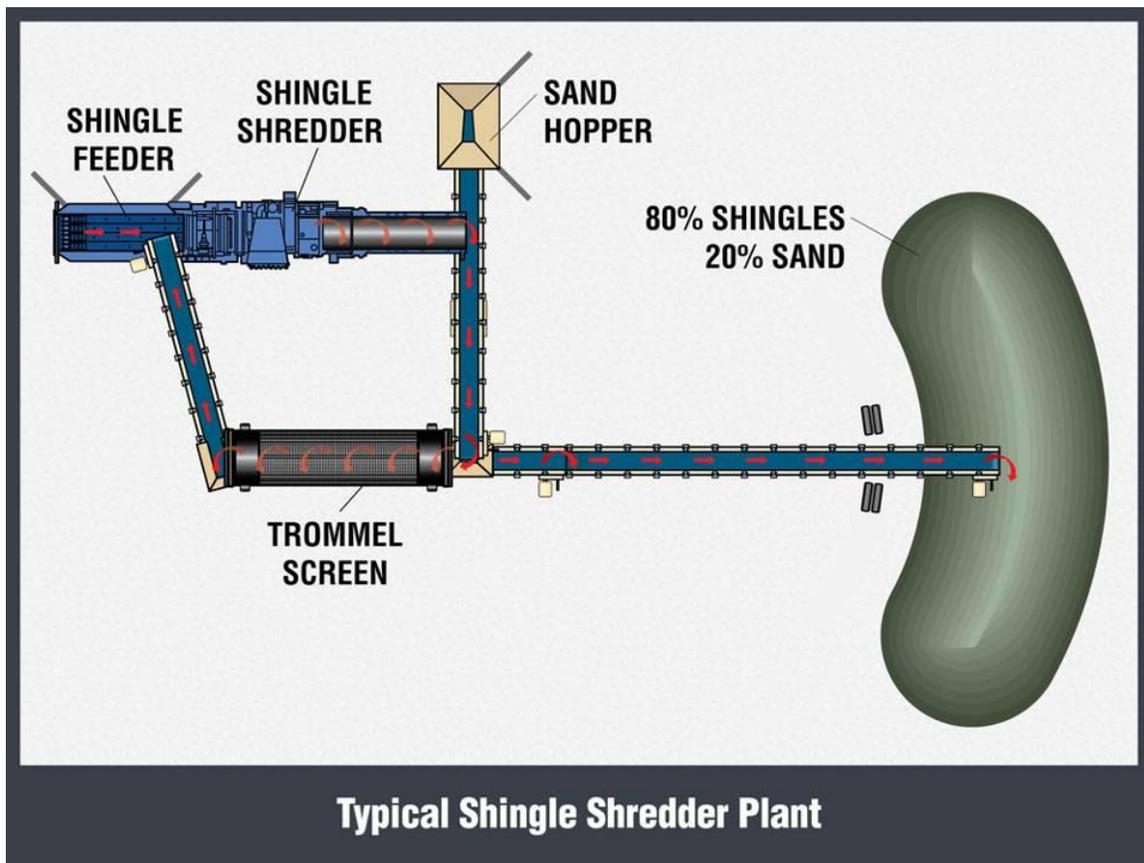
Ben Brock presented at the 3rd *Asphalt Shingle Recycling Forum* on the economics of RAS in HMA (Brock, November 2007). Some of the U.S. background data presented by Brock included the following points:

- About 25 contractors in North America run RAS in HMA as standard practice.
- 675-750 million tons of HMA produced per year (or 2.25 to 2.50 per person) in the U.S.
- About 18 billion tons of HMA pavement is in place today.
- About 3,900 HMA plants in U.S. today.
- 77 shingles manufacturing plants in U.S. today generating about 1.3 million tons of scrap each year.
- 8.5 million tons per year of post-consumer (tear-off) shingle scrap mostly going to landfill at a cost of \$15 to \$100 per ton.

Concerning the specific value of RAS in HMA, Brock stated that:

- Volumetrics force knowing the asphalt cement (AC) content in RAS.
- Energy costs reduced relate directly to our the effective amount of AC replaced.
- There is a substantial return on investment (ROI) if RAS is incorporated appropriately.
- Volumetrics force sizing RAS to similar sizes as virgin materials (1/4-inch minus preferred, but 1/2-inch minus is OK).
- Pre-blending finished RAS with 20% bituminous sand is one of the best ways to prevent reagglomeration of high-AC recycled shingle piles.
- See Figure 4 for a “Typical” shingle shredder / grinder system as designed by Astec. This system includes.

Figure 4
“Typical” Shingle Processing System
(By Astec Industries, Inc.)



Source: Brock, November 2007

- There is also a need to add new, addition cold feed RAS bins to meter the RAS (often together with RAP) into the HMA plant.
- Multiple “sizing” (or “fractionating”) of RAS can be similar to and parallel with the multiple sizing (or “fractionating”) of RAP and controlled feeding of multiple recycled sizes into a modern HMA plant.
- Measuring all feedstocks’ (virgin asphalt binder oil, RAP, RAS) AC content is critical to mix design. Table 4 lists the AC content of various types of RAS.
- Controlling actual feed rates of recycled RAS and RAP into the HMA plant via metered cold feed bins is critical to the QA/QC process operations.
- Fractionating RAP and RAS can help the operator attain higher degree of control of the relative amounts of AC content as fed into the HMA plant.

Table 4
“Typical” Shingle Composition Analysis
 (By Astec Industries, Inc.)

	Organic		Fiberglass		Old	
	(lbs. per 100 sq. ft.)	(%)	(lbs. per 100 sq. ft.)	(%)	(lbs. per 100 sq. ft.)	(%)
Asphalt	68	30	38	19	72.5	31
Filler	58	26	83	40	58	25
Granules	75	33	79	38	75	32
Mat	0	0	4	2	0	0
Felt	22	10	0	0	27.5	12
Cut-out	(2)	1	(2)	1	0	0
TOTALS	221		202		235	

Roofing Shingle Analysis

Source: Brock, November 2007

- Table 5 displays one preliminary economic analysis of RAS in HMA as prepared by Astec Industries.

Table 5
“Typical” HMA Plant Economic Savings When Using RAS
 (By Astec Industries, Inc.)

	Organic	Fiberglass	Old
Asphalt @ 400.00/ton	\$120.00	\$76.00	\$124.00
Filler @ 10.00/ton	2.60	2.80	2.50
Granular @ 10.00/ton	3.33	2.66	3.20
Mat @ 10.00/ton		.14	
Felt @ 10.00/ton	1.00	.07	1.20
Sub-totals	126.93	81.67	130.90
Disposed cost	25.00	25.00	25.00
Sub-totals	151.93	106.67	155.90
Process cost	(10.00)	(10.00)	(12.00)
NET VALUE	141.93	96.67	143.90
Savings in hot mix asphalt (per ton)	Organic	Fiberglass	Old
4%	\$5.68	\$3.86	\$5.76
5%	7.10	4.83	7.19
6%	8.32	5.80	8.63

Hot Mix Savings Using Roofing Shingles

Source: Brock, November 2007

5.6 Economic Trends

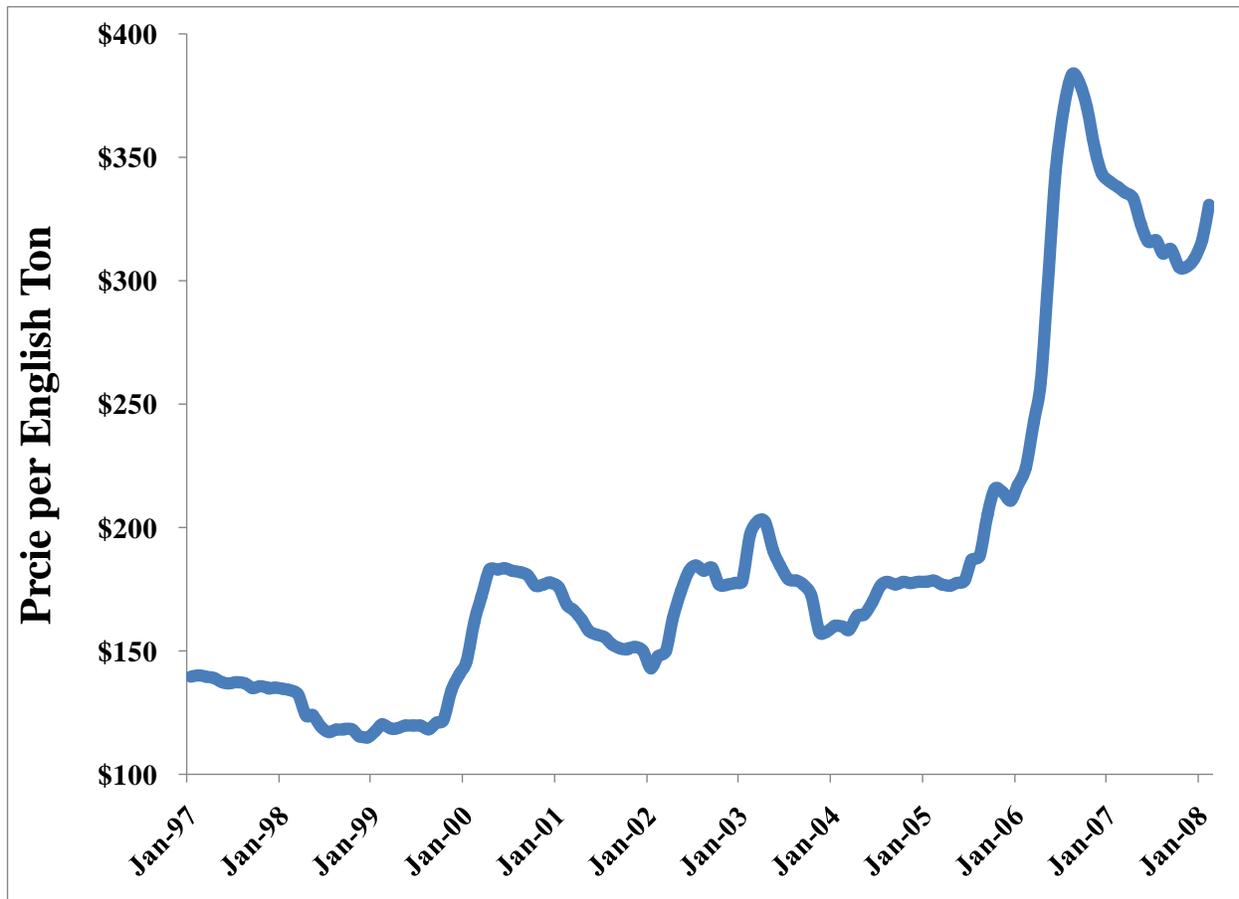
The economics of tear-off asphalt shingle recycling are currently driven by three main factors: (1) the prevailing landfill tipping fees; (2) the price of virgin asphalt cement (AC); and (3) the cost of RAS production.

5.6.1 Virgin Asphalt Prices

The virgin AC price, as a world commodity, will generally follow national/international trends. The future of virgin asphalt costs is expected to continue to increase over the long term. One illustration of the price trend for virgin asphalt is depicted in the Figure 5.

Prevailing landfill tipping fees vary by region within the United States. Therefore, the economics of shingle recycling are much more favorable on the North East region of the U.S. where landfill tipping fees can reach over \$100 per ton. Most other parts of the country report tipping fees averaging from under \$10 per ton to \$45 per ton.

**Figure 5 -
Price Trend for Virgin Asphalt Cement**
Asphalt Performance Grades (Ohio Group A): PG 58-28, PG 64-22



Source: Ohio Department of Transportation web page (as of February 7, 2008):
<http://www.dot.state.oh.us/construction/OCA/AC/PlaceIdx1997.htm>

5.6.2 Landfill tipping fees from 2007 CD&I (Phase One) Study

The average tip fee at 35 Minnesota C&D landfills was calculated at \$7.80 per cubic yard or \$32.20 per ton. The tipping fee for facilities that charge by weight ranges from \$16.00 per ton to \$43.00 per ton. The average tipping fee for facilities that charge by weight is approximately \$32.20 per ton.

The *CD&I Study* literature search and other studies have indicated throughout the U.S., a tip fee of \$50.00 per ton appears to be the price that stimulates the industry to take additional action for recovery of materials.

Disposal is cheaper than recovery for several reasons such as labor costs for sorting, capital costs for processing equipment, relatively low cost of disposal, low market values for recovered products, and transportation costs (especially in Greater Minnesota). Also, the total volumes of recoverable C&D material delivered to a facility may be relatively low (particularly in Greater Minnesota). Finally, these tonnages and economies of scale are even lower when attempting to recover just one marketable material such as RAS.

One alternative shingle recycling business design model is to provide mobile shingle processing services. Similar to the way many HMA producers contract for the grinding and processing of RAP, clean, non-regulated tear-off shingles could be stockpiled for months at the HMA plant site to accumulate an adequate supply. Then, a shingle processing service could mobilize in their grinding and screening equipment to the shingles stockpile. The finished RAS product would remain on-site at the HMA plant site. This is similar to the mobile shingle grinding services provided by Recycling & Processing Equipment / Asphalt Shingle Grinding Service (Bowyer, January 2008).

6 Environmental Benefits: Preliminary Analysis

6.1 Energy Savings

Using RAS in HMA plants results in energy savings from three sources:

- Reduction in the use of virgin asphalt cement (liquid asphalt oil).
- Reduction in energy used to heat and dry virgin aggregates prior to incorporation into the HMA drum.
- Reduced electricity and other fuel to run the overall HMA plant.

Depending on the logistics of the specific shingle recycling system compared to the traditional HMA plant based solely on virgin materials, there could also be substantial energy savings due to reduced transportation (e.g., if shingles are processed and used closer to the source of generation).

Dr. Kimberly Cochran (U.S. EPA) conducted a preliminary analysis of energy savings of recycling tear-off shingles. Her preliminary results are displayed in Table 6.

**Table 6 -
EPA's Preliminary Analysis of Energy Savings
Due to Tear-Off Shingle Recycling Into HMA**

300,000 to 400,000 tons per year of asphalt shingles
60,000,000 to 80,000,000 KWH per year

Source: Dr. Kimberly Cochran, December 2007.

This analysis indicates that the equivalent of about 200 kilowatt hours per year of electricity is saved for every ton of tear-off asphalt shingles recycled per year. This analysis is very preliminary and should be refined if need warrants.

6.2 Green House Gas Emissions

6.2.1 Preliminary Analysis from U.S. EPA

Dr. Kimberly Cochran (U.S. EPA) conducted a preliminary analysis of reductions in green house gas emissions due to recycling tear-off shingles. Her preliminary results are displayed in Table 7.

**Table 7 -
EPA's Preliminary Analysis of Green House Gas Savings
Due to Tear-Off Shingle Recycling Into HMA**

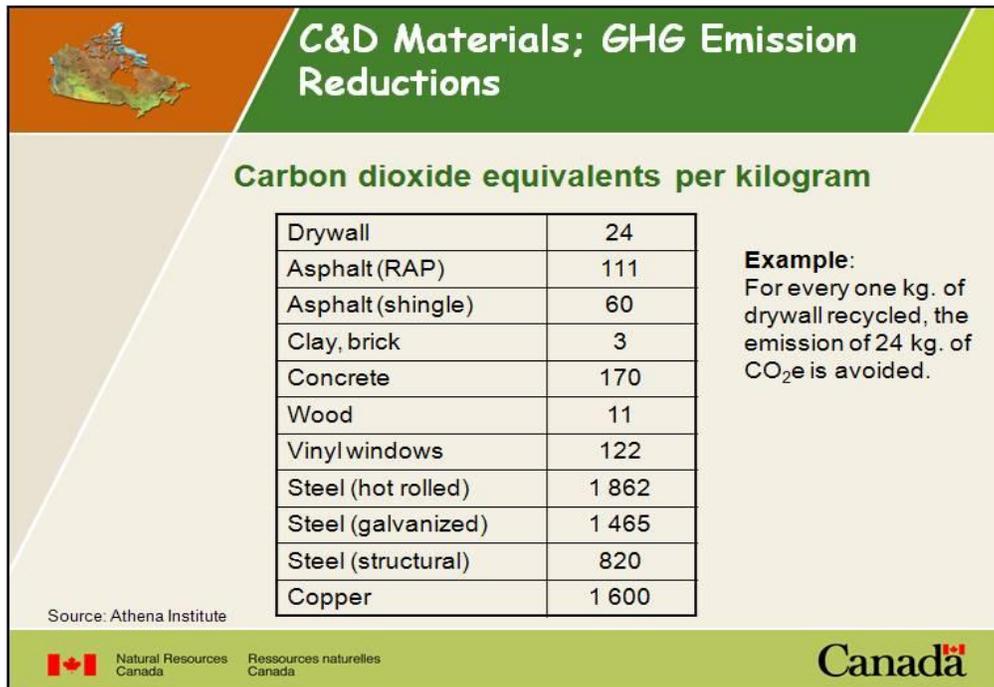
300,000 to 400,000 tons per year of asphalt shingles
40 to 50 metric tons of CO² equivalents per year
0.293 to 0.275 pounds of CO² equivalents per ton of shingles

This analysis indicates that the equivalent of about 0.27 to 0.29 pounds of CO² equivalents are reduced for every ton of tear-off asphalt shingles recycled per year. This analysis is very preliminary and should be refined if need warrants.

6.2.2 Analysis from Natural Resources Canada

Mike Clapham, (Natural Resources Canada) presented their own analysis of the reductions of green house gas emissions due to recycling of various C&D materials as displayed in Table 8.

**Table 8 -
Natural Resources Canada Analysis of Green House Gas Savings
Due to Recycling Various C&D Materials**



Source: Clapham, November 2007.

7 Market Development Options

7.1 Inventory of All Options

This section is an attempt to itemize and inventory all potentially viable market development options that may help promote the recycling of asphalt shingles. This subsection does not attempt to analyze or prioritize these options as to relative feasibility. Rather, the intent is to catalogue all options.

The *2007 CD&I (Phase One) Study* contained a number of proactive market development options specific to shingles recycling, including:

1. SWMCB, MPCA and Mn/DOT should continue and expand inter-agency collaboration towards adoption of a new state materials specification providing for the appropriate use of tear-off recycled asphalt shingles in hot mix asphalt (HMA). Tactics should include
 - Continue and the *Technical Working Group (TWG)* as planned for the remainder of 2008 as part of this larger *2008 CD&I (Phase Two) Project*.
 - Expand the *TWG* to enlist MPCA as a full co-sponsor and third co-chair.
 - Develop plans for extending the term of the *TWG* through 2012.
 - Under Mn/DOT direction, form the 2008 – 2009 shingles project *Technical Advisory Panel (TAP)* as per the new MPCA research grant. Mn/DOT should consider forming this *TAP* as an ad hoc working subgroup of the *TWG*. Membership of the *TAP* should also include other SWMCB county engineers that have direct experience with tear-off shingles.
2. Continue to monitor and support industry developments on other higher value end use applications (e.g., as a fuel supplement in cement kilns, as a boiler fuel supplement, as aggregate for new shingles). This option for other markets should be considered secondary to the primary strategy of HMA market development.
3. SWMCB Counties should implement best practices for affirmative state and local government HMA procurement policies to offer incentives and market signals to use tear-off RAS. One example scenario could be:
 - As a temporary means to help stimulate market demand, SWMCB Counties should collectively identify at least two projects in 2008 and two projects in 2009 that will employ a strict “...**shall** use tear-off shingles in HMA...” purchasing policy as a short-term market development subsidy. This should help develop the tear-off shingle processing infrastructure over the next two years. Beyond 2009, if adequate processing capacity available, and after Mn/DOT adopts a permissive tear-off specification, SWMCB Counties should follow Mn/DOT’s lead and employ a more permissive “...**may** use tear-off shingles in HMA...”
4. Develop a targeted grant and loan program for new business development of tear-off shingle recycling operations.

The *2007 CD&I (Phase One) Study* also contained a number of proactive market development options that were generic. All options from the *2007 CD&I (Phase One) Study* are retained in this subsection without regard to cost-effectiveness or feasibility. The options have been

embellished as part of this shingles *White Paper* to further refine the strategies and more fully document the wide range of market development strategies available to the responsible government agencies.

The following options are general to all viable C&D commodities but could substantially help improve the market for shingles recycling:

5. SWMCB and MPCA could promote sustainable building goals such as LEED™ guidelines and recovery standards (e.g., 50% = “silver”, 75% = “gold”), in particular for shingles recycling initiatives.
6. MPCA could standardize the materials management definitions and C&D recycling measurement guidelines. For example on shingles recycling, require annual certification reports from generators (both shingle manufacturers and roofing companies).
7. MPCA could develop new, independent C&D recycling certification programs similar to field verification systems such within the LEED™ program.
8. SWMCB and MPCA could develop shingles waste reduction and recycling technical assistance programs.
 - These programs could be patterned after similar initiatives for municipal solid waste (MSW) and residential recycling programs.
 - SWMCB and MPCA could promote pre-demolition inspection practices that not only complies with existing asbestos regulations but proactively promotes the recovery of eligible, non-regulated asphalt shingle scrap.
9. SWMCB and MPCA could promote numerous best practices via networking, workshops, and forums for designers, developers, contractors, etc. The recent CMRA publication, *Recycling Tear-Off Asphalt Shingles: Best Practices Guide*, could be used as one technical assistance tool and workshop curriculum framework.
10. SWMCB and MPCA could recommend legislation that would dedicate a portion of the current C&D and industrial waste taxes to promoting material recovery initiatives such as shingles recycling.
11. SWMCB and MPCA could expand grants programs to explicitly cover C&D related recycling activities such as shingles recycling, especially investments in the end use and processing infrastructure. Three specific examples of such potential new grant programs include:
 - SWMCB and MPCA could create a coordinated grant program that subsidizes local government road construction projects that include “shall use tear-off shingles in HMA” as part of the individual project materials specifications.
 - SWMCB and MPCA could create a separate coordinated grant program to help finance a share of the capital costs of shingles processing equipment (e.g., similar to the current MPCA “CAP” grant program).
 - Develop other grant and loan programs for targeted market infrastructure development allowing private companies to be directly eligible recipients (rather than CAP grant restrictions that require the facilities to be owned by a local government agency).

12. SWMCB could develop model county C&D recycling programs that include a number of requirements such as:
 - Phased in requirements for all cities and townships to adopt complementing municipal C&D recycling programs.
 - Building / demolition permits to include deposits with funds returned for documented recycling and recovery.
 - Requiring shingle recycling as part of certain size projects (e.g., over \$100,000 in new construction or demolition).
 - Affirmative procurement strategies (e.g., required purchase of HMA derived from tear-off shingles) for any construction projects.
 - Specific diversion goals (reduction and recycling) for all C&D materials, with specific targets for asphalt shingles (e.g., 100% of all non-regulated asphalt shingles shall be recycled by the year 2012).
13. SWMCB and MPCA could document current diversion levels, including for shingles recycling efforts, so that goals are set at proper levels and monitored appropriately
14. SWMCB and MPCA could recommend legislation for a statewide, mandatory C&D processing requirement for projects above a certain size (larger than single-family residential or small commercial). This approach would likely facilitate private companies to invest in facilities to provide the processing service.
15. If voluntary efforts to meet C&D goals are not successful (e.g., by 2012), SWMCB and MPCA could recommend adoption of mandatory recycling goals and landfill bans, especially for materials with well-established markets such as manufacturers' asphalt shingle scrap.

In 2004, the original SWMCB shingles recycling project initiated a discussion of a wide range of broad policy initiatives (DKA, August 2004). The 2004 SWMCB project steering committee discussed two concepts for legislative initiatives that could be evaluated further by SWMCB Counties, MPCA and Mn/DOT:

16. Prohibiting the landfilling of specified recyclable manufacturer shingle scrap.
17. Creation of a landfill surcharge on all state C&D landfills to fund additional recycling initiatives, including shingles recovery.

The concept of a landfill prohibition would need to be specific to "recyclable" manufacturer shingle scrap material only as defined by a consensus of current and prospective shingle recycling operators. This definition needs to consider the range of shingle recycling equipment and overall processing systems design options. Currently "whole scrap shingles derived from shingle manufacturing plants" might enjoy such a consensus within the definition of a "recyclable" type of manufacturing scrap. Other forms of manufacturers' scrap that represent properties not currently amenable to recycling into HMA include:

- "Tab" (or "slugs") resulting from the cut-outs in "three-tab" asphalt shingles;
- "Globs" of residue from line clean-outs; and
- Other debris and asphalt "contaminants" such as rocks, paper, plastics, wood or other trash / refuse.

Such a legislated definition of “recyclable” manufacturer shingle scrap vs. plant “contaminants” together with a scheduled landfill prohibition could help stimulate and accelerate market development. Any manufacturer shingle scrap landfill prohibition that is considered should provide for several years of intentional transition before implementation (e.g., an effective date in 2010) to allow private companies to make appropriate plans and investments in recycling systems. Any such tear-off shingle scrap landfill prohibition should provide additional time for this new tear-off shingles recycling infrastructure to be initiated, develop and mature (e.g., an effective date of 2014).

Some interests have stated that the current tipping fees at local C&D landfills are not high enough to make shingle recycling alternatives competitive for recyclers trying to start such operations. This has led to discussions about the concept of a C&D landfill surcharge. Funds from this C&D surcharge could be used to help pay a small share of capital costs to start up new or expanded C&D recycling facilities such as shingle recycling operations. It may be more feasible to limit such a market development grant program to a relatively short – term development period (e.g., five years, 2009 through 2012). The downside is that higher local tipping fees may drive the waste industry to seek landfill disposal options outside of Minnesota.

Differential tipping fees could also be explored by the State and Counties. Today, some transfer stations utilize differential tipping fees to encourage source separation of roofing materials before loading into roll-off boxes. For example, tear-off shingles only are loaded first (at the bottom) of the roll-off box. Then, after the re-roofing tear-off step is finished, the other non-shingle debris (e.g., plastic, metal, paper, wood) is loaded carefully on top and / or at the front of the roll-off box. This method allows for much easier separation of the debris from the shingles once tipped at the transfer station.

18. MPCA and SWMCB could explore various options for voluntary and mandatory differential tipping fees for mixed roofing materials vs. source separated tear-off shingles at transfer stations and landfills. For example:

- Document existing differential tipping fees as implemented by private transfer stations and landfills on a voluntary basis. Inquire with these operators as to how the government sector can enhance and help the private sector expand such pricing policies. (For example, publish a report on statewide differential tipping fee practice and include notable case studies.)
- Consider developing county ordinances that would require differential tipping fees.
- Consider developing legislative recommendations that would require differential tipping fees.

As alternatives to a legislative initiative, the preferred market development strategies utilized to-date have focused on deliberate, individual development projects, including research studies funded by SWMCB, MPCA, Mn/DOT and federal research institutions such as the Recycled Materials Resource Center (RMRC) and the Federal Highway Administration (FHWA). These ongoing programs have positioned the government sector in a role of facilitating an improved business climate for new recycling investments, largely through research and technology information exchange. Both approaches, legislative and public-private collaborative development, could be employed in the future if necessary.

7.2 Analysis of Market Development Priorities

The previous subsection itemized all known market development “options”. Not all options are equally effective or feasible. Each option has different costs to different interests (e.g., government agencies, private contractors, waste generators).

This subsection attempts to establish broad priorities based on the judgment of cost-effectiveness. I.e., those strategies that can do increase recycling of tear-off shingle scrap the most (i.e., tons per year) for least cost to the key interests.

Table 9 displays the Consultant Team’s analysis of all market development options. The resulting conclusions and recommendations are based on this very preliminary analysis of cost-effectiveness and overall feasibility. Other interest groups should be consulted to verify and comment on this consultant analysis. Key interest groups in the shingles recycling “system” (current and future) in Minnesota include:

1. C&D waste management companies (e.g., landfill operators, transfer station operators, recovery operators).
2. Existing shingle recyclers.
3. HMA producers.
4. Other pavement construction contractors.
5. Mn/DOT
6. MPCA
7. SWMCB and all other Minnesota Counties
8. Other local units of government

The most sustainable infrastructure for tear-off shingles recycling will be systems that are built upon long-term capital investments from the private sector in a competitive marketplace built upon a basis of fair and equitable financial incentives and market development policies from the government sector. Thus, the private companies described within the groups one through four above should be encouraged to make appropriate investments in new tear-off shingles recycling infrastructure to fulfill the governments projected needs for new pavement.

Table 9 - Analysis of Market Development Options

White Paper Number	Concept	Description	Primary Responsible Party ^(a)	Diversions Potential ^(b)	Cost	Impact on Generator	Government Role	Impact on Private Waste Industry ^(c)	Political Acceptance
1.	Continue and expand SWMCB / Mn/DOT / MPCA collaboration	Focus on new, Mn/DOT tear-off shingles HMA specification and related BMP's for QA/QC	Mn/DOT	High	Low	Low	High	High	High
2.	Monitor other efforts to develop other (secondary) end-use markets	Monitor and support other states and federal market development programs for use of tear-off shingles as fuel, in cement kilns, and in "shingles-to-shingles" technologies.	SWMCB	Low	Medium	Low	Low	Low	High
3.	Implement affirmative procurement policies	E.g., "...shall use tear-offs in HMA..." as a temporary strategy for R&D and market development purposes. <u>Also, consider bid alternatives, bid advisories</u>	SWMCB	High	Low	Low	Medium	High	Medium
4.	Targeted grant and loan program for shingles recycling	Allocate a portion of SCORE, CAP and direct private grant programs to shingles recycling	MPCA	High	Medium	Low	High	Medium	High
5.	LEED™ - type of recycling rate goals for shingles recycling standards	Develop a new recycling rate standard schedule for shingles recycling (e.g., 50% = "silver", 75% = "gold", etc.)	MPCA	Medium	Low	Medium	Low	Low	High if voluntary. Low if mandatory.
6.	Standardize definitions and measurement protocols	Annual certification reports from generators (shingle manufacturers and roofing companies)	MPCA	Low	Low	Low	Low	Low	High
7.	Develop new independent shingles recycling certification program	Develop a shingles recycling technical memorandum that could be adopted by Minnesota's LEED™-type of organization(s)	MPCA	Medium	High	High	High	High	Medium

Notes:

(a) "Primary Responsible Party" implies that other secondary parties will be involved depending on the option.

(b) "Diversions Potential": Low Diversion < 10%, Medium Diversion = 10% to 30%, High Diversion > 30%.

(c) "Impact on Private Industry": is a judgment of the consultant author based on assumed operational and financial changes that may be required. This judgment is not a reflection of feasibility, willingness or acceptance of these options.

(Table 9 continued on the next page)

Table 9 - Analysis of Market Development Options (continued)

White Paper Number	Concept	Description	Primary Responsible Party ^(a)	Diversion Potential ^(b)	Cost	Impact on Generator	Government Role	Impact on Private Waste Industry ^(c)	Political Acceptance
8.	Develop shingles recycling technical assistance tools	Brochures and web page information that can help contractors and building owners easily find recycling alternatives. Tools could also be used at pre-demolition inspections.	SWMCB	Low	Medium	Low	Medium	Medium	High
9.	Promote best practices in shingles supply development and processing	Use recent CMRA <i>Best Practices Guide</i> (BPG) as curriculum resource	MPCA	Medium	Medium	Medium	Medium	Medium	High
10.	Dedicate a portion of CD&I waste taxes to promote material recovery initiatives	Recommend legislation as one means of obtaining specific authority to use CD&I tax funds for C&D recovery initiatives	MPCA	Medium	High	Low	High	Medium	High
11.	Expand grants programs to explicitly cover C&D recycling activities such as shingles recycling	Special investments in RAS end use and processing infrastructure. Include match requirements to leverage grant funds.	MPCA	High	High	Low	High	High	High
12.	Develop model C&D recycling programs	Counties can lead by example and also require local units to adopt C&D recycling technical assistance, info exchange programs	SWMCB	High	Medium	High	High	High	Low
13.	Document current C&D diversion levels, including waste reduction and recycling of shingles	Base goals and enhancement policies and programs on actual, current recovery rates and needs	MPCA	Low	Medium	Low	Medium	Low	High
14.	Require C&D processing for large projects	Develop legislation for mandatory C&D processing requirements for larger projects.	MPCA	Medium	Medium	High	High	High	Low

Notes:

- (a) **"Primary Responsible Party"** implies that other secondary parties will be involved depending on the option.
- (b) **"Diversion Potential"**: Low Diversion < 10%, Medium Diversion = 10% to 30%, High Diversion > 30%.
- (c) **"Impact on Private Industry"**: is a judgment of the consultant author based on assumed operational and financial changes that may be required. This judgment is not a reflection of feasibility, willingness or acceptance of these options.

(Table 9 continued on the next page)

Table 9 - Analysis of Market Development Options (continued)

White Paper Number	Concept	Description	Primary Responsible Party ^(a)	Diversion Potential ^(b)	Cost	Impact on Generator	Government Role	Impact on Private Waste Industry ^(c)	Political Acceptance
15.	Establish policy "triggers" for additional recycling requirements	Develop legislation for mandatory C&D recycling requirements and landfill bans for materials with well-established markets.	MPCA	High	High	High	High	High	Low
16.	Prohibit landfilling of specific recyclable manufacturers' shingle scrap	Propose legislation that clearly defines and specifies "recyclable" manufacturers' shingle scrap. Set reasonable deadlines for 100% recovery.	MPCA	Medium	Low	High	High	High	Low
17.	Create new C&D landfill surcharge to be used for C&D abatement programs.	Propose legislation that imposes an increased C&D tax to provide financial incentive to increase diversion while funding above recovery initiatives.	MPCA	High	High	Medium	High	High	Low
18.	Differential tip fees for loads of mixed roofing material vs. source separated loads of clean, tear-off shingles	Publish a report on current statewide differential tipping fee practices. Develop recommendations for both voluntary and mandatory approaches to enhancing differential tipping fees.	MPCA	High	High	Medium	High	High	High for voluntary. Low for mandatory

Notes:

(a) "Primary Responsible Party" implies that other secondary parties will be involved depending on the option.

(b) "Diversion Potential": Low Diversion < 10%, Medium Diversion = 10% to 30%, High Diversion > 30%.

(c) "Impact on Private Industry": is a judgment of the consultant author based on assumed operational and financial changes that may be required. This judgment is not a reflection of feasibility, willingness or acceptance of these options.

8 Conclusions

Recycling of tear-off asphalt shingles in Minnesota has great potential in the near future to divert significant tonnage from landfills. Using a moderately aggressive forecast estimated at 75% recovery by the end of 2012, the State could recycle approximately 175,000 tons of tear-off shingles that are all currently being landfilled.

Today, recycling of manufacturers' shingle scrap is being done on a regular basis by at least three HMA producers. Rough estimates indicate that about 60 to 80 percent of the approximately 70,000 tons per year of manufacturers' shingle scrap is currently being recycled. It is reasonable to assume and promote 100% recovery of manufacturers' shingle scrap in the near future. The development of a strong market for tear-off shingle scrap will build directly upon the past success of recycling manufacturers' shingle scrap into HMA. HMA is the primary, higher value end market for recycled shingles. Other alternative markets that are currently viable include the use of RAS as an unbound aggregate supplement for road construction projects such as gravel base. Less feasible end market options can be explored, but will not have the same demand as HMA.

Table 1 in subsection 1.4.2 of this *White Paper* documents the various stages of Mn/DOT's specification development beginning with the original research in the early 1990's. Currently manufacturers' shingle scrap enjoys the benefit of being allowed within Mn/DOT's materials specifications on a "permissive" basis. This means contractors may use manufacturers' RAS in their HMA unless explicitly prohibited by the project engineer. The successful use of manufacturers' shingle scrap in HMA is a primary indicator that such recycling technology can be developed for tear-off shingles as well. Also, there are number of private companies that have indicated their willingness to invest in tear-off shingle recycling ventures once a more certain HMA market is developed. Thus, there is great potential for public – private partnerships to emerge as a strategy to expand tear-off shingle recycling.

Approximately 13 million tons of HMA is used in Minnesota each year. RAS is normally used at a maximum rate of 5% by weight of aggregate in the mix. Thus, there is more than enough HMA capacity to use the tear-off shingles if appropriate quality assurance / quality control (QA/QC) methods are employed for the development of clean supplies and processing into a suitable RAS product. About 3.5 million tons of HMA per year could consume all of the forecasted 175,000 tons per year of tear-off shingles.

MPCA has a well established solid waste utilization program with rules established in early 2004. Manufactured shingle scrap and ground tear-off shingle scrap when used in asphalt pavement or road subbases enjoys the advantage of a "standing beneficial use determination" (SBUD). While all other applicable rules, laws and policies must be followed, the SBUD status for shingle scrap means that the generator or end user can recycle shingles when used in these two applications without contacting the agency.

The overall economics of shingles recycling looks very promising. The competing cost of new, virgin asphalt continues to steadily increase as a general long term trend, with a marked spike over the past two years. The shingles processing technology is readily available and costs are fairly well known. Different business models and economies of scale will affect production efficiencies. Recycling tear-off shingles will be slightly more expensive than recycling manufacturers' shingle scrap because of additional costs of scrap supply development and certification from more diverse sources (e.g., roofing companies, haulers, transfer stations, and /

or processors). Also, processing of tear-offs is slightly more expensive because of added sorting and cleaning steps needed to obtain a RAS product that meets the same type of quality standard as derived from recycling of manufacturers' shingles scrap.

A total of 18 market development strategies are identified and analyzed in the previous section of this *White Paper* (see Table 9 and related text).

One of the key barriers to the development of this market is the absence of a clear, reasonable materials quality specifications for the tear-off RAS. Mn/DOT currently has on its books such a specification for recycled manufacturers' shingle scrap. One of the most cost-effective market development options identified in this *White Paper* is to work closely with Mn/DOT to promote the early adoption of a new, provisional materials specification for recycled tear-off shingles (option #1). A longer term strategy is to encourage Mn/DOT to adopt a permanent, more permissive tear-off shingles specification similar to the current manufacturers' specification.

MPCA has funded Mn/DOT to conduct a new Mn/DOT lab research project on tear-off shingles into HMA. Mn/DOT staff have stated it is their intent to adopt a full "permissive" tear-off specification (to be published in the Mn/DOT "spec book") by the end of 2009. This would result in a similar implementation approach that is currently used for manufacturers' shingle scrap and RAP. I.e., once adopted, the permissive Mn/DOT tear-off specification should provide for adequate QA/QC procedures and allow contractors, at their own discretion, to use tear-off RAS in selected HMA mix types unless explicitly prohibited by the project engineer.

While this Mn/DOT lab study is underway, Mn/DOT staff have stated that they will approve project – specific provisional specifications for use tear-off shingles in HMA. Such a special provisional specification was developed and approved by Mn/DOT for the recent Ramsey County pedestrian trail construction project adjacent to *Lower Afton Trail (LAT)* in Maplewood. Constructed as an off-road pedestrian / bicycle trail in the fall of 2007, the HMA pavement incorporated 5% tear-off shingles as required by the project specifications (Ramsey County, 2007). Mn/DOT staff have stated recently that similar provisional engineering specifications could be approved by Mn/DOT for other local agency road construction projects on a job-by-job basis if similar QA/QC procedures and standards are enforced.

Counties and other local governments also have an important role to play in the development of the market for recycled tear-off shingles. An argument has been forward that the Counties have a greater incentive, and therefore a greater responsibility, to take the lead in developing markets for C&D materials such as tear-off shingles. In any case, the SWMCB and Greater Minnesota counties should closely collaborate with Mn/DOT and MPCA in this effort.

There needs to be further discussion about how SWMCB and Greater Minnesota County – sponsored technical and financial assistance programs can help accelerate the implementation of shingles recycling best management practices. In general, the State and Counties do not require such "recycling" facilities to have a separate recycling license. Therefore, these operations will be designed, constructed and operated to meet specific quality standards such as the Mn/DOT tear-off RAS materials specification. Also, the compliance with other local and state rules and laws will be driven in part by enforcement and education efforts for these other issues (e.g., solid waste storage, air quality, stormwater management, etc.)

MPCA also has an important role as the State Agency responsible for both environmental protection and statewide market development. Thus, MPCA should continue to collaborate

closely with all Minnesota counties and Mn/DOT. As needs and funds are identified, MPCA should continue to provide financial assistance.

9 Recommendations

The following recommendations are presented in order of suggested priority.

1. Mn/DOT will continue to provide special, provisional project specifications for use of tear-off shingles in HMA that can be used by local governments and contractors on a job-by-job basis.
2. Mn/DOT plans to adopt a “permissive” specification for use of tear-offs by the end of 2009 based on results of a new 2008 – 2009 lab study such that contractors can use tear-off RAS unless explicitly prohibited by the local project engineer.
3. The Minnesota Shingles Recycling *Technical Working Group (TWG)* will continue to convene to help coordinate related market development initiatives by State and local government agencies.
 - a. Adding MPCA as a full co-sponsor. A MPCA staff representative should be designated to serve as a third co-chair.
 - b. Establishing a sunset date of 2012 or when the tear-off shingles market is self-sustaining (whichever comes first).
 - c. Establishing a regular schedule of meetings (twice per year) through 2009.
 - d. A budget should be developed for the *TWG* for 2009.
4. As a temporary means to help demonstrate the feasibility of use of tear-off RAS into HMA, willing SWMCB County departments of transportation should consider a designing **selected** 2008 and 2009 construction demonstration projects that specify the use tear-off derived HMA. Beginning in about 2010, (assuming that Mn/DOT has adopted a permissive tear-off specification in 2009) Counties should use regular purchasing procedures (e.g., “...may use tear-off shingles...”).
5. All SWMCB member Counties should announce their individual plans for using tear-off shingles in HMA construction projects in 2008 and 2009. Each SWMCB County should consider which affirmative procurement policy method they will use for their respective project specifications.
6. MPCA and SWMCB should develop a dedicated tear-off shingles recycling market development grant program for 2009 through 2012. This “dedicated, targeted” tear-off shingles grant approach should be sunset in 2012 or when the tear-off market is self-sustaining (whichever comes first).
7. MPCA should develop a sustainable building technical memo (e.g., for use by LEED™ – type of programs) specific to recycling of tear-off shingles that includes requirements for:
 - a. Standard definitions and terminology
 - b. Standard measurement methods
 - c. Recommended means to develop independent certification of recycling
 - d. Recommendations for funding such certification

8. SWMCB and MPCA should develop tear-off shingles recycling technical assistance tools such as brochures and web page information. Such tools should be used, as appropriate, when State and local regulators conduct on-site, pre-demolition inspections.
9. If there is not reasonable and steady progress towards the proposed targets for recovery of tear-off shingles by the end of 2009, MPCA should evaluate legislative options which may include authority and funding to further promote the market development for tear-off shingles.
10. SWMCB should develop a model C&D recycling program, including specific provisions for tear-off shingles recycling requirements. Such a model program should include options for:
 - a. Required bid advisories (i.e., voluntary preferences for purchase of tear-off derived HMA).
 - b. Required bid alternatives (i.e., explicit itemization of the price difference for tear-off derived HMA pavement)
 - c. Other voluntary affirmative procurement methods (“...may use tear-off shingles in HMA...”) such as would be provided by Mn/DOT’s proposed new permissive specification for tear-off shingles.

References Cited

Ayers, Bob; (April 2003) Presentation at the Second Asphalt Shingle Recycling Forum. "[Shingle Recycling: A Paving Contractor's Perspective](#)", Second Recycled Asphalt Shingles Forum in Minneapolis, MN.

Bowyer, Mark (January 14, 2008). Personal communication with Debra Haugen, DKA. Recycling & Processing Equipment / Asphalt Shingle Grinding Services (Peru, Indiana; www.recyclingandprocessing.com).

Brock, J. Don, (Original 1996, revised 2007) "[From Roofing Shingles to Roads](#)", Technical Paper T-120, Astec Industries, Inc., Chattanooga, Tennessee.

Brock, Ben; Astec Industries, Inc. (November 2007). "[Economics of RAS in HMA](#)" A presentation at the 3rd Asphalt Shingles Recycling Forum held in Chicago, November 1 – 2, 2007.

California Integrated Waste Management Board (CIWMB) (July 2007). Online fact sheets: *Construction and Demolition Recycling: Asphalt Roofing Shingles Recycling*: Link directly at: <http://www.ciwmb.ca.gov/ConDemo/Shingles/default.htm>.

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).

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).

Clapham, Mike; Natural Resource Canada, (November 2007), "*Recycling Roofing Materials in Canada*" A presentation at the 3rd Asphalt Shingles Recycling Forum held in Chicago, November 1 – 2, 2007.

Cochran, Kimberly PhD; U.S. EPA Office of Solid Waste (November 2007) "[Asphalt Shingles Recycling: A National Perspective](#)" A presentation at the 3rd Asphalt Shingles Recycling Forum held in Chicago, November 1 – 2, 2007.

Cochran, Kimberly (December 2007). Personal communication with Wayne Gjerde, MPCA.

Dan Krivit and Associates (DKA), "An Environmental White Paper Report as Part of the RMRC Project Overcoming the Barriers to Asphalt Shingle Recycling". Prepared for the Minnesota Department of Transportation and the Recycled Materials Resource Center. 2003.

DKA, August 27, 2004. "Manufacturer Shingle Scrap Recycling Project: Final Report" for the SWMCB. Posted on the SWMCB web page: http://www.swmcb.org/files/ManufacturedShingleScrap_final.pdf

DKA, January 2005. "Overcoming the Barriers to Asphalt Shingle Recycling: Final Report for the RMRC Project 22" Recycled Materials Resource Center, Durham, NH. Final report: <http://www.rmrc.unh.edu/Research/past/P22/P22final.pdf>

DKA, January 2006. "Increasing the Recycling of Manufactured Shingle Scrap in Minnesota: A Market Development Project". (Also known as the *Mn/DOT "Phase Two" Shingle Recycling Project*) Prepared for the Minnesota Department of Transportation. Final report can be found at: <http://www.lrrb.org/PDF/200707.pdf>.

DKA, (July 24, 2006). "Dakota County Demonstration: An OEA - Funded Recycled Shingles Lab Study Project: Description of Sourcing, Sorting and Processing of Tear-Off Shingle Scrap"

DKA, (August 2006). "Dakota County Demonstration: An OEA - Funded Recycled Shingles Lab Study Project: Summary and Minutes of a Project Wrap-Up Meeting and Workshop as Held on July 12, 2006 at Mn/DOT's Offices in Maplewood, MN"

DKA, (September 25, 2007). "List of Minnesota's Research Publications" as prepared for first meeting of the Minnesota Shingles Recycling *Technical Working Group (TWG)* held in at Mn/DOT's offices in Maplewood, MN.

Foth Infrastructure & Environment and Dan Krivit and Associates, September, 2007. *Minnesota Construction, Demolition, and Industrial Waste Study* (Project No.: 06S015). Prepared for the Solid Waste Management Coordinating Board. Final report: <http://www.swmcb.org/files/CD&I%20Waste%20Study.pdf>. Appendices: http://www.swmcb.org/resources/studies_policy_reports/non_municipal_solid_waste.

Hughes, Charles S., (1997) "Uses of Waste Asphalt Shingles in HMA." Special Report 179, National Asphalt Pavement Association, Lanham, Maryland.

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.

Johnson, Greg (November 2001). *Construction of Field Evaluation Sections for the Use of (Manufacturer) Waste Shingles*. A field report on the demonstration of using manufacturers' RAS as dust control on a gravel road at the SKB industrial waste landfill in Rosemount.

McGraw, Jim; Adam Zofka; Dan Krivit; Joe Schroer; Roger Olson; and Mihai Marasteanu. (March 14, 2007) "Recycled Asphalt Shingles in Hot Mix Asphalt". A technical paper and presentation at the Association of Asphalt Paving Technologists (AAPT) annual meeting in San Antonio, Texas

Minnesota Department of Transportation (Mn/DOT) Standard Construction Materials Specifications, Excerpt from the combined 2360/2350 bituminous (Gyratory/Marshall) mix. [Mn/DOT's shingle scrap specification](#) is found within section 2360.2 Materials: A2h Scrap Asphalt Shingles.

Mn/DOT's Draft Scrap Shingles (Guidelines) on file in the Mn/DOT Bituminous Office: (http://shinglerecycling.org/images/stories/shingle_PDF/mndot%20draft%20spec%202382.pdf)

Mn/DOT and MPCA *Toolkit: A Guide to the Use of Roofing Shingles in Road Construction* (2002): <http://www.pca.state.mn.us/oea/market/shingles.cfm>

Minnesota Pollution Control Agency (MPCA; February, 2008) web page: Solid Waste Utilization – Standing Use Determinations: <http://www.pca.state.mn.us/waste/swutil-sbud.html#list>.

MPCA (September 2006) *Solid Waste Storage Standards* within Minnesota Rules Chapter 7035.2855 (Current as of 9/07/06) <https://www.revisor.leg.state.mn.us/arule/7035/2855.html>

MPCA (October 2005), *Solid Waste Utilization Program Fact Sheet Waste/Solid Waste #3.26*, October 2005 as accessed via the MPCA web site at: <http://www.pca.state.mn.us/waste/sw-utilization.html#utilization> and <http://www.pca.state.mn.us/publications/w-sw3-26.pdf>.

National Asphalt Pavement Association (NAPA; September, 2000) Special Report 187, "Recycling Practices for HMA".

Newcomb, David, et al., 1993, "Influence of Roofing Shingles on Asphalt Concrete Mixture Properties." Report MN/RC-93/09, University of Minnesota, Minnesota.

Newcomb, David; Mary Stroup-Gardiner; Brian M. Weikle; and Andrew Drescher. (June 1993) "Influence of Roofing Shingles on Asphalt Concrete Mixture Properties." Report MN/RC-93/09, University of Minnesota, Minnesota.

Newcomb, Dave (2006). "Five Ways to Save Your Asphalt!... And Still Build a Sexy Pavement" (SR-191) National Asphalt Pavement Association (NAPA).

New Jersey Department of Transportation web page of virgin HMA price indexes based on cement selling prices from suppliers in the Northern part of the State. As accessed on January 26, 2008: <http://www.state.nj.us/transportation/business/trnsport/PriceIndex.shtm>

Peterson, Kent, (April 2003) "[Operators Experiences: Minnesota's Experience](#)", Second Recycled Asphalt Shingles Forum, in Minneapolis, MN.

Peterson, Kent (Bituminous Roadways, Inc.). (August 9, 2004) *A Project to Improve a System for Processing Shingle Scrap and to Increase the Market for Processed Shingles. Final Report.* Submitted to the Minnesota Office of Environmental Assistance in completion of a Targeted Market Development Grant for Fiscal Years 2001-2002 (extended to April 2004).

Ramsey County *Lower Afton Trail Project* specifications excerpts relevant to RAS use in HMA. http://shinglerecycling.org/images/stories/shingle_Word/rc%20lat%20spec%20ras%206-07.doc

Townsend, Dr. Timothy, Xu, Dr. Chad, Powell, Jon. (October 2007) "*Environmental Issues Associated with Asphalt Shingle Recycling*" for the *CMRA Tear-Off Shingles Recycling Project*.

Turgeon, Curtis M., February, 1991, "Waste Tire & Shingle Scrap Bituminous Paving Test Sections On The Munger Recreational Trail Gateway Segment." Office of Materials and Research, Minnesota Department of Transportation.

Appendix A: **Definitions**

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 the CMRA *Tear-Off Shingles Recycling Best Practices Guide* (DKA, October 2007). In general, this *White Paper* and the *Guide* uses the definitions and terminology itemized in the AASHTO specification.

Final Blended Binder for the purpose of this *Guide* shall follow the AASHTO provisional specification and shall mean the mixture of virgin asphalt binder and shingle asphalt binder.

Hot-Mix Asphalt (HMA) is an engineered road construction material used in a variety of paving applications made from liquid asphalt, aggregate, and recycled materials (e.g., RAP and/or RAS). State departments of transportation and FHWA specify standardized HMA designs and quality control procedures for road construction projects using state or federal highway funds.

Manufacturers' Asphalt Shingle Scrap (also referred to as “pre-consumer” or “new” asphalt shingle scrap) includes rejected asphalt shingles or shingle tabs that are discarded in the manufacturing process of new asphalt shingles. This may include excess whole shingles, sheet cuttings, or “tabs”. While not used as such in this *Guide*, this type of shingle scrap is also sometimes abbreviated as “MASS” or sometimes “MSS”.

[Note: This *Guide* recommends the term manufacturers' asphalt shingle scrap to indicate that it is excess recyclable material not usable directly by the shingle manufacturing plants, but not yet processed into a recycled asphalt shingle (RAS) product. This *Guide* does not recommend the term “manufactured” shingle scrap as it may imply scrap that has already been processed.]

New (or “Virgin”) Asphalt Binder for the purposes of this *Guide* shall follow the AASHTO provisional specification and shall mean new performance graded asphalt binder to be used in the new hot mix asphalt.

New Hot Mix Asphalt for the purpose of this *Guide* shall follow the AASHTO provisional specification and shall mean hot mix asphalt manufactured using aggregates, recycled asphalt pavement (if used), virgin asphalt binder, and reclaimed asphalt shingle.

RAS Asphalt Binder for the purpose of this *Guide* shall follow the AASHTO provisional specification and shall mean the asphalt binder that is present in the recycled asphalt shingle.

Reclaimed Asphalt Pavement (RAP) (sometimes referred to as “recycled asphalt pavement”) 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 the intermediate crushed, screened product. RAS is most often processed into a form ready for use in hot-mix asphalt plants. Other documents may use the term “processed shingles”.

Residential Tear-Off Shingle Scrap includes the 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.

[Note: Residential houses, as used in this *Guide*, are non-regulated facilities as defined by U.S. EPA’s NESHAP regulations.]

Roofing Scrap generally refers to mixed roofing materials from tear-off demolition and re-roofing operations. In addition to tear-off shingles, mixed roofing scrap may include non-shingle items such as:

- Recyclable metal: flashings; used plumbing stacks; used roof vents; gutters, and other roofing fixtures.
- Roofing nails.
- Plastic waste such as wrap from new shingle bundles, plastic cellophane strips from new shingles, plastic wrap from rolled roofing felt.
- Wood from repaired and new framing, roofing sheeting or other dimensional lumber.

Shingle Aggregate for the purpose of this *Guide* shall follow the AASHTO provisional specification and shall mean mineral granules, sand, or other mineral matter present in the RAS, excluding the shingle fiber content.

Shingle Fiber for the purpose of this *Guide* shall follow the AASHTO provisional specification and shall mean, glass felt, paper felt, foil, fabrics or films used as the structural basis of asphalt shingle and other asphalt roofing products.

Shingle Scrap is the more generic term and includes both manufacturers’ and tear-off shingle scrap before processing. In the context of this *Guide*, the term refers to recyclable asphalt shingle scrap. In other documents, it may be used more generically to include other types of roofing shingles including cedar shake shingles, transite shingles, and other types of shingles.

Tabs are discarded, small cut-out sections discarded by manufacturers derived from new production of the traditional three-tabbed style of asphalt shingles. These are also sometimes called “cut-outs”, “fingers”, or “slugs”.

Tear-Off Asphalt Shingle Scrap (also referred to as “post consumer” or “used” asphalt shingle scrap) includes the 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” (also sometimes referred to as “TOSS”) for the eligible source of recyclable tear-off shingle scrap.

Virgin Aggregate for the purpose of this *Guide* shall follow the AASHTO provisional specification and shall mean coarse and fine aggregate introduced into new hot mix asphalt that is exclusive of the shingle aggregate.

Virgin Asphalt Binder (See “New Asphalt Binder”)

Appendix B:
Shingles Composition Data From
CD&I Phase I (2007) Project Report

Table B-1
Composition Study Summary Results of Field Sorting Data
 (Excerpts for “Roofing” Materials)

Type	Direct Haul Construction	Direct Haul Demolition	Transfer	Roofing	Total Percentage
Roofing					
Roofing (incl. shingles & tear off)	20.7%	6.0%	15.4%	32.6%	15.2%
Flat roofing	<u>0.0%</u>	<u>0.0%</u>	<u>0.0%</u>	<u>63.9%</u>	<u>1.9%</u>
<i>Subtotal ROOFING</i>	20.7%	6.0%	15.4%	96.5%	17.1%