Recycling Tear - Off Asphalt Shingles:

Best Practices Guide

CMRA
Construction Materials Recycling Association

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Disclaimer

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CHAPTER 1 -

INTRODUCTION

ABOUT THIS *BEST PRACTICES GUIDE* AND THE *CMRA PROJECT*

This *Best Practices Guide* is part of the larger project produced by the Construction Materials Recycling Association (CMRA) to help develop the market for recycling of tear-off asphalt shingles. This CMRA project is funded in part by a grant from the U.S. Environmental Protection Agency's (EPA) Office of Solid Waste and Emergency Response (OSWER) Innovations Workgroup.[1]

The primary goal of this project is to develop, demonstrate and document best practices that can be utilized by shingle recycling operators. The *Project* had three principal objectives:

1. Demonstrate effective environmental and worker health protection procedures.
2. Develop operational guidelines that maximize cost-efficiency while attaining the highest feasible level of environmental, worker health / safety, and engineering standards.
3. Share the results through informational and outreach tools.

The project has key support from a wide variety of public and private partners and builds directly on many other research efforts in order to help accelerate the development of tear-off shingle recycling technology. A draft of this *Guide* was reviewed by a variety of field practitioners active in shingle recycling. (See Appendix A: Acknowledgements.)

This *Guide* is intended to accompany two other key products. The first is the ShingleRecycling.org webpage.[2] The second is a report titled *"Environmental Issues Associated with Asphalt Shingle Recycling"* written by Innovative Waste Consulting Services, LLC and produced by CMRA. [3]

This *Guide* presents the best available information, concepts and lessons learned from ongoing shingle recycling operations. Three major best practice (BP) strategies that address the above-mentioned goals are highlighted in the appropriate chapter. They are:

B.P. #1: Recyclers handling tear – off shingles should carefully plan and implement a supply quality assurance / quality control (QA/QC) system.

B.P. #2: Tear – off shingle recyclers should optimize their operations to produce a RAS product that meets or exceeds specifications of their end markets.

B.P. #3: Tear – off shingle recyclers should develop a comprehensive marketing plan based on multiple outlets.

Individual, supporting best practice guidelines are then enumerated and described in more detail within the text of each chapter. Chapter 6 contains an index of all best practices.

This *Guide* provides a starting point for shingle recyclers to plan and improve their operations. It helps identify key business planning, recycling operations, marketing and compliance recommendations. The basic philosophy in producing this *Guide* is to improve quality in all aspects of the recycling system.

Each shingle recycling project and local situation is different and environmental regulations vary from state to state. Shingle recyclers need to fully understand these requirements and adapt their business plan and ongoing operations to these particular circumstances.

Tear-off shingles can be successfully recycled into a variety of end market applications. It is clear that there is significant opportunity for tear-off shingle recycling technology to grow into a mature and sustainable industry, in part because of the large volume of readily available post-consumer roofing waste currently disposed in landfills as well as favorable market conditions for asphalt recovered from recycled asphalt shingles (RAS). Both the supply of tear-off asphalt shingles and end markets are well dispersed within populated regions.

This *Guide* uses specific, standard, recommended terminology (see Appendix B) throughout the document. The specific terms, “tear-off” or “manufacturers”, are used to discuss two distinct grades of asphalt shingle supplies. The more generic term “shingles”, without a grade qualifier, is used if both tear-off and manufacturer’s scrap are being referenced.

HISTORICAL CONTEXT OF TEAR-OFF SHINGLE RECYCLING

Composition of Residential Asphalt Shingles

It is very helpful to understand the composition of asphalt shingles in order to better manage shingle recycling systems. Also, knowledge of historical and projected future trends in shingle composition can enhance a shingle recycling operator’s ability to characterize their supply, anticipate changes, fully comply with regulations, and adjust processing / marketing operations and strategies accordingly. There are many types of shingles and their individual material composition can be a primary indicator of the best and highest value use as a recyclable commodity.

A primary reason for the high potential value of recycled shingles is that they contain ingredients that hot mix asphalt (HMA) producers purchase to enhance their paving mixtures including: asphalt cement (or AC “binder”) and mineral aggregate. Asphalt shingles also contain a fibrous mat made from organic felt (cellulose) or fiberglass that can also be valuable as fiber in some asphalt paving mixes.

The composition of a typical, new residential asphalt shingle, made today, is shown in Table 1.

Table 1 -
Typical Asphalt Shingle Composition

(Percent by Weight)

32%	to	42%	Coating filler (limestone or fly ash)
28%	to	42%	Granules (painted rocks & coal slag)
16%	to	25%	Asphalt cement
3%	to	6%	Back dust (limestone or silica sand)
2%	to	15%	Mat (figerglass, paper, cotton rags)
0.2%	to	2%	Adhesives (modified asphalt based)

Source: Owens Corning

<u>History of Asphalt Shingle Recycling</u>

Shingle recycling has evolved during the past 25 years. In the late 1970s and early 1980s, some of the original pioneers developed the first shingle recycling plants and began experimenting with initial HMA mix designs incorporating RAS with some of the first technical literature published in the late 1980's. [4, 5, 6] Over the past 15 years, several additional HMA producers and paving companies have developed substantial in-house expertise in shingle recycling.[7, 8, 910, 11, 12, 13, 14]

The historical evolution of tear-off shingles recycling technologies is based on the knowledge and successful development of related recycling and materials processing industries. There has been extensive research and development on the recycling of manufacturers' shingle scrap. Manufacturers' shingle scrap recycling relies on supplies of high quality, industrial scrap. In some cases, enough shingle scrap can be supplied from one shingle manufacturing plant to sustain a recycling operation. Manufacturers' RAS has traditionally been more accepted by government engineers and regulators in the development of construction materials specifications and environmental regulations. These manufacturers' RAS market development efforts have led similar marketing trends for tear-off RAS.

The primary high-value market today for RAS is hot mix asphalt (HMA) due to the quality and content of asphalt cement in shingles. RAS is just one of several types of recycled feedstock materials used by HMA plants today. [15, 16, 17] Use of recycled asphalt pavement (RAP) has grown into an ongoing, standard procedure for many HMA producers because of the overall cost savings and stringent asphalt paving industry QA/QC standards. [18] This long-standing history of RAP processing and marketing technology is directly relevant to today's best practices for shingle recycling.

RAP, recycled concrete and other recycled aggregates such as RAS, are also used extensively as supplements to virgin sand and rock aggregates for other construction applications (e.g., road base, fill in embankments, etc.). Each of these other commodities has gone through similar research, development and implementation histories, often using similar equipment and QA/QC procedures employed for tear-off shingle recycling.

Finally, recycled tear-off shingles are considered one commodity within the larger family of recyclable construction and demolition (C&D) materials. The overall technology developments in C&D recycling are directly relevant to tear-off shingles recycling. The development of sorting platforms, grinders / shredders, magnetic separators, and screens for mixed C&D processing plants all have relevance to processing of tear-off shingles. Also, there are relevant lessons from C&D recycling businesses for each shingle recycling component: sorting/sourcing, processing and marketing. Many tear-off shingle recycling operations are part of larger C&D recycling facilities. [19, 20]

Asphalt shingle recycling will lead to further reduction in C&D waste generation, which is the goal of many states as well as EPA. In addition, shingle recycling contributes to sustainability in construction practices as well as green building objectives.

REGULATORY COMPLIANCE

Shingle recycling operations must comply with all local, state and federal regulations. This *Guide*, along with additional information in the web page, www.shinglerecycling.org, should help as a starting point for determining which regulations apply to the local situation. Most county and state regulatory agencies have technical assistance programs that can help direct companies to specific rules and laws.

The generic types of regulations include, but may not be limited to:

- Local city, township or County zoning, construction and operations permits, licenses and other approvals (e.g., land use zoning and operational restrictions).
- Local, state and federal solid waste and/or recycling facility licenses and permits.
- State and federal worker health and safety regulations such as U.S. Occupational Health and Safety Administration (OSHA) rules.
- State and federal asbestos management regulations such as U.S. EPA's rules for National Emission Standards for Hazardous Air Pollutants (NESHAP), Subpart M: National Emission Standard for Asbestos (30 CFR 61 Subpart M). [21] Other state and county asbestos regulations may also apply.
- State and federal water quality protection, including ground water protection and storm water runoff management systems.
- State and federal air emissions regulations, including dust control.

Tear off shingle recyclers have demonstrated the ability meet or exceed compliance with applicable regulations. [22]

CHAPTER 2 -

SECURING A SUPPLY AND SORTING OPTIONS

OVERVIEW OF CURRENT PRACTICE

Securing a clean supply of tear-off asphalt shingles is the first step in a successful recycling system. Feasible and cost-effective best practices have been demonstrated by operators and a wide variety of supply development strategies have been employed depending on local market conditions.

The two basic types of strategies to develop a clean, secure supply are:

1. "Source Separated" - Attracting high quality, separated loads of tear-off shingles only. The roofing contractor or hauler must first separate out the non-shingle debris before loading and/or tipping at the shingle recycling plant.
2. "Mixed Roofing Material" – Attracting mixed loads of roofing waste without requiring source separation such that the shingle recycler conducts most if not all of the materials separation. Non-shingle debris (e.g., plastic, metal, wood) is sorted from the tear-off shingles at a recycling facility.

Under either strategy, tear-off shingle recyclers must work proactively with suppliers to ensure that no asbestos containing material (ACM) is delivered to the recycling plant. After the tear-off shingles are tipped at the recycling plant, a second stage of quality inspection and sorting take place. Most facilities use both manual separation (e.g., "dump and pick", sorting conveyors, etc.) and mechanical equipment (e.g., screens, air classifiers, etc.).

Asbestos testing may be required by some states and/or local government agencies. Shingle recyclers have demonstrated a wide variety of techniques to cost-effectively meet and exceed the minimum waste sampling and asbestos testing requirements as explained in further detail within this chapter of this *Guide*. Innovations have developed recently such as establishing "in-house" laboratories that use standard, certified detection methods and personnel. Such in-house labs minimize the turn-around time for lab results. Together with other in-house personnel training and supplier technical assistance, tear-off shingle recyclers are proactively managing their supplies through "upstream" quality control and quality assurance.

SUPPLY DEVELOPMENT AND SORTING CHALLENGES

Several challenges face shingle recyclers when trying to develop a clean, reliable supply of tear-off shingles. Some of the challenges include:

1. Inconsistent laws, rules, interpretations, implementation and enforcement. For example, each state and local community may apply regulations differently.
2. Low tipping fees at landfills.

3. Additional costs of sampling and, if required, stockpiling loads in quarantine awaiting asbestos lab results

DESIGN CONSIDERATIONS

Developing a clean and reliable supply of tear-off asphalt shingles is a critical component within the overall recycling system. Technical, economic and regulatory requirements need to be addressed as discussed below.

It is very important from the start to fully understand and comply with all environmental and other regulations. Each state has unique environmental protection requirements affecting recycling, which impact all components of the recycling system including sourcing, processing, and marketing. Many states' environmental regulations relating directly to shingle recycling are posted on the web page www.shinglerecycling.org.

BP#1: Recyclers handling tear – off shingles should carefully plan and implement a supply quality assurance / quality control (QA/QC) system.

As an integral part of this supply QA/QC system, **shingle recyclers should publish a written specification as to the type and quality of material that is acceptable and the criteria for rejecting loads (BP#1.1)**. [See Appendix C for an example supply specification and related certification forms.]

There are two separate but related objectives for this supply QA/QC system:

1. To assure the cleanest, most reliable source of tear-off asphalt shingles possible.
2. To comply with federal NESHAP asbestos regulations.

Attaining the first objective will greatly impact the overall economics and sustainability of a shingle recycling operation. **Shingle recyclers should have a secure supply of clean tear-off material (BP#1.2).** Overall system performance and final product engineering depend on the ability to reasonably predict the composition, quality and quantity of tear-off RAS.

"Clean" tear-off should be defined as free of any hazardous material or items that may be harmful to recycling equipment or employees. Asbestos containing material (ACM), as defined by NESHAP, should be prohibited (e.g., cementitious shingles, transite siding, etc.). Shingle recyclers will need to define their own specifications for what other foreign materials are prohibited from loads (e.g., plastic, wood, metal).

Attaining the second objective is a matter of standard operations for tear-off shingle recyclers. Depending on the specifics of individual state asbestos testing requirements, successful recyclers adapt their individual asbestos management plans to meet or exceed the minimum asbestos testing requirements. The operating goal for any tear-off shingle recycler should be to **develop a supply of post consumer scrap material that is free of known asbestos containing material (ACM) (BP#1.3).** This means working aggressively down the supply chain through the haulers, roofers, and building owners to help educate each responsible party about asbestos testing and management requirements. For more information and details about avoiding ACM, see the section "Compliance with Asbestos Regulations (page 12).

TEAR – OFF VS. MANUFACTURERS' SHINGLE SCRAP

This *Guide* is intended primarily for recycling of tear-off RAS. However, if a tear-off shingle recycler has the opportunity to supplement his supply with manufacturers' scrap, this may provide additional business and market opportunities. **Manufacturers' shingle scrap can also be targeted as another source of recyclable material supply (BP#1.4).** The number of shingle manufacturers with available supply is decreasing each year because more plants are committing their industrial scrap to recycling operations. Plus, not every region has a shingle manufacturing plant. However, nearly all regions of the United States have both available supplies of tear-off shingles and potential markets for RAS.

Quality standards, certification requirements, and sorting procedures need to be established that are specific to the recycling of tear-off shingles (BP#1.5). These tear-off quality control practices will likely be more stringent than similar procedures for manufacturers' shingle scrap.

STRATEGIES TO DEVELOP A CLEAN, SECURE SUPPLY

There are two basic models that tear-off shingle recyclers use to plan for securing a supply of clean, reliable material:

1. Require loads to be "source separated" at the roofing job site.
2. Accept mixed roofing waste loads.

It is feasible for tear-off shingle recyclers to develop a plan that is a mixture of both sourcing strategies. If mixed loads are accepted, **the shingle recycler should have a means to safely and efficiently sort the asphalt shingles from the non-shingle debris (BP#1.6)**.

Source Separated Systems

A number of shingle recyclers use a wide variety of source separated sourcing systems that rely upon the generator (e.g., roofing contractor) and/or hauler to sort the shingles from the other roofing debris at the job site. [23, 24, 25] For example, roofing companies can use separate trailers or roll-off boxes for shingles and smaller containers for non-shingle debris (e.g., plastic, wood, metal). The specific parties involved, job site operations and sorting specifications depend on the individual site and the shingle recycler's supply specifications. In general **source-separated tear-off shingles should be kept separate from other roofing debris (e.g., plastic, metal, wood) at the site before loading and then loaded separately onto the truck, trailer or roll-off box (BP#1.7).**

Most recyclers have specified that the loads must be clean shingles only without any debris. [26] If materials are source separated, the shingles should be free of wood, plastics, large scrap metal, dirt, rocks, adhesives, solvents, petroleum contamination, other trash and other substances deleterious to the shingle recycling processes. See Appendix C for an example list of acceptable and unacceptable items.

Figure 1 displays a photo of a roofer separating shingles for recycling from other roofing debris. The roofing company can avoid double handling or sorting of the roofing scrap if materials are separated directly from the roof top into separate containers (e.g., trailers for shingles) or piles (e.g., tarps for other debris).

Picture 1 -
Source Separation of Tear-Off Shingles at a Job Site
Roofer is dropping tear-off shingles only directly into trailer.
Plastic, wood and metal debris is piled separately on the tarp spread out on the ground nearby.

Some tear-off recyclers have instructed their suppliers to load the shingles first at the bottom of the trailer or roll-off box. Then, the non-shingle debris (e.g., plastic, wood, metal) can be placed on top of the large, shingles layer so that it can be easily separated when the load is tipped at the recycling plant. If tipped without any mixing, the debris should remain on top of the pile and is relatively easy to pick off of the shingle pile. Picture 2 displays such a separated load being tipped. When hauling, loads should be covered with tarps.

<u>Picture 2</u> -
Trailer Load of Tear-Off Shingles with Some Minor Debris
Shingles are loaded at the bottom of the trailer.
Scrap wood and other debris are loaded on top of the shingles.

<u>Picture 3</u> -
Pile of Source Separated Tear-Off Shingles
Clean, tear-off shingles only with only minor amounts of non-shingle debris.

Roofing companies and haulers should plan ahead by making arrangements for delivery of clean tear-off shingles to a recycling facility. Materials quality specifications, prices, hours, scale procedures and other logistics should be discussed and agreed upon prior to delivery. Shingle recyclers may wish to provide evidence to their supplier customers that their facility has all the required government licenses and permits as required by the appropriate local and state agencies.

<u>Picture 4</u> -
Sign Listing Acceptable and Unacceptable Materials with Prices

Sign includes a statement: "Unacceptable materials include: household trash, paint, solvents, gasoline, anti-freeze, dead animals, asbestos, explosives, or any other material deemed hazardous or inappropriate by site manager."

<u>Mixed Waste Sorting Systems</u>

Roofing companies may wish to contract with haulers who utilize materials-recovery facilities or transfer stations where recyclable materials are sorted from mixed loads. Roofing contractors using a hauler or recycling facility to sort out recyclables should verify that materials are indeed recycled or recovered for some form of beneficial use. Shingle recyclers should be prepared to answer questions about the type of end use applications. This will help roofers and haulers understand the reasons for the strict supply quality requirements and inspections.

Sorting systems at shingle recycling plants can take on a range of designs. Many tear-off shingle recyclers use a simple "dump and pick" operation to remove other debris and waste C&D waste materials (see Picture 5). Some of these recyclers use a concrete tipping floor within enclosed or semi-enclosed (open on one side) transfer station buildings.

<u>Picture 5</u> -
Non-Recyclable Debris Removed from Mixed Roofing Loads at a Transfer Station
Below grade transfer station pit allows non-recyclable debris to be pushed into roll-off box.
Lower value wood and plastic items are shown awaiting disposal at landfill.
Recyclable aluminum and steel materials are kept separate (not shown).

Other recyclers using mixed waste supply systems invest in higher technology sorting equipment using a conveyor-fed sorting line. Often these sorting systems include grapple cranes, loading hoppers, and screens (see Picture 6) followed by a series of manual picking stations (see Picture 7), usually on elevated platforms so that the sorters can pull off ("positively" sort) the non-shingle debris.[27, 28, 29]

<u>Picture 6</u> -
Grapple Crane Loading a Shingle Sort Line
Grapple crane helps sort shingles from non-shingle debris.
Picture shows grapple crane loading trommel screen used to help sort out large, bulky debris (e.g., dimensional wood) as “overs”. Shingles pass through as “unders” to be conveyed to sort line.

<u>Picture 7</u> -
Elevated Shingle Sorting Platform
Multiple sorting stations available. Also, belt speed can be varied.

Picture 8 -
Manual Sorting Stations on Elevated Platform
Quality of sorted shingle product is affected by belt speed, burden depth, number of sorters, and sorters' performance.

Picture 9 -
Clean, Residential Tear-Off Shingles at End of Sort Line
Clean, sorted shingles ready for grinding.

The supply plan for a particular recycler will depend on the local conditions, environmental regulations, and marketplace. Landfills are the key competition in today's marketplace. Therefore, depending in part on location, the operator may set recycling tipping fees to be competitive with local landfill facilities. A few shingle recycling companies are structured as a separate cost center or business unit adjacent to active C&D landfills.[30] This situation can be an advantage in that roofing companies and haulers delivering loads to the landfill are already an established customer base delivering known volumes for disposal. Eligible loads of clean asphalt shingles can then be diverted right at the gate and/or scale-house to the recycling tipping area away from the landfill face. New tear-off shingle recycling operations without such an established customer base will need to develop a clear marketing strategy based on location, tipping fee and quality service.

Shingle recyclers accepting mixed roofing materials should make it clear that no hazardous waste will be permitted. Suppliers should be notified in writing that if any such waste is found, it will be handled, manifested and disposed according to all regulations. All related disposal costs can be charged back to the supplier. (BP#1.8) Even if the final responsibility for such costs may be shared, such written notification will help provide legal evidence of this warning.

Other Supply Quality Control Strategies

Shingle recyclers may wish to use video cameras, if feasible, to supplement manual, in-person visual inspection of loads as trucks cross the facility scale. Ideally, all loads should be inspected before tipping to avoid re-handling of rejected loads.

Shingle recyclers should carefully track and record all loads by customer name, truck number, source(s) of loads, materials description, date, time and weight or volume estimate.

Shingle recyclers should maintain close communication with their suppliers, especially if unacceptable material is received. If prohibited materials are delivered, truck drivers and their dispatchers should be notified as soon as possible. If feasible, prohibited materials already tipped should be loaded back directly into the same truck (BP#1.9).

COMPLIANCE WITH ENVIRONMENTAL REGULATIONS

Owners and operators of facilities that collect, process, and recycle solid wastes are responsible for determining which environmental regulations and permitting requirements must be met. Asphalt shingle processors are no exception. There is no federal law or rule that governs non-asbestos-containing asphalt shingle recycling specifically. **It is up to the recyclers to determine the specific state and local regulations that may apply (BP#1.10).** However, Federal law does prohibit recycling of ACM material (i.e., materials with over 1% asbestos).

The types of requirements vary from state to state, and, in some communities, county to county. A permit to operate a processing facility may be required in some areas. Also, environmental testing may be required in other areas. In addition, depending on the particulate emissions from the recycling process, an air permit and/or stormwater runoff permit may be required at the facility.

The single biggest issue that has been raised with respect to asphalt shingle recycling is asbestos. A naturally occurring mineral that has been used in many different products in the past, asbestos has been raised as a concern with asphalt shingles. The vast majority of tests conducted on asphalt shingles have found no asbestos.[31] But some types of other asphalt roofing products, such as roll roofing, adhesives, paints or waterproofing compounds may contain asbestos. Several states have worked with recyclers to conduct initial testing on their waste stream to demonstrate the safety of their operation.

Results of past asbestos sampling studies were summarized as part of the ongoing “Asphalt Roofing Shingle Recycling Assessment Project” (ARSRAP). Dr. Timothy Townsend, et. al. (Innovative Waste Consulting Services, LLC) recently updated the summary and analysis of this ARSRAP data in a separate document entitled “*Environmental Issues Associated with Asphalt Shingle Recycling”*.[32]

The shinglerecycling.org web page is a key portal to a significant amount of EPA and other regulatory information about asbestos regulation, management and other recommended best practices. **It is up to the recycler to determine the specific state and local regulations that may apply (BP#1.10).** The ShingleRecycling.org web page contains notices of policy, law and rule changes. including:

1. Examples of asbestos containing products
2. Asbestos-related regulations and issues
3. The National Institute of Standards and Technology maintains a Directory of Accredited Laboratories that conduct asbestos fiber analysis using Polarized Light Microscopy (PLM).

Shingle recycling systems should be planned, designed and implemented to fully comply with or exceed all waste disposal regulations (BP#1.11). Asbestos management plans must be developed in accordance with federal NESHAP asbestos regulations as promulgated by the U.S. EPA (BP#1.12).[33] NESHAP is often administered and enforced by the state environmental agency if such authority is delegated. Contacts for most state NESHAP contacts can be found on the ShingleRecycling.org website within the “State Experience” pages.

Tear-off shingles can remain unregulated under NESHAP, even when the material is ground up for recycling. Tear-off shingle recyclers can plan to reduce the chance of ACM reaching their recycling facility using the following techniques. In some states, a combination of two or more of these techniques will be needed to meet or exceed the environmental regulations.

Develop an Asbestos Testing Proposal

Shingle recycling operators may need to develop some form of asbestos testing plan. This may include testing of the incoming loads of whole shingle scrap and/or may also include testing of outgoing, finished RAS product as well.

Asbestos is not typically found in the tear-off asphalt shingles (i.e., traditional “three tab” shingles). U.S. manufacturers discontinued the use of asbestos asphalt shingles more than thirty years ago. Therefore, domestic manufacturers’ shingle scrap will be asbestos free. Dr. Townsend’s report on recent data indicate that asbestos may be present at low frequency and in small amounts in other related roofing materials such as roofing felt and/or mastic. [34] For this reason, new tear-off shingle recycling operations may be required to develop a testing protocol based on the state and local agency requirements, including a QA/QC supply plan, and contingency plans if any ACM is detected. Appendix D provides one example of such a testing protocol.

Asbestos testing involves sampling each “layer” of roofing material using standard methods prescribed in NESHAP rules. The samples must be labeled (e.g., sample number, date, location, layer, etc.), recorded in a sample log book, and then sent to an accredited asbestos testing laboratory[35] to analyze the samples for asbestos content. Tear-off shingle recyclers should contact the appropriate state environmental and/or health agency[36] to determine specific state requirements for sample collection, analytical procedures, data reporting and records retention.

The most typical analytical procedure used to detect asbestos fibers is the Polarized Light Microscopy (PLM) method. PLM requires a trained and certified asbestos lab technician to prepare a sample for viewing under a polarized light microscope. PLM can detect asbestos down to the level of 1%.

Tear-off shingle recyclers have begun to invest in their own on-site asbestos labs with the necessary microscopes and sample preparation supplies.[37, 38] These recyclers also invest in the training and certification of their own in-house asbestos detection lab technician. These in-house technicians use the same type of standard procedures and equipment as the independent labs, receive annual certification, and are backed up by an approved quality control plan to assure and verify accuracy of their results. Such in-house asbestos detection can be a tremendous advantage if tear-off shingle scrap would otherwise have to be stockpiled in quarantine while waiting for results. The quarantine time can be reduced to a matter of hours.

Picture 10 -
Microscope within In-House Asbestos Lab

Restrict Supply to Tear-Offs from Private, Residential Homes Only

One option that may be proposed to the state environmental regulatory agency during the start-up phase of a new tear-off recycling business is to **restrict the supply to private, residential homes only. These homes are considered as “non-regulated facilities” as defined by U.S. EPA rules in the NESHAP (BP#1.13).** Such private, residential re-roofing projects are defined as single-family structures up to buildings with four units per structure. There may be exceptions to this determination if the building structures are commercial, institutional, or owned by a government agency.

This strategy may be especially useful during the start-up of a new tear-off recycling business. The shingle recycler and the state and/or local asbestos regulatory agency will gain experience with the new recycling venture using a more restrictive, narrow target supply market. This strategy has been successful in several Minnesota tear-off shingle pilot demonstrations.[39, 40, 41]

To implement this strategy, shingle recyclers should **require suppliers such as roofing companies and other haulers to provide written certification that the source of the tear-off asphalt shingle scrap and other incidental roofing waste is private, residential homes only no larger than four-units per structure (BP#1.14).** (See Appendix C for examples of supplier certification forms.) Shingle recyclers may need to conduct spot inspections of their suppliers re-roofing job addresses.

At a later stage, recyclers may wish to modify this supply strategy and accept shingles from commercial buildings, institutional buildings or other "regulated facilities" as defined by NESHAP as a secondary source if additional supply volumes are needed. Such **owners of regulated buildings may be required by state regulatory agencies to test their roofing waste for ACM as per NESHAP rules (BP#1.15).** Therefore, this broader supply strategy could be implemented in a later phase of a shingle recycling business after initial start-up.

Regardless of the method used for avoiding known ACM, **the roofing company and hauler should certify in writing that the used roofing materials are primarily asphalt shingles (such as three-tab shingles) and are free of prohibited materials (BP#1.16).**

In addition to ACM, **the list of other prohibited materials for a tear-off asphalt shingle recycler should also include:**

1. Cementitious shingles, shake shingles, and transite siding that may be suspect ACM.
2. Any type of hazardous waste (e.g., mercury containing devices such as thermostats, paint, solvents or other volatile liquids, etc.).
3. Significant amounts of other debris that is not asphalt shingles (e.g., plastic, paper, glass, or metal).
4. Significant amounts of trash. (BP#1.17)

Each load should be inspected by personnel trained to visually detect possible ACM (BP#1.18). Such ACM identification training would ideally be part of a regular state-organized program. Shingle recycling operators should attend state-sponsored training courses to become licensed as asbestos inspectors. This training will help increase the awareness of potential asbestos containing materials and allow company personnel to help provide accurate, timely and state-approved information and related technical assistance to material suppliers and other customers. Shingle recycling operators should contact their state NESHAP contact for technical assistance resources including listing of organizations providing asbestos inspector training.

<u>Picture 11</u> -
Promotion of Asbestos Inspector Certification Status

State environmental protection agencies may require asbestos testing even if all of the above best practices are implemented. If so, **shingle recycling operators should work with their respective state environmental agency to develop a mutually acceptable asbestos testing plan (BP#1.19). Such a plan should have an initial "baseline" testing period followed by a test results conference to review the baseline data and develop recommendations for the next phase (BP#1.20)**. **If no asbestos was detected during the baseline period, the shingle recycler may wish to propose a program of random or unannounced testing frequency at the agency's discretion (BP#1.21)**. This approach of an initial baseline testing period followed by the agreement to allow random samples at any time has been used successfully by operators and regulatory agencies.

CHAPTER 3 -

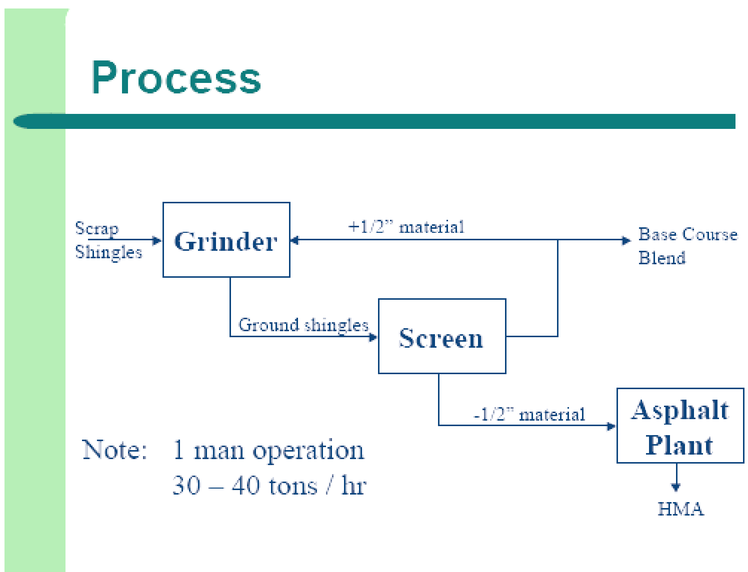
PROCESSING

OVERVIEW OF CURRENT PRACTICE

Tear-off shingle processing today consists of a wide variety of system, equipment and operational designs. Each processing facility has the following common elements:

1. Feedstock quality assurance
2. Receiving and stockpiling of raw feedstock
3. Size reduction and screening
4. Final recycled asphalt shingle (RAS) product stockpiling
5. Final RAS product QA/QC
6. Transport to end market

Figure 1 -
Simplified Shingle Processing Diagram



Source: Bob Ayers, Allied Blacktop (2003) [42]

A number of facilities relying on source separation of tear-off shingles involve only a minimum amount of feedstock quality assurance through further inspection of the pile. Most often the front end loader or skid steer operator is in charge of inspection at the same time material is loaded into the first feed hopper (see Picture 12).

Picture 12 -
Front End Loader and Operator
Moving Material from a Pile of Source Separated Tear-Off Shingles

Other facilities relying on mixed waste sorting systems must employ more intensive front-end manual inspection and separation at the tear-off shingle recycling plant. Grapple cranes are often used instead of front end loaders to assist with pile management, rejecting large bulky items (e.g., scrap metal, plastic, wood), while also loading the cleaner tear-off shingle scrap into the feed hopper (see Pictures 6 and 13).

Picture 13 -
Grapple Crane Servicing Indoor Loads of Mixed Roofing Materials
(Together with Floor Picker Coupled With Elevated Sort Line)

Trommel drum screens are often used to size material either before (see Picture 6) or after grinding (see Picture 14) depending on the system design and supply plan. Manual sorting to remove non-shingle debris is most often employed at the tipping floor in close coordination with the grapple crane or loader (see Picture 13).

Picture 14 -
Shingle Grinder Followed by Trommel Screen

As noted in the last chapter, a few facilities have elevated sort platforms to complete the separation into a clean stream of tear-off shingles only at the end of the belt. Debris is removed from the sorting conveyor and dropped into designated bunkers by commodity. Most facilities will recover metal and cardboard (perhaps in baled form) as secondary recyclable products. Trash from such sorting will consist of plastic, non recyclable metal and paper. Most of this material is low density. Recovery rates of tear-off shingles from mixed waste sorting systems range from 15 to over 90 percent, depending on the feedstock and the efficiency of the separation. The low end of this range is more typical of facilities handling mixed C&D materials from residential and commercial sources. The high end of this range is more typical for operations targeting tear-off shingles from loads comprised exclusively of residential re-roofing waste.

A number of patented grinders are used to process shingles. Each grinder manufacturer uses a unique combination of material handling and size reduction designs. RAS sizing is a key specification and will determine the product’s suitability for various applications. For example, the larger particle size (3/4 –inch plus) may be more suitable for aggregate supplement. The smaller grades (1/2 –inch minus) are generally suitable for HMA. In general, the grinder will include a loading hopper, feeding drum to present the shingles into the grinding chamber, grinding chamber including cutting teeth, sizing screen and exit conveyor. Most often, a pulley head magnet at the end of the exit conveyor is standard equipment for removing nails and other ferrous metal. Most operators want this pulley head magnet and it is not an expensive item. Final RAS product is stacked using a stacking conveyor or front end loader.

Most shingle grinders are modified wood hog shredders. The grinder chamber consists of cutting teeth (see Picture 15) and a series of sizing screens (see Picture 16).

Picture 15 -
Cutting Teeth Inside Grinding Chamber
One example of cutting teeth showing wear due to abrasive nature of the hard shingle aggregate.

Picture 16 -
Grinding Chamber Sizing Screens
One example of new grinding chamber screens (not yet used) showing various sizes.

PROCESSING CHALLENGES

Shingles, by design, are a very durable, composite material. Asphalt shingles today are most often made using fiberglass as the backing material. Historically, shingles were made predominantly from cellulose (often recycled paper). Several shingle recycling studies have reported on the generic composition of asphalt shingles. [43, 44, 45] The characterization of tear-off shingle scrap has been changing over time reflecting the changing composition of new shingles. For example, older shingles used prior to the 1970's were predominantly made using a cellulose fiber mat. Today, the majority of new shingles are made using a fiberglass mat. This changing composition of new shingles needs further research to document the relative share of cellulose vs. fiberglass asphalt shingles over time (e.g., the past 20 to 30 years). Also, there are subtle but potentially significant differences between the processing and final product of cellulose vs. fiberglass shingles. For example, the asphalt cement (AC) content is about 15 to 25 percent in most fiberglass shingles while in older, cellulose shingles, the AC content is 30 to 40 percent. [46, 47, 48, 49]

Another variable in addition to the type of fiber mat used that may affect final RAS product quality is the degree of aging of the tear-off shingles. It is not well known how the oxidation process of the AC content of tear-off shingles impacts the amount and quality of AC content of the final RAS product. It is known that the shingles themselves are more brittle and therefore easier to grind. The percent loss of AC due to volatilization and oxidation on the roof is currently being investigated but has not yet been reported.

The surface coloring granules and filler inside the shingle matrix are very hard, tightly specified mineral aggregate. This quality is designed to protect and extend the life of the shingle. But the same quality makes it a very abrasive material that accelerates normal wear on recycling processing equipment, especially the grinding surfaces inside of the grinding chamber. This abrasion can create excessive heat, which is one reason why shingle recyclers add water to the material as it is fed into the grinding chamber.

The AC content of shingles is most often the primary driver of the value of the end RAS product, but it also causes processing challenges. The AC also can contribute to the heat generated during grinding. But after grinding, the RAS product has a strong tendency to reagglomerate or "chunk up" after stockpiling. A number of strategies are suggested in the best practices below to mitigate this problem.

Stockpiling of the finished product is difficult, as the material tends to re-agglomerate in storage. It may be feasible to blend the material with RAP or "bituminous aggregate" (BA) sand meeting HMA specifications. This pre-blending may help alleviate the re-agglomeration problem during stockpiling.

Fugitive dust and blowing debris such as litter, especially during grinding, can be a challenge for shingle recyclers; strategies are suggested below to mitigate this problem.

DESIGN CONSIDERATIONS

BP#2: Tear-off shingle recyclers should optimize their operations to produce a RAS product that meets or exceeds specifications of their end markets.

The tear-off processing design plan should link all components of the recycling system together (i.e., supply development, sorting, processing, RAS storage, and marketing) to assure a high-quality, final RAS product is consistently produced.

A primary design criteria when planning a shingle processing system is to **maximize the processing capacity (i.e., tons per hour) while assuring the final RAS product will meet or exceed market specifications (BP#2.1).** Typical processing design capacities range from 40 to 100 tons per hour. Each shingle recycling facility will have unique features but **should be designed both on final RAS product quality specifications and on the supply characteristics (BP#2.2).** Processing system plans will be based either on processing source-separated asphalt shingles or mixed roofing or other building construction and demolition (C&D) loads.

An overall processing system plan will be anchored by the shingles grinding component but should include some type of front-end materials sorting and/or inspection. **For mixed load systems, if an elevated, manual sort line is utilized to further remove non-shingle debris, the material must be "presented" on the sorting conveyor at the proper depth and speed (BP#2.3).** This often is accomplished by a combination of a loading hopper and adjustable speed feed conveyor. Also, the feed conveyor's incline angle and belt cleats will help meter the desired burden depth onto the sorting conveyor. Trommel screens immediately after the feed hopper can also be included as part of the front-end sorting and materials preparation component of the processing system.

For mixed load systems, a tracked, back-hoe type **grapple-equipped loading crane is superior to a larger capacity bucket wheel loader (BP#2.4).** Grapple cranes have greater ability to mechanically sort both large bulky debris (e.g., plastic, wood, metal) compared to wheel loaders. Grapple cranes, if properly sized and located, should have adequate loading, capacity. The grapple crane operator should become skilled at removing any large, unacceptable material. The crane operator should also be the primary controller of the feed rate into the loading hopper.

To promote end market development during the early stages of a new business, **the shingles recycling processor should provide for agency inspections of the sourcing, processing and final RAS product stockpiles (BP#2.5).** Government agencies that should be invited to conduct these inspections include the local and/or state DOT's that are using the RAS in their paving project(s) and the environmental regulator(s). To verify quality, sampling of the RAS product may be required before it is incorporated into HMA or blended into other road construction materials (e.g., aggregate for road base). The opportunity for such recycling plant inspections and RAS product sampling may become part of the regular QA/QC plan for each new agency customer.

The shingle recycling operator should also provide the local and state agency staff with a description of the tear-off shingles processing and worker health / safety plans as part of the facility planning and permitting process. Updated versions of these plans, based on initial operating experience and employee feedback, may also be submitted after facility construction and initial shakedown operations.

WORKER HEALTH AND SAFETY

Tear – off shingle recyclers must strive to maximize the protection of the health and safety of their workers (BP#2.6) as suggested in the guidelines below**.** This goal should be achieved at all stages including system planning, design, construction, ongoing operations, and marketing. **Management should develop a comprehensive, written employee hazard prevention and training plan (BP#2.7).** As a part of this plan, **management should provide accurate**

information about potential risks and preventative measures (BP#2.8). It is important to note that these workplace risks will be negligible if best practices are implemented and the overall recycling system QA / QC plan and implementation is thorough.

The employee hazard prevention plan should include best available information about asbestos management and exposure prevention (BP#2.9) similar to the types of information provided in this *Guide* and in the shinglerecycling.org web site. Shingle plant operators that are fully informed and trained will be the company's most important strategy to safely produce a high quality product free of any asbestos. Employees will be the first line of quality assurance from every step such as feedstock quality control (e.g., rejecting unacceptable loads), through dust management during grinding (e.g., maintaining optimum grinding conditions), to RAS product sampling.

Shingle recyclers should develop a comprehensive dust control and management plan (BP#2.10). This will include a number of additional items of equipment and operational procedures as detailed below.

Shingle recyclers should continuously water the material just before it is fed into the grinding chamber(s) (BP#2.11). The material should be sprinkled wet (e.g., the amount from a standard garden hose), and not soaked, before entering a grinding chamber. This is currently the standard practice for all known tear-off shingle operations. The two key operational objectives for watering during the grinding phase are:

1. Fugitive dust control
2. Cooling of material in grinding chamber.

Operators have been observed watering the active feedstock pile of whole shingles to control fugitive dust during loading operations (see Picture 17). Thus, water is used both during feedstock piling and system loading and during the grinding process. Water has been observed being added at other system handling components (e.g., conveyors) to control dust as determined by environmental conditions and the overall processing system design.

Picture 17 -
Water Sprinkler Covering Tear-Off Shingle Feedstock Pile

Shingle recyclers that are targeting HMA as a primary market outlet must be careful to optimize the watering during processing because the moisture in the RAS product can be detrimental to proper heating and mixing in the asphalt plant. Final RAS product as used in HMA plants should have less than 10 percent moisture, ideally less than 5 to 7 percent. Product moisture levels can be measured using probes or via standard laboratory procedures. The rate of water "sprinkling" can be adjusted as needed. Also, the final RAS product can be allowed to drain for a minimum of one to two weeks during stockpiling (if covered to protect from precipitation) before use in the HMA plant.

Shingle recycling operators should consider purchasing optional dust control devices (e.g., enclosed grinding chambers with pneumatic conveyance, air separation, bag house filters, and dust containment) as part of any new grinding equipment system (BP#2.12). Picture 18 displays such a pneumatic dust control system installed on a shingle grinder.

Picture 18 -
Pneumatic Dust Control System
Added on to a Standard Shingle Grinder

The two primary environmental and design objectives for such optional grinder "add-ons" should be:

1. Employee health / safety (e.g., reduce exposure to fugitive dust).
2. Elimination of blowing litter.

Shredding and grinding of shingles can be considered similar to other aggregate processing operations (e.g., RAP processing and virgin aggregate production). Dust control is important for any type of aggregate production operation. Shingles processing has additional considerations for fiberglass emissions and blowing debris that can cause nuisance litter.

In addition to watering, other options to control dust include such techniques as:

1. Installing shrouds around the grinder feed hopper and exit conveyor.
2. Enclosed cabs for front end loaders.

3. Personal particulate respirators for grinder operators and during equipment maintenance if deemed necessary (e.g., for clean-out procedures or other especially dusty conditions).

Shingle recyclers should use standard, industrial workplace protective clothing and safety equipment (e.g., hard harts, eye protection such as goggles or safety glasses, gloves, steel shank / steel toe work boots, long pants, long sleeved shirts, fabric dust masks, safety vests, etc.) (BP#2.13).

Some states may require that all shingle grinding operations be conducted in an enclosed building (BP#2.14). This allows for more control of environmental conditions (e.g., temperature, water run-off, air flow, blowing debris, dust, etc.). It is recognized that such a requirement to be inside of processing building may be cost prohibitive and the feasibility will be determined by a larger business plan and facility design.

OSHA

Occupational exposure to asbestos is regulated by the U.S. Occupational Safety and Health Administration (OSHA) under standards 1910.1001 for general industry[50] and 1926.1101 for construction work.[51] Such federal safety and health regulations are often administered and enforced by state "OSHA" agencies. These rules provide for specific permissible exposure limits (PEL) for employees.

Shingle recyclers may be regulated by OSHA rules that require that no employee is exposed to an airborne concentration of asbestos in excess of specified, maximum personal exposure limits. If regulated facilities are suspected to have asbestos-containing material, OSHA rules regulate both roofing contractors at the re-roofing job site under the construction regulations (1926) and at the shingle recycling site under general industry regulations (1910). Federal OSHA rules were amended in 1995 to allow re-roofing contractors to assume no asbestos exposure is likely if: the shingles remained intact; employees are properly trained; and if the re-roofing crew has a competent person on site to determine that the material being removed is intact. Proper training includes having at least one person on the roofing crew that is trained through a state-sponsored asbestos inspection course.

Shingle recycling operators may wish to invite OSHA staff to visit to their operations to observe and comment on the facility's employee health and safety procedures, equipment and policies are being implemented and followed (BP#2.15). OSHA staff welcome these type of "advisory / technical assistance" opportunities to help comment on and offer preventative advice outside of the strict regulatory / enforcement framework.

U.S. OSHA, together with the state agencies with OSHA authorities, regulate the occupational exposure to airborne dust. There are specific limits on the amounts of total dust and specific types of fibers that employees may be exposed to over an 8 – hour time period. Shingle recycling operators should be familiar with the OSHA rules for such permissible exposure limits (PEL's) for airborne dust and fibers. Operators should contact their local and state health agencies for further information and technical assistance. The shinglerecycling.org web page has OSHA – types of contacts listed for some of the states.

CHAPTER 4 -

END USES

OVERVIEW OF CURRENT PRACTICE

Shingle recycling has enjoyed a diverse history of research and market development for nearly 30 years. The primary high-value market has typically been use as a feedstock supplement in hot mix asphalt (HMA) for paving roads and parking lots. RAS brings the value of its asphalt cement (AC) content and the hard mineral aggregates to HMA pavement that uses both materials.

HMA formulations are based on two factors: climate and traffic conditions. Because climate and pavement specifications vary from state to state, state departments of transportation (DOT) have opted to independently test the effect that adding RAS has on pavement performance. Test pavements with batches containing a maximum of 5% shingles by weight of mixture have performed as well as traditional pavement (both manufacturers' scrap and tear-off were tested).[52, 53, 54] However, with current technology, if shingles are added at a higher percentage without other mix adjustments, HMA performance may be impacted due to the harder AC content found in shingles. Employing a softer grade of virgin asphalt cement in the HMA mix design may allow greater quantities of asphalt shingles to be used. This is the subject of a number of pending research and development projects. [55, 56, 57, 58]

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 three 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.

Two states are used as case studies for this *Guide*: Minnesota and Missouri. Their state DOT shingle specifications are included as Appendix E (Mn/DOT specification limited to manufacturers' shingle scrap) and F (MoDOT specification allowing tear-off shingle scrap).

Table 2 -
List of States with Known DOT Materials Specifications for Use of RAS in HMA and/or Beneficial Use Determination (BUD) Approvals for RAS

State	State DOT Specs	RAS Type	State BUD License	RAS Type
Only Manufacturer Scrap Allowed				
DE			BUD for M scrap	M
IN	5% M scrap only	M		
NC	5% M scrap only	M		
NJ	5% M scrap only	M		
PA	Provisional Spec P—c04031A	M		
TX	M scrap only	M		
VA	Special provision	M		
Tear-off Scrap Allowed				
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		

Key to type of shingle scrap allowed:
M: Manufacturers' shingle scrap is allowed / recycled
T: Tear-off shingle scrap is allowed / recycled

The North East Waste Management Officials' Association (NEWMOA) is an interstate association that has a membership composed of the hazardous waste, solid waste, waste site cleanup and pollution prevention programs in the northeast states. Each NEWMOA state has developed a program to evaluate beneficial use determination (BUD) proposals. NEWMOA established a BUD Workgroup that produced a searchable database of all the BUDs that have been issued by the NEWMOA states and a table comparing the BUD application requirements of the NEWMOA states. [59]

Use of RAS in HMA is very similar to the technology for using recycled asphalt pavement (RAP) in HMA. In general, using RAP in HMA and as an aggregate supplement for road base construction is nearly ubiquitous today, especially in the more urbanized regions that may be more distant from aggregate supplies (i.e., gravel pits). The research and development history of RAP provides a model for some of the market challenges facing RAS today.

Two other markets for RAS have the potential to become high-value outlets: (1) as a feedstock supplement in cement kilns; and (2) as a fuel supplement in coal-fired boilers. Both of these market applications are in a research and development stage. These two alternative applications may be more tolerant of the greater variability of tear-off RAS. But these additional applications are not fully commercialized yet. Therefore, the HMA outlet remains the preferred market for most shingle recyclers today.

Additional pavement construction applications for use of RAS include:

1. Lightweight pavements
2. Aggregate supplement for gravel road base.
3. Aggregate supplement for preparation of road bed subgrade (or "underlayment")
4. Dust control on gravel roads.
5. Cold patch.

As a general rule, these five additional pavement construction applications listed above will probably not enjoy the same price as the three higher value end uses (i.e., HMA, cement kilns, and coal-fired boilers). However, these applications may be able to consume large quantities of RAS. The aggregate supplements when used underneath pavement structures as base or subgrade may have less stringent final product quality specifications.

This *Guide* gives a higher priority to HMA market as the primary outlet for RAS. This priority is similar to the current market demand trend in the industry today.

AASHTO SPECIFICATION

In July 2006, the American Association of State Highway and Transportation Officials (AASHTO) published a new provisional specification and recommended practice for shingle recycling into HMA. (See Appendix G to read the full AASHTO specification.) This culminated a substantial amount of recycled shingles specification development work supported in part by the Recycled Materials Resource Center (RMRC). A background *White Paper* report was prepared for RMRC [60] in 2003.

One objective of the AASHTO provisional specification and practice is to address the needs for quality assurance / quality control (QA/QC) during the processing and utilization of recycled asphalt shingles in HMA. The AASHTO standard and practice provide detailed technical guidance including:

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

Shingle recyclers should continue to monitor and comment on, as appropriate, the development and adoption of ongoing revisions to the AASHTO shingle recycling provisional specification and recommended practice. A three-state DOT task force is currently in the process of preparing a report on their review of the current AASHTO standard and practice. This task force will likely recommend changes to the AASHTO standard and practice that will be presented to the AASHTO committees in the spring of 2008. [61]

MARKETING CHALLENGES

There are a number of barriers to increased recycling of shingle scrap. The market for RAS is generally "demand limited". Increased use of RAS-derived products, especially HMA, is needed. Increased research, development and use of RAS for other applications are also needed. Current attitudes of key audience groups (e.g., agency materials engineers, HMA producers) are affected by lack of information about the technical and economic benefits of RAS-derived HMA.

It is important to note, however, that the available supply of manufacturers' shingle scrap may become a more limiting barrier. Additional HMA producers would be willing to consider investments in shingle recycling if they knew they could obtain long-term scrap supply commitments from shingle recyclers.

DESIGN CONSIDERATIONS

BP#3: Tear – off shingle recyclers should develop a comprehensive marketing plan based on multiple outlets.

One of the first steps in planning a new or expanded shingle recycling business is to develop a clear, written marketing plan. Ideally this marketing plan would be based on multiple outlets and not just one buyer for the final RAS product. A diverse list of intermediate products will help stabilize and sustain a shingle recycling business.

The HMA market is the most mature and well developed, based on years of government – sponsored research. Cement kiln and fuel supplement markets are relatively newer and will require more research and development for their market value to be fully realized. **Shingle recyclers should develop both short – term and long – term marketing plans that optimize the value of each outlet based on local market conditions (BP#3.1).** For example, an entire shingles recycling business plan could be anchored by one primary HMA end use customer. However, to maintain the ability to continuously develop new market prospects, a shingle recycler should not dedicate 100% of the RAS product to one end user. Rather, a fraction of the product should be retained for market research and development.

Shingle recycling operators should guarantee their product quality to their end use customers. **In general, recycling operators should guarantee their RAS product to be:**

1. **Asbestos free.**
2. **Nail free.**
3. **In specified mix ratios when preparing a blended product (e.g., 75% RAS / 25% sand or RAP) (BP#3.2).**

In general, when the RAS is produced to meet the specifications of HMA producers, the final product should be (in addition to the specifications #1 through #3 above):

4. ½ - inch minus
5. Less than 10% moisture
6. Meet or exceed state QA/QC requirements for traditional HMA.

To prepare for market development and sales calls, **shingle recyclers should plan to conduct their own internal, independent sampling and testing (BP#3.3).** This data will help recyclers develop confidence in their own RAS product quality leading to guarantees. In addition, **shingle recyclers should work with their end-use customers to sample and characterize their RAS product to determine if it meets the particular market's specifications (BP#3.4).** Material characteristics that can be analyzed using standard tests in a lab can include:

1. Gradation (standard sieve analysis).
2. Asphalt cement (AC) content.
3. Deleterious materials (i.e., non-asphalt shingle debris such as paper, wood and plastic).

HMA

Often, a HMA producer will have an on-site lab that can perform these types of tests. Otherwise, such HMA producers will use a local contract lab for their tests. Such RAS material testing should become a routine quality assurance practice. Deleterious test procedures should follow the AASHTO recommended method if possible.[62, 63]

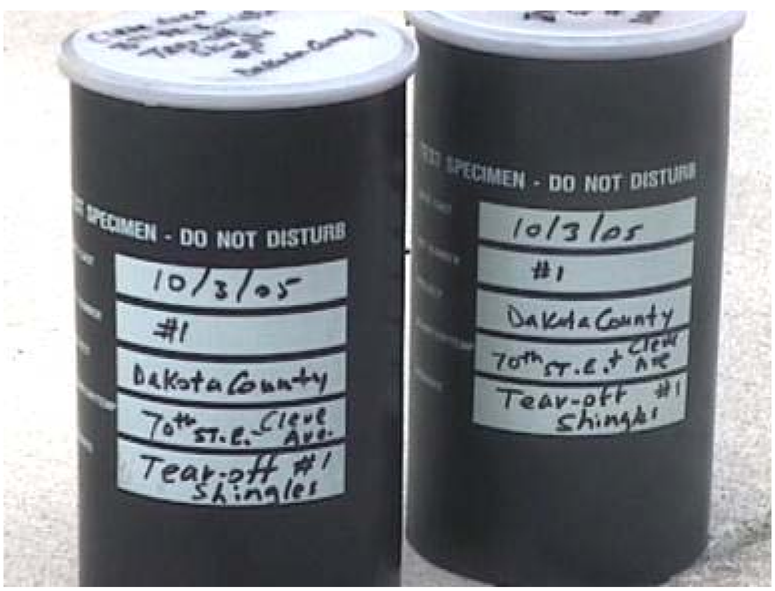
Shingle recyclers should encourage the HMA producers and paving contractors to report back on the results of the standard HMA mix and bituminous pavement quality control tests for HMA produced with recycled shingles (BP#3.5). These HMA mix and pavement evaluations could include:

1. HMA mix gradation
2. AC content of the final HMA mix
3. Tensile strength resilient (TSR) modulus
4. Air voids of the HMA mix (as sampled behind the paver before compaction)

5. In-place density (after compaction)
6. Comments from paving crew on workability and final product quality
7. Final inspection after pavement installation for cracking and other visual observations.

Picture 19 -
HMA Sampling Behind the Paver

Picture 20 -
HMA Samples



Recording and summarizing these results in writing is especially helpful during the early market development phases of a new shingle recycling business (BP#3.6). Such information can provide valuable customer testimonials as to the suitability of the RAS product for the end-use application.

State DOT materials researchers and academic institutions may wish to consider additional testing for research and specification development purposes (BP#3.7). Such tests may include analyses such as:

1. Binder extraction
2. AC performance grade (PG)
3. Bending beam rheometer (BBR)
4. Deleterious materials content (AASHTO method recommended)
5. Indirect tensile strength (IDT) tests

Shingle recyclers should advocate for "affirmative, environmentally preferable procurement" policies that give a preference for RAS – derived HMA (BP#3.8).

CEMENT KILNS

RAS, whether derived from manufacturers' or tear-off shingle scrap, can be used in cement kilns as a fuel and mineral supplement. Recycling in cement kilns is a newer RAS end use application.

In 2005, the U.S. Department of Energy (U.S. DOE) awarded a grant to Owens Corning, Inc. to further develop this market. Much of this technology is under patents, either awarded or pending.[64] Various public data have been released that generally describes the technology.[65, 66]

The RAS is introduced into the cement kiln, and the organic fractions (e.g., asphalt cement, cellulose felt) are combusted as a fuel supplement. The noncombustible, inorganic portion of the shingles (e.g., mineral filler aggregates, surface granules, talc dust, fiberglass, any remaining nails or other metals) remains in the kiln and becomes part of the kiln's end product, typically referred to as clinker. The inorganic materials from the shingles become part of the useful ingredients needed for cement production including: limestone, dolomite, silica, calcium, magnesium, aluminum, and/or iron.

As with other higher value end market uses of RAS, the economics of this cement kiln technology is driven by the avoided landfill disposal costs; the energy value of the combustible organic fraction; and the mineral value of inorganic fraction.

The stated advantages of using RAS in cement kilns include:

- The calcining and sintering temperatures in the kiln to form the end product are much higher than in HMA plants. This may allow more complete conversion of any asbestos that may be in the roofing waste into a non-asbestos mineral form.
- The material specification for RAS may be less stringent than for HMA plants. For example, a coarser particle size (e.g., larger than ½ - inch minus) may be suitable. One early claim is that the roofing material could potentially be introduced without grinding.[67]
- The RAS may not need to be entirely free of non-shingle debris (e.g., nails, wood, felt, ice barrier "felt", metal flashing) as it must be for HMA applications. The nails and other

metal debris may provide incremental amounts of additional iron and aluminum that may be beneficial to the Portland cement production. The other organic debris items such as wood, felt, and rubberized ice barriers may provide an additional fuel.

Several other types of waste materials have been claimed as patented inventions for use in Portland cement kilns including tires, various sludges[68] and solid forms of selected hazardous waste [69, 70]. These other recovered materials provide some of the precedent technology experience, but also will compete with RAS as a fuel / mineral supplement.

COAL – FIRED FUEL SUPPLEMENT

This potential market uses RAS as a supplement to coal in the production of electricity or steam. Energy recovery from RAS is reported to be an established market in Europe.[71] Only recently has the concept been applied in the U.S. Development of this market is limited, however, in part because use of a recyclable product for energy recovery is often considered a lower policy priority than recycling within a manufacturing process. Little data has been published into the public domain on this new technology.

SHINGLE-TO-SHINGLE RECYCLING

This is a relatively new concept that has not yet been fully developed into any known commercial scale operation. Little data has been published in the public domain on shingle-to-shingle recycling. One patent application describes a specific process for milling the recycled aggregate derived tear-off shingles together with limestone or dolomite ore to produce a highly refined, powder-like product claimed to be ready for use as an admix by shingle manufacturers.[72] The limestone and asphalt shingle constituents can be ground into fine homogeneous particulate powder (35 mesh minus) that is free of re-agglomeration.

There are no known facilities producing new shingles from either manufacturer's scrap or tear-off material on a commercial basis. A challenge with closed-loop recycling of asphalt shingles is conforming to very stringent, feedstock product specifications.

OTHER APPLICATIONS

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.[73]

<u>RAS as a Supplement for Road Base and Subbase</u>

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.[74, 75]

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.[76] 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 containing 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. [77, 78]

Lightweight Pavements

RAS has been used in lightweight pavement for low volume roads, driveways, and parking lot surfaces.[79, 80, 81] RAS is typically ground to ½- to ¼-inch minus and passed under a magnetic separator in order to sufficiently remove all nails. The processed shingles are spread and compacted.[82] Some shingle recyclers / paving companies have successfully used RAS in combination with RAP to provide a firm, temporary pavement at about half the cost of HMA. The two recycled materials (RAS + RAP) have been pre-blended before trucking to the paving project site. In other demonstrations, the RAS and RAP are trucked separately to the project site, windrowed in equal volumes, bladed together for mixing / spreading, and then compacted in place using standard roller compactors. One company has used a commercial emulsifier as additional binder.[83] The blending ratios have ranged from 25% to 50% RAS. The demonstration projects have resulted in successful, lightweight pavements.

Dust Control on Gravel Roads

This application has been tested in many locations.[84, 85, 8687] RAS has been successfully mixed with traditional gravel aggregates and used to cover rural, unpaved roads. The mixing and compaction procedures tested are similar to the windrow and compaction methods described above under lightweight pavements. The mixture can have potential benefits in these rural roads, including:

- Dust is minimized. The Iowa DOT study showed little or no dust for two years on a rural road.[88]
- Reduced loss of gravel into side ditches.
- Vehicle noise can be reduced.
- The roads may have a longer life and require less maintenance. The study conducted by the Iowa DOT noted that the road performed well for at least two years.

Cold Patch

The use of RAS as cold patch is a practice that has been employed for years. It has been used in New Jersey, Washington, Minnesota and California as well as the city of Chicago. Presently, Gardner Asphalt Corporation of Tampa, FL supplies Home Depot with an RAS cold patch product. According to field tests, RAS cold patch behaves like a "high-performance" patch, outlasting HMA and traditional cold mixes. The fiberglass and/or cellulose fibers in the shingles apparently add to the structural integrity of the patch.[89]

Although the initial cost of RAS cold patch is usually higher than HMA and traditional cold patch, the overall cost may be lower due to longer life and decreased maintenance costs. When compared to other high performance patches, the RAS cold patch usually costs less.

Advantages to using cold patch comprised of RAS include the following:

- Lighter weight
- The patch material is very easy to apply. A pothole is simply filled approximately an inch over grade. No equipment is needed as the patch may be compressed by vehicle traffic. The patch is also less dense than other materials, making it easier to haul.
- The RAS cold patch material can be stored longer because it does not "clump" as quickly as other materials.[90]
- Time flexibility (after applying, traffic can be allowed over the area immediately).[91]
- Patches have a longer life compared to other patch materials. This is likely due to the fibers from the felts or fiberglass in shingles.

CHAPTER 5 -
ECONOMICS

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. 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 2.

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.

HMA producers are interested in considering RAS as a new recycled material because of its relatively high AC content. RAS becomes a partial replacement of the virgin AC. In the past, HMA producers have reported savings of approximately $.50 to $1 per ton of finished HMA product with the use of 5 percent RAS.[92, 93] The total, average cost per ton for HMA production and sale varies with the grade of pavement and geographic location. Studies have indicated a savings of up to $3 per ton of final HMA.[94]

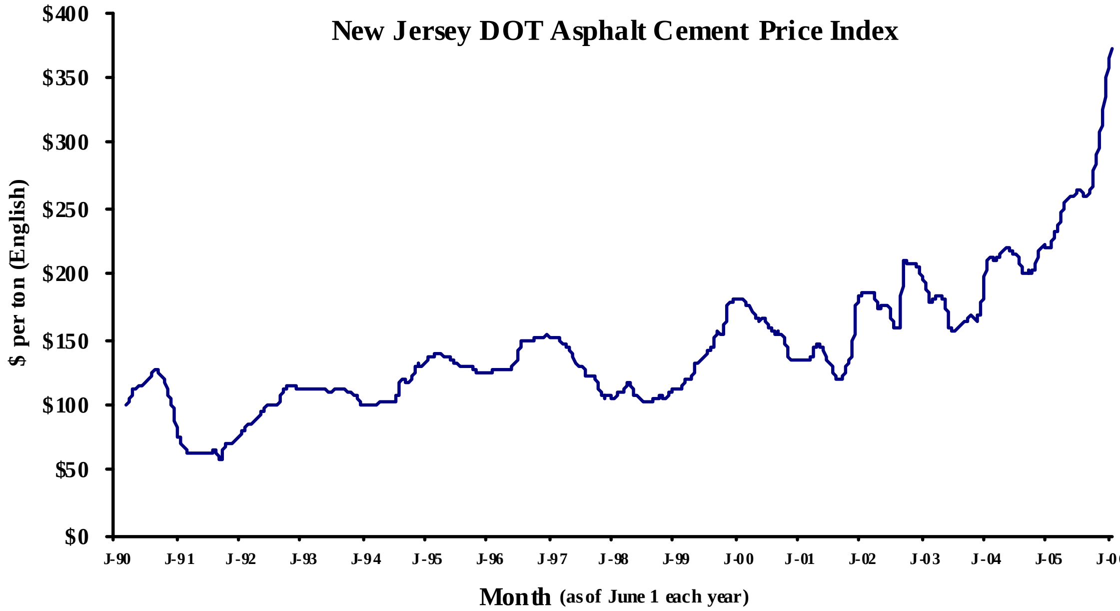
Shingle recyclers must budget for all capital (equipment, buildings and land) and operating costs. Grinding equipment may need to be modified (e.g., dust shroud installation). Operations should include adequate budget for repair and maintenance (e.g., hard surfacing of grinding / wear parts). Asphalt shingles will always be extremely abrasive given the hard, ceramic mineral granules used in the shingle design and manufacturing process.

Most shingle grinding operations will probably require two operators to safely staff a shingles processing crew. From a mechanical point of view, it may be possible to design and operate a shingle recycling system 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, especially if the shingle plant is in a remote or rural location. Increasing from one to two operators can be a significant, but necessary, cost impact for recyclers.

In order to reduce the costs 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. If a choice is available, it may be best to locate the shingle recycling operation closer to the HMA plant. This may prove more economic because of opportunities for transfer stations to help reduce shingle scrap hauling costs. Transfer stations may need to be employed to arrange for tipping locations for roofing companies and haulers that are competitive with landfill locations. For example, tear-off shingles could be shipped from a transfer station located near an urban center and trucked to a more distant shingles recycling plant located adjacent to an existing HMA producer.

Figure 2 -
Price Trend for Virgin Asphalt Cement

(Asphalt Performance Grade = PG 84 - 22)



Source: New Jersey Department of Transportation.[95]

Table 3 is a blank economics template or worksheet for recycling RAS into HMA based on a generic cost – benefit model originally published by NAPA.[96] Any specific net savings calculations must include calculations for the budgeted capital (e.g., land, buildings, equipment) and operations / maintenance costs. Operating cost estimates should include labor, sales and other marketing costs, utilities (including water) and transportation. All QA/QC costs must also be included, including any lab costs for asbestos testing and final product engineering tests.

Table 3 -
Economic Analysis of Shingle Recycling Into HMA [97]

		$/ton of Finished HMA
Revenue (including virgin material cost savings)		
A.	Savings from reduced need for new (virgin) asphalt cement (AC) New AC $/ton ( ) **X** AC in RAS ( ) **X** % of RAS in mix ( )	________
B.	Savings from new (virgin) fine, bituminous aggregate New fine agg. $/ton ( ) **X** % fine agg. In RAS ( ) **X** % of RAS in mix ( )	________
C.	Tipping fee (if charged by shingle recycler) Tipping fee $/ton ( ) **X** % RAS in mix ( )	________
D.	**Total Gross Savings per ton of hot mix (add: A + B + C) =**	________
Costs		
E.	Less acquisition cost of RAS (e.g., trucking cost): Acquisition cost $/ton ( ) **X** % of RAS in mix ( )	________
F.	Less additional processing costs (e.g., sorting, crushing, screening): Processing cost $/ton ( ) **X** % of RAS in mix ( )	________
G.	Less capital costs (e.g., equipment, land, improvements) Capital costs $/ton ( ) **X** % of RAS in mix ( )	________
H.	Other miscellaneous costs of testing, engineering design (e.g., asbestos monitoring, mix design, other QA/QC) Costs $/ton ( ) **X** % RAS in mix ( )	________
I.	**Total costs (add: E + F + G + H) =**	________

Net revenue per ton of hot mix asphalt =
(Subtract: D - I) ________

CHAPTER 6 -

INDEX OF BEST PRACTICES

This Chapter is intended to provide a quick reference index of the more significant best practice recommendations contained within in this *Guide.*

BP#1: Recyclers handling tear – off shingles should carefully plan and implement a supply quality assurance / quality control (QA/QC) system.

1.1 Shingle recyclers should publish a written specification as to the type and quality of material that is acceptable and the criteria for rejecting loads.

1.2 Shingle recyclers should have a secure supply of clean tear-off material.

1.3 Develop a supply of post consumer scrap material that is free of known asbestos containing material (ACM).

1.4 Manufacturers' shingle scrap can also be targeted as another source of recyclable material supply, if it is available.

1.5 For tear-off shingles, additional quality standards, certification requirements, and sorting procedures will need to be established that are not required with manufacturers' shingle scrap.

1.6 The shingle recycler should have a means to safely and efficiently sort the asphalt shingles from the non-shingle debris.

1.7 Source-separated tear-off shingles must be kept separate from other roofing debris (e.g., plastic, metal, wood) before loading and then loaded separately onto the truck, trailer or roll-off box.

1.8 Shingle recyclers accepting mixed roofing materials should make it clear that no hazardous waste will be permitted. Suppliers should be notified in writing that if any such waste is found, it will be handled, manifested and disposed according to all regulations. All related disposal costs can be charged back to the supplier.

1.9 Shingle recyclers should maintain close communication with their suppliers, especially if unacceptable material is received. If prohibited materials are delivered, truck drivers and their dispatchers should be notified as soon as possible. If feasible, prohibited materials already tipped should be loaded back directly into the same truck.

1.10 It is up to the recycler to determine the specific state and local regulations that may apply.

1.11 Shingle recycling systems should be planned, designed and implemented to fully comply with, if not exceed, all waste disposal regulations. Shingle recyclers may wish to provide evidence to their supplier customers that their facility has all the required government licenses and permits as required by the appropriate local and state agencies.

1.12 Asbestos management plans must be developed in accordance with federal NESHAP asbestos regulations as promulgated by the U.S. EPA.

1.13 During the start-up phase of a new tear-off recycling business, shingle recyclers may wish to restrict the supply of tear-off asphalt shingles to private, residential homes only. These homes are considered as "non-regulated facilities" as defined by U.S. EPA rules in NESHAP.

1.14 Require suppliers such as roofing companies and other haulers to provide written certification that the source of the tear-off asphalt shingle scrap and other incidental roofing waste is private, residential homes only.

1.15 Owners of regulated buildings may be required by state regulatory agencies to provide for testing their roofing waste for ACM as per NESHAP rules.

1.16 The roofing company and hauler should certify in writing that the used roofing materials are primarily asphalt shingles (such as three-tab shingles) and are relatively free of other prohibited materials.

1.17 The list of other prohibited materials for a tear-off asphalt shingle recycler should also include:

   a. Cementitious shingles, shake shingles, and transite siding that may be suspect of ACM.
   b. Any type of hazardous waste (e.g., mercury containing devices such as thermostats, paint, solvents or other volatile liquids, etc.).
   c. Significant amounts of other debris that is not asphalt shingles (e.g., plastic, paper, glass, or metal).
   d. Significant amounts of trash.

1.18 Each load should be inspected by using personnel trained to visually detect suspect ACM.

1.19 Shingle recycling operators should work with their respective state environmental agency to develop a mutually acceptable asbestos testing plan.

1.20 Such a plan should have an initial "baseline" testing period followed by a test results conference to review the baseline data and develop recommendations for the next phase.

1.21 If no asbestos was detected during the baseline period, the shingle recycler may wish to propose a program of random or unannounced testing frequency at the agency's discretion.

BP#2: Tear – off shingle recyclers should optimize their operations to produce a RAS product that meets or exceeds specifications of their end markets.

2.1 Shingle recycling operators should maximize the processing capacity (i.e., tons per hour) while assuring the final RAS product will meet or exceed market specifications.

2.2 Each shingle recycling facility will have unique features but should be designed both on final RAS product quality specifications and on the supply characteristics.

2.3 For mixed load systems, if an elevated, manual sort line is utilized to further remove non-shingle debris, the material must be "presented" on the sorting conveyor at the proper depth and speed.

2.4 Grapple-equipped loading crane is superior to a larger capacity bucket wheel loader.

2.5 The shingles recycling processor should provide for agency inspections of the sourcing, processing and final RAS product stockpiles.

2.6 Tear – off shingle recyclers must strive to maximize the protection of the health and safety of their workers.

2.7 Management should develop a comprehensive, written employee hazard prevention and training plan.

2.8 Management should provide accurate information about potential risks and preventative measures as part of a full employee education program.

2.9 The employee hazard prevention plan should include best available information about asbestos management and exposure prevention.

2.10 Shingle recyclers should develop a comprehensive dust control and management plan.

2.11 Shingle recyclers should continuously water the material just before it is fed into the grinding chamber(s)

2.12 Shingle grinding equipment manufacturers should consider offering dust control devices (e.g., enclosed grinding chambers with pneumatic conveyance, air separation, bag house filters, and dust containment) to be sold as optional equipment components.

2.13 Shingle recyclers should use standard, industrial workplace protective clothing and safety equipment (e.g., hard harts, eye protection such as goggles or safety glasses, gloves, steel shank / steel toe work boots, long pants, long sleeved shirts, fabric dust masks, safety vests, etc.).

2.14 Some states may require that all shingle grinding operations be conducted in an enclosed building.

2.15 Shingle recycling operators may wish to invite OSHA staff to visit to their operations to observe and comment on the facility's employee health and safety procedures, equipment and policies are being implemented and followed.

BP#3: Tear – off shingle recyclers should develop a comprehensive marketing plan based on multiple outlets.

3.1 Shingle recyclers should develop both short – term and long – term marketing plans that optimize the value of each of outlet based on local market conditions.

3.2 In general, shingle recycling operators should guarantee their RAS product to be:

a) Asbestos free.

b) Nail free.

c) In specified mix ratios when preparing a blended product (e.g., 75% RAS / 25% sand or RAP).

3.3 Shingle recyclers should plan to conduct their own, internal, independent sampling and testing**.**

3.4 Shingle recyclers should work with their end-use customers to sample and characterize their RAS product to determine if it meets the particular market's specifications.

3.4 Shingle recyclers should encourage the HMA producers and paving contractors to report back on the results of the standard HMA mix and bituminous pavement quality control tests for HMA produced with recycled shingles.

3.5 Recording and summarizing these results in writing is especially helpful during the early market development phases of a new shingle recycling business.

3.6 State DOT materials researchers and academic institutions may wish to consider additional testing for research and specification development purposes.

3.7 Shingle recyclers should advocate for state and local governments to use "affirmative, environmentally preferable procurement" policies that give a preference for RAS – derived HMA.

APPENDIX A:
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APPENDIX B:

RECOMMENDED TERMINOLOGY

As with most new or developing technologies, there are a wide variety of new terms that are used inconsistently. One means of improving communications and understanding of key market development barriers and improvement opportunities is to use a consistent set of well-defined terms and acronyms. This glossary represents the recommended definitions used in this *Guide*. In general, this *Guide* uses the definitions and terminology itemized in the AASHTO provisional specification. (See Appendix G.)

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 <u>manufacturers'</u> 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 of 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” 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 C:

EXAMPLE OF A SUPPLY SPECIFICATION

Source Separated Tear – Off Shingles:
An Example List of Acceptable and Unacceptable Items

List of Roofing Waste Items Included for Recycling

"YES"	**"NO"**
Include these items:	**Do NOT include these items:**
▪ Shingles	▪ Wood
▪ Felt attached to shingles	▪ Metal flashings, gutters, etc
	▪ Nails (best effort)
	▪ Plastic wrap, buckets
	▪ Paper waste
	▪ Other garbage, trash or dirt

EXAMPLES OF SUPPLY CERTIFICATION FORMS:

Roofing Company or Other Supplier of Whole Tear-Off Shingles

Delivery Company Name:

____

Address: ____

____

Contact: ____

Phone: ____

E-mail: ____

We the undersigned, certify that:

1. All tear-off shingle scrap came from residential buildings having four or fewer dwelling units (see addresses below or attached);
2. These residential buildings are not “regulated facilities” according to state and federal NESHAP rules; and
3. The roofing waste material delivered consists of asphalt shingles and normal roofing debris only and contains no known hazardous material (e.g., asbestos).

Residential re-roof customer address(es) where the tear-off shingle scrap originated:

____

____

(Please attach additional sheets as needed to record each customer address)

Name and address of processor where the shingle scrap was supplied to:

____

____

____

________________________________ ________________

Tear – Off shingles supplier (signature) Date

Tear – Off Shingle Processor

Paving project site information:

Paving project name: ____

Paving project owner: ____

Contact person / phone: ____

Paving project location (address, city):

____

____

Shingle recycling processor:

Company name: ____

Contact person / phone: ____

Address:

____

____

E-mail: ____

We the undersigned, certify that: (1) All of the tear-off shingle scrap to be used on this project came from residential buildings having four or fewer dwelling units; and (2) These residential buildings can not be defined as an institutional or commercial "facility" according to state and federal NESHAP regulations. We certify that the material processed consisted of asphalt shingles only and contains no known hazardous material.

_______________________________________ ____________________

Processor of shingle scrap (signature) Date

APPENDIX D:

Example Roofing Material Sampling and Testing Plan

The shingle recycling operator could collect random samples of finished RAS product using the following procedures:

1. Normal operations and processing methods and equipment shall be in use at time of sampling. I.e., no changes or special arrangements in processing should be made for samples (other than to enhance safety of sample collection).
2. Sample final RAS product after any screening or any other finishing.
3. The operator should propose sample location. The proposed sample location should be approved by state environmental agency. Potential sample locations could include:
   - On the final exit conveyor (stopped for sampling),
   - Just after the final exit conveyor, captured as product is falling to the ground, or
   - In the final RAS product storage pile using standard aggregate sampling techniques.
4. Other sampling collection details should also be proposed by the operator and approved by the state environmental agency. This may include the means of random sample selection (e.g., random time or random stockpile location).
5. Each sample size should be a minimum of 80 pounds.
6. One random sample could be collected for every 100 tons of finished RAS product as produced during the grinding process. More frequent testing may be initiated if laboratory analysis indicates finished RAS sample product is found to contain ≥ 1% asbestos containing material (ACM) as defined by NESHAP.
7. All samples should be split into two duplicates (approximately 40 – pounds each). Each sample should be labeled with date, time, sample location, sampling staff name and accompanied by a simple sample report form approved by the state environmental agency.
8. One 40 – pound sample should be submitted to the approved asbestos testing lab and the companion duplicate sample shall be retained by the operator.
9. The operator should arrange for the asbestos testing of the final RAS product samples using the polarized light microscopy (PLM) methods as per NESHAP using an accredited laboratory.
10. Document and maintain adequate records of analyses.
11. Allow the state environmental agency staff to inspect the operation, laboratory data and analyses, and collect their own samples as requested.

The federal asbestos regulations do not provide specific guidance on sampling "loads" of asphalt shingles arriving at a recycling facility, but some guidance may be gathered from the solid waste test methods. See Chapter 9 of SW-846, Test Methods for Solid Waste and these ASTM guidelines:

D4687 Guide for General Planning of Waste Sampling

D6051-96 Standard Guide for Composite Sampling and Field Subsampling for Environmental Waste Management Activities

D6044-96 Standard Guide for Representative Sampling for Management of Waste and Contaminated Media

D6009-96 Standard Guide for Sampling Waste Piles.

APPENDIX E:

Minnesota Department of Transportation

Discussion of Materials Specification for RAS use in HMA

Minnesota has been one of the state leaders in the research and development of shingles recycling specification and implementation for almost two decades. In 1990, the Minnesota Department of Transportation (Mn/DOT) began investigating whether recycled asphalt shingles could prove a usable and beneficial additive to hot-mix asphalt for paving. Through its research and field testing, Mn/DOT confirmed that asphalt pavement mix containing manufacturers' RAS performed at least as well or better as those mixes without shingle byproduct. As a result, in 1995 Mn/DOT first issued its specification for the use of up to 5 percent RAS in all courses for most mixtures. The Minnesota specification limits the Mn/DOT- approved to RAS derived from manufacturers only. Tear-off shingles are not yet allowed but intensive research is currently underway.

Similar to road construction practices in most states, the Mn/DOT construction materials specifications are the accepted industry standard within the state. Mn/DOT specifications must be used in road construction design and implementation on any state aid road project. Other government and private paving standards are not bound by Mn/DOT specifications but the majority of paving professionals choose to defer to Mn/DOT materials and design specifications as the industry standard. Therefore, these Mn/DOT specifications play a very significant role in the commercial expansion and economic implementation of such recycled commodity development.

Shingle Scrap Specification

Mn/DOT's shingle scrap specification (see section 2360.2 Materials: A2h Scrap Asphalt Shingles) was originally issued in 1995. The principal section of the Mn/DOT shingle scrap specification currently reads:

> **2360.2 Materials**
>
> "**A2h Scrap Asphalt Shingles** - Scrap asphalt shingles may be included in both wear and non-wear courses to a maximum of 5 percent of the total weight of mixture. Only scrap asphalt shingles from manufacturing waste are suitable. The percentage of scrap shingles used will be considered part of the maximum allowable RAP percentage (see Table 2360.3-B2a). Refer to Section 2360.2 G1 to select a virgin asphalt binder grade (use requirements for > 20% RAP, regardless of total RAP/shingle percentage). Scrap Shingle Specifications are on file in the Bituminous Office."

Two recent changes were made by Mn/DOT to this specification. The first change, made in the fall of 2002 was to delete the qualifying approval step. The original specification issued by Mn/DOT in 1995 allowed the use of manufacturer shingle scrap "…when approved by the project engineer." Thus, using shingle scrap was prohibited unless actively approved by the local engineer on the agency project (e.g., city or county engineer). The current specification allows using manufacturers' shingle scrap in HMA at the discretion of the HMA producer unless specifically prohibited by the project engineer. This current version now treats approval of the use of recycled shingle scrap similar to the approval of recycled asphalt pavement (RAP) whereby it is allowed by Mn/DOT specification unless actively prohibited by the local engineer.

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

The second specification change 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)."

This most recent addition to the specification was needed to address the question of the relative amount of new or "virgin" asphalt binder in HMA. It is important that the total amount of asphalt binder (new asphalt binder + RAS asphalt binder) meet minimum standards required for the performance of that particular road construction project, especially for the higher traffic volume highways. Mn/DOT specifications define "level 4" highways as a 20 year design for three to 10 million Equivalent Single Axle Loads (ESAL's) and "level 5" highways as a 10 to 30 million ESAL's.

There is ongoing research on the question of "**effective**" amounts of asphalt binder contributed by either RAS or RAP to the total asphalt binder in the final HMA product. AASHTO specifications and many states require mixture blending charts to be used when mixes are designed with RAP content of 20 percent or more. Mn/DOT specifications define RAS as type of "recycled" asphalt and therefore is considered, in effect, as a type of RAP when calculating the maximum amount of RAP allowed in a mix. For example:

- Assumed the total amount of RAP allowed in a mixture for a particular road project is 30 percent,
- If 5 percent RAS is used,
- Then a maximum of 25% of RAP is allowed to complement the 5% RAS for a total of 30 percent "recycled" material.

Current and proposed Mn/DOT research projects are further analyzing the relative effects of RAS on the final HMA product. Also, the Mn/DOT research, together with the University of

Minnesota (U of M) Department of Civil Engineering, is examining the different performance impacts of tear-off RAS vs. manufacturers' RAS.

Additional applied research is being conducted by Mn/DOT and the University of Minnesota Department of Civil Engineering. The design of such additional research is based in part on the testing requirements within the new AASHTO specification. Other state DOT materials researchers and academic institutions may wish to consider similar studies or participating in future Minnesota projects.

Scrap Shingle Specifications on File in the Mn/DOT Bituminous Office
(http://shinglerecycling.org/images/stories/shingle_PDF/mndot%20draft%20spec%202382.pdf)

Mn/DOT also has developed a draft "Recycled Shingle Scrap Specification on File in the Bituminous Office" for purposes of providing additional guidance about the sourcing and technical details of processing manufactured shingle scrap. This draft "…specification on file…" includes the following provisions:

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

APPENDIX F:

Missouri Department of Transportation

Discussion of Materials Specification for RAS use in HMA

Missouri Department of Transportation (MoDOT) adopted a HMA materials specification that allows both manufacturers' shingle scrap and tear-off shingle scrap. The MoDOT specification was issued in 2005. Research and development has continued since that time. Some of the Missouri research has continued in partnership with the Mn/DOT and the University of Minnesota Department of Civil Engineering.

The MoDOT specification states:

> **"MSP03-01B Substitution of Asphalt Shingles**
>
> **2.0 Shingles.** Up to 5.0 percent of asphalt shingles may be substituted in lieu of mineral aggregate. Asphalt shingles will be included in the total amount of recycled asphalt pavement (RAP) when RAP is added to the mixture.
>
> **3.0 Material Requirements.** Asphalt shingles may contain a maximum of 3.0 percent deleterious material by weight consisting of plastic, wood, metal, soil or other contaminating substances as might routinely be included with used shingles. A maximum of 1.5 percent wood shall be allowed. Shingles containing asbestos shall be handled in accordance with applicable regulations.
>
> **4.0 Mix Design Requirements.** Bituminous mixes utilizing asphalt shingles may require binder testing of the shingle asphalt to determine the appropriate grade of virgin binder. The combined binders shall meet the grade specified in the contract. The virgin binder grade for mixtures containing shingles shall be PG 58-28. Other grades combining to meet the specified grade may be used by providing test results of the binder blends and virgin binder with the job mix formula. ….."

The standard virgin binder grade for traditional HMA mixtures in Missouri is PG 64-22. MoDOT engineers commented that the asphalt binder extracted from shingles samples was exceptionally stiff or "harder" compared to such traditional virgin binder grades used in HMA for road construction. This shingle binder property could potentially be a benefit in reducing the tendency for HMA pavement to rut during the hot months of summer, but could be a disadvantage if it increased the amount of low temperature and fatigue cracking. Thus, the MoDOT specification was developed with the intent that at 5 percent RAS in the HMA mix, the mix design with shingles must be adjusted to incorporate a "softer" virgin binder. HMA with shingles must use a virgin binder that is one grade softer from the traditional grade. This softer virgin binder of PG 58-28 must be used unless additional test results could support alternative mix design plans.

Based on this specification and additional testing, MoDOT has allowed up to 2% RAS in HMA without adjusting the virgin binder with a softer grade. MoDOT has continued to work with one of the HMA producers, Pace Construction, to conduct additional mix designs and final HMA product testing.

APPENDIX G:
AASHTO Provisional Materials Specification and Recommended Practice for RAS use in HMA *

* As balloted at the American Association of State Highway Transportation Officials (AASHTO) Subcommittee on Materials in August 2005

Notes about the AASHTO provisional specification:

For ordering the final AASHTO provisional specification or more information, visit the publication-specific web page : **https://bookstore.transportation.org/item_details.aspx?ID=383** or the general AASHTO web site: **www.transportation.org** or call AASHTO at: 1-800-231-3475 (U.S. and Canada only) or e-mail: **aashto@abcgroup.com**.

Publication details: Item code: PS-09; ISBN number: 1-56051-340-3; Item format: paperback; Item pages: 360; Date published: July 2006.

An AASHTO task force is working on a current amendment to the this provisional specification. Representatives from the following State DOT's are represented: Missouri (chair of task force), Minnesota and Kentucky. An draft amended RAS specification is schedule to be presented to the AASHTO annual meeting in the next two months.

For background and historical context of the AASHTO provisional specification, visit the RMRC web page: http://www.rmrc.unh.edu/Research/Rprojects/Project13/Specs/RASAC/p13RASAC.asp. Henry Justus (Chesner Engineering, Commack, NJ) authored the RAS "White Paper" for RMRC as part of a larger project to help develop recycled materials specifications for transportation applications. The Justus RAS "White Paper" served as a background research paper to the AASHTO provisional specification and recommended practice.

M2005A-TS-2c –

Provisional Standard Specification For Use of Reclaimed Asphalt Shingle as an Additive in Hot Mix Asphalt

1. SCOPE

1.1 This specification covers reclaimed asphalt shingle material used as an additive in hot mix asphalt (HMA). The use of reclaimed asphalt shingle in hot-in-place pavements, cold-in-place pavements, and cold recycled pavements is not included in this specification.

1.2 The values stated in SI units are to be regarded as the standard.

Note 1 – Refer to "R-2005A TS-2c" "Standard Recommended Practice for Design Considerations when using Reclaimed Asphalt Shingles in New Hot Mix Asphalt" for information on mix design, determining shingle aggregate gradation and binder considerations, when designing HMA mixtures which incorporate reclaimed asphalt shingles as an additive.

2. DEFINITIONS

2.1 The definition of coarse and fine aggregate in terms of bituminous paving mixtures is provided in AASHTO M 29, ASTM C 125, and D 692.

2.2 *Manufactured Shingle Waste* – For the purpose of this specification, shall mean rejected asphalt shingles or shingle tabs that are discarded in the manufacturing process of new asphalt shingles.

2.3 *Post-Consumer Asphalt Shingle* – For the purpose of this specification, shall mean asphalt shingles that are removed from the roofs of existing structures when the new roofs are being installed. Post-consumer asphalt shingle is often called "Tear-Off" shingle.

2.4 *Reclaimed Asphalt Shingle* – For the purpose of this specification, shall mean either manufactured shingle waste or post-consumer asphalt shingle that has been processed into a product that meets the requirements of this standard.

2.5 *Shingle Asphalt Binder* – For the purpose of this specification, shall mean the asphalt binder that is present in the reclaimed asphalt shingle.

2.6 *Shingle Aggregate* – For the purpose of this specification, shall mean mineral granules, sand, or other mineral matter present in the reclaimed asphalt shingle, excluding the shingle fiber content.

2.7 *Shingle Fiber* – For the purpose of this specification shall mean, glass felt, paper felt, foil, fabrics of films used as the structural basis of asphalt shingle and other asphalt roofing products.

2.8 *Virgin Asphalt Binder* – For the purposes of this specification, shall mean new performance graded asphalt binder to be used in the new hot mix asphalt.

2.9 *Final Blended Binder* – For the purpose of this specification, shall mean the mixture of virgin asphalt binder and shingle asphalt binder.

2.10 *Virgin Aggregate* – For the purpose of this specification shall mean coarse and fine aggregate introduced into new hot mix asphalt that is exclusive of the shingle aggregate.

2.11 *New Hot Mix Asphalt* – For the purpose of this specification shall mean hot mix asphalt manufactured using aggregates, recycled asphalt pavement (if used), virgin asphalt binder, and reclaimed asphalt shingle.

3. REFERENCED DOCUMENTS

3.1 AASHTO Standards:
M 29 Fine Aggregate for Bituminous Paving Mixtures
T 2 Sampling of Aggregates

T 30 Mechanical Analysis of Extracted Aggregate

T 319 Quantitative Extraction and Recovery of Asphalt Binder from Hot Mix Asphalt

Provisional Practice: R-2005A-TS2c

3.2 ASTM Standards:
C 125 Terminology Relating to Concrete and Concrete Aggregates

D 692 Coarse Aggregate for Bituminous Paving Mixtures

4. ORDERING INFORMATION

4.1 The purchaser or specifier shall include the following information in the purchase order or contract documents:

4.1.1 Reference to this specification and year of issue,

4.1.2 Additional testing requirements, and

4.1.3 Any exceptions to this specification.

5. SOURCES AND SAMPLING

5.1 Reclaimed asphalt shingle may be derived from either manufactured shingle waste or from post-consumer asphalt shingle (see Note 2).

5.2 Post-consumer asphalt shingle shall be processed prior to use to meet the requirements of Section 8 of this specification and shall consist of asphalt roll roofing, cap sheets, and shingles, including underlayment, only. Roofing debris, including coal tar epoxy, rubber materials, or other undesirable components, shall not be used. Post-consumer asphalt shingle shall be certified to be asbestos free.

5.3 Manufactured shingle waste and post-consumer asphalt shingles shall not be blended for the production of new hot mix asphalt.

5.4 Reclaimed asphalt shingle samples collected and analyzed, for the purpose of identifying the properties of reclaimed asphalt shingle as defined in this specification shall be representative of the reclaimed asphalt shingle material that will be used in the full production run of new hot mix asphalt.

Note 2 –Asphalt shingle material is construction debris and various state and local regulations may be applicable to its use. The user of this specification is advised to contact state and local transportation departments and environmental agencies to determine what additional requirements may be necessary.

6. GRADATION OF RECLAIMED ASPHALT SHINGLE

6.1 Reclaimed asphalt shingle shall be processed so that 100 percent passes the 12.5 mm (0.5 inch) sieve, or as required by the specifying jurisdiction.

Note 3 – The hot mix asphalt supplier may wish to uniformly blend fine aggregate with the reclaimed asphalt shingle as a method of preventing the agglomeration of reclaimed asphalt shingle particles. The fine aggregate so added must be considered in the final gradation of the new hot mix asphalt.

7. ADDITION RATES OF RECLAIMED ASPHALT SHINGLE

7.1 The addition rate of reclaimed asphalt shingle shall be such that the gradation of the new hot mix asphalt shall comply with the gradation requirements of M 323 (see Note 4).

Note 4 – The gradation of the new hot mix asphalt shall account for the shingle aggregate as well as the virgin aggregate. The shingle aggregate gradation shall be determined in accordance with the procedures outlined in R**-2005A TS-2c** Section 5 or an equivalent method approved by M 323.

7.2 The addition rate of reclaimed asphalt shingle shall be such that the new hot mix asphalt shall comply with the volumetric mix design requirements of the specifying jurisdiction.

7.3 If the total available shingle asphalt binder content expressed as a fraction or percentage of the new hot mix asphalt content is greater than 0.75 percent (see Note 5), the virgin asphalt binder and shingle binder combination shall be further evaluated to ensure that the performance grade of the final blended binder complies with the performance grade requirements of M 323 (see Note 6).

Note 5 – The total available shingle asphalt binder content, expressed as a fraction or percentage of the new hot mix asphalt, is the product of the percentage of reclaimed asphalt shingle introduced into the new hot mix asphalt (P_s) and the percentage of shingle asphalt binder present in the reclaimed asphalt shingle (P_{sab}).

Note 6 – The performance grade and percentage of virgin asphalt binder introduced into the new hot mix asphalt shall be determined in accordance with the procedures outlined in R**-2005A TS-2c** Section 6 of the specification or an equivalent method approved by the specifying jurisdiction.

8. DELETERIOUS SUBSTANCES

8.1 Reclaimed asphalt shingle shall not contain extraneous waste materials. Lightweight extraneous materials (those having a density less than that of water, including such materials as paper, wood and plastics) shall not exceed 0.05 percent, as determined on material retained on the 4.75 μm (No. 4) sieve. Heavyweight extraneous materials (those having a density greater than that of water, including such materials as metals, glass, rubber, nails, soil, brick and tars) shall not exceed 0.5 percent as determined on material retained on the 4.75 μm (No. 4) sieve.

8.2 Reclaimed asphalt shingle shall contain less than the maximum percentage of asbestos fibers based on testing procedures and frequencies established in conjunction with the specifying jurisdiction and state or federal environmental regulatory agencies.

9. METHODS OF SAMPLING AND TESTING

9.1 Sample and test the reclaimed asphalt shingle with the following methods of the American Association of State Highway and Transportation Officials, except as otherwise provided in this specification.

9.1.1 Sampling T 2.

9.1.2 Extraction of Bitumen T 319.

9.1.3 Mechanical Analysis of Extracted Aggregate T 30

R2005A-TS-2c –

Provisional Standard Recommended Practice for Design Considerations when using Reclaimed Asphalt Shingles in New Hot Mix Asphalt

1. SCOPE

This recommended practice provides guidance for designing new hot mix asphalt (HMA) which incorporates reclaimed asphalt shingles. Specific guidance includes design considerations, how to determine the shingle aggregate gradation, how to determine the virgin performance grade and percentage of the virgin asphalt binder and how to estimate the contribution of the shingle asphalt binder to the final blended binder.

NOTE 1: Refer to “M-2005A TS-2c” Standard Specification For Use of Reclaimed Asphalt Shingle as an Additive in Hot Mix Asphalt for information specifying the use of reclaimed asphalt shingle in HMA.

2. REFERENCED DOCUMENTS

2.1. AASHTO Standards:

- AASHTO R 30
- AASHTO R 35
- Provisional AASHTO M-2005A TS-2c
- AASHTO M 320
- AASHTO M 323
- AASHTO T 319
- AASHTO T 30
- AASHTO T164
- AASHTO T170

2.2. ASTM Standards:

- ASTM D 228

3. INTRODUCTION

3.1. Although the use of reclaimed asphalt shingle (RAS) has been used as an additive in hot mix asphalt in the United States for over 15 years, it remains a relatively new application. As a result there are design considerations that are not generally known to the specification user. Four separate areas are addressed by this recommended practice, with each elaborating on and providing recommendations relative to the following:

- Design Considerations When Using Reclaimed Asphalt Shingles in Hot Mix Asphalt
- Determining the Shingle Aggregate Gradation
- Estimating the Contribution of the Shingle Asphalt Binder to the Final Blended Binder in New Hot Mix Asphalt (Values of F)
- Determining the Virgin Performance Grade and Percentage of the Virgin Asphalt Binder in the New Hot Mix Asphalt

4. Design Considerations When Using Reclaimed Asphalt Shingle in New Hot Mix Asphalt

4.1.1. The introduction of shingle aggregate from the reclaimed asphalt shingle will affect the gradation properties of the new hot mix asphalt. The designer must determine the particle size and fraction of shingle aggregate present and adjust the virgin aggregate composition, if necessary, to ensure that the new hot mix asphalt meets the appropriate gradation requirements.

4.1.2. The introduction of reclaimed asphalt shingle will affect virgin asphalt binder content requirements. The designer must determine the virgin asphalt binder content of the new hot mix asphalt as part of the volumetric design procedure.

4.1.3. During the production of the new hot mix asphalt, shingle asphalt binder present in the reclaimed asphalt shingle will mix with the virgin asphalt binder to produce a final blended binder. Since the properties of the shingle asphalt binder can be considerably different from those of virgin asphalt binder, if the quantity of shingle asphalt binder exceeds 0.75 percent by weight of the new hot mix asphalt, the properties (performance grade) of the final blended binder may be measurably different from the design performance grade of the binder as specified by the local jurisdiction. In addition, the size of reclaimed asphalt shingle can be expected to affect the fraction of shingle asphalt binder that contributes to the final blended binder. For example, material that is ground to a size passing a 12.5 mm (0.5 inch) sieve can be expected to release lower levels of available asphalt shingle binder (20 to 40 percent) than reclaimed asphalt shingle ground to a size passing a 4.75 mm (No. 4) sieve (as much as 95 percent available). The designer must be prepared to adjust the performance grade of virgin asphalt binder to compensate for this effect.

4.1.4. The release of shingle asphalt binder into the virgin asphalt binder can result in reduced virgin asphalt binder requirements. It is unlikely, however, that all of the shingle asphalt binder will dissolve and blend with the virgin asphalt binder. Particles of undissolved asphalt binder may act like aggregate particles that require more virgin asphalt binder to accomplish coating. Additionally, particles of shingle asphalt binder may absorb bituminous oils from the virgin asphalt binder. The fibrous material present in reclaimed asphalt shingle may also require additional virgin asphalt binder to accomplish coating. The location in a hot mix asphalt plant where reclaimed asphalt shingle is introduced into new hot mix asphalt can also affect the binder blending process. This point of introduction must minimize damage to the reclaimed asphalt shingle from excess heat and maximize the softening of shingle asphalt binder to facilitate the blending of the shingle asphalt binder with virgin asphalt binder.

5. Determining the Shingle Aggregate Gradation

5.1.1. Collect a representative sample of reclaimed asphalt shingle and proceed in accordance with AASHTO T 319, AASHTO T 164 or AASHTO T T170, to extract the shingle asphalt binder. The size of the sample should be such that the amount of aggregate material recovered will meet the size requirements of the gradation procedure. An alternate extraction method, when it is not necessary to retain the shingle asphalt binder, is provided in ASTM D 228, Sections 13 or 14.

5.1.2. To determine the shingle aggregate gradation, it is suggested that the shingle fiber present in the shingle be removed prior to testing the recovered aggregate in accordance with AASHTO T-30. Since the major portion of the shingle fiber will be retained on a 4.75 mm (No. 4) sieve, the fiber fabric can be removed by tweezers or other appropriate method prior to grading the shingle aggregate during the AASHTO T 30 test procedure.

6. Estimating the Contribution of the Shingle Asphalt Binder to the Final Blended Binder in New Hot Mix Asphalt (Values of F)

6.1.1. When reclaimed asphalt shingle is added to new hot mix asphalt there is uncertainty as to the exact amount of asphalt binder that is released from the shingle asphalt binder to blend with the virgin asphalt binder. There are many factors that control the blending of these two binders. Perhaps the most significant factor is the size to which the reclaimed asphalt shingle is ground. The finer the grind the greater the amount of the contribution of binder from the reclaimed asphalt shingle to the final blended binder. But there are other factors also. These include the location in the manufacturing process where the reclaimed asphalt shingle is added to the new hot mix asphalt, the temperature of the aggregates, the temperature of the virgin asphalt binder, and the length of mixing time.

6.1.2. A calculated initial estimate of the percentage of asphalt binder (F_c) that is released from the reclaimed asphalt shingle and blends with the virgin asphalt binder may be made by subtracting the difference between the design binder content of a virgin mix without reclaimed asphalt shingle (P_{vav}) and the design binder content of the new hot mix asphalt with reclaimed asphalt shingle (P_{var}), and dividing this value by the total available asphalt shingle binder in the new hot mix asphalt. Expressed mathematically:

$$F_c = \frac{P_{vav} - P_{var}}{(P_s)(P_{sab})}$$

where F_c = a calculated estimate of the shingle asphalt binder availability factor.

Determine the value of $\triangle$, defined as follows:

$$P_{vav} – P_{var} = \triangle.$$

Then:

$$F_c = \frac{\triangle}{(P_s)(P_{sab})}$$

This initial estimate will underestimate the value of F_c. A corrected value of F used in Section 7.1.3 is defined as follows:

$$F = \frac{1 + F_c}{2}$$

A discussion of the corrected value of F is presented in Section 7.1.9. More detailed descriptive instructions, which outline the steps in this procedure, are as follows:

6.1.3. Perform a volumetric mix design on the new hot mix asphalt combination that includes all of the components of the mixture except for the reclaimed asphalt shingle in accordance with the procedures set forth in AASHTO R 35. Select the design aggregate structure and prepare replicate mixtures in accordance with Section 10.1 of AASHTO R 35. Condition the mixtures according to AASHTO R 30. Determine the design binder content (P_{vav}).

6.1.4. Perform a second volumetric mix design procedure with the same combination of materials but including the reclaimed asphalt shingle in the percentage desired for the new hot mix asphalt. The reclaimed asphalt shingle should be added at ambient temperature to the heated aggregate materials just prior to the addition of the heated virgin asphalt binder. Condition the mixtures according to AASHTO PP2. Determine the design binder content (P_{var}).

6.1.5. If the value of $\triangle$ is positive, then the shingle asphalt binder is contributing to the final blended binder. If the value of $\triangle$ is negative, then coating recycled asphalt binder particles and absorption of virgin asphalt binder by reclaimed asphalt shingle particles resulting from the introduction of the reclaimed asphalt shingle is exceeding the amount of asphalt shingle binder contributing to the final blended binder. Additional virgin binder will then be required.

6.1.6. Multiply the percentage of asphalt binder in the reclaimed asphalt shingle (P_{sab}) by the percentage of reclaimed asphalt shingle added to the mixture (P_s). This value represents the total available shingle asphalt binder expressed as a fraction or percentage of the new hot mix asphalt.

6.1.7. Divide the value determined in Section 6.1.5 by the product of $(P_s)(P_{sab})$ determined in Section 6.1.6

6.1.8. Theoretically, the value of F can be represented by the equation

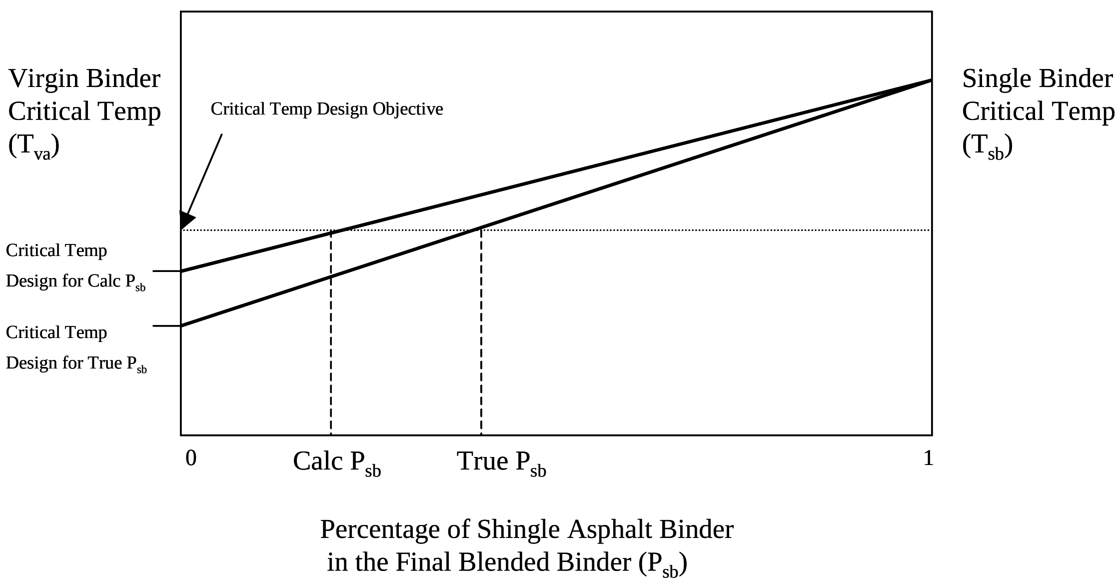
$$F_c = \frac{P_{vav} - P_{var}}{(P_s)(P_{sab})}$$

presented in Section 6.1.2. There are practical limitations, however, to this approach for estimating the value of F. These limitations are inherent in the assumption that $\triangle$ is the quantity of shingle asphalt binder that is contributing to the final blended binder. This is because the value of $\triangle$ is dependent on at least three factors, which include:

- The amount of shingle asphalt binder released into the mix
- Minus the additional absorption due to the reclaimed asphalt shingle present in the mix
- Minus the additional existing coating requirements due to the reclaimed asphalt shingle present in the mix.

As a result, the calculated value of F ($\triangle/(P_s)(P_{sab})$) will always be less than the true value of F, and the critical design temperature of the virgin asphalt will always be overestimated. This is illustrated more clearly in the hypothetical reclaimed asphalt shingle blending chart shown below.

Recycled Asphalt Shingle
Hypothetical Blending Chart



In the blending it can be observed that since the calculated value of P_{sb} will always be less than the true value, the calculated critical temperature will always be higher than the true critical temperature. In the design (selection of critical temperature/performance grade of the virgin binder) this must be taken into account, otherwise a harder asphalt will always be chosen.

Since the maximum value of F is theoretically equal to 1, the true value of F can be expected to lie between the value of F_c and 1, or expressed mathematically, $F_c < F < 1$. As a result, the best approximation of F can be expressed by the following equation:

$$F = \frac{1 + F_c}{2}$$

This value of F is used as input to calculate P_{sb} in Section 7.1.3.

7. Determining the Virgin Performance Grade and Percentage of the Virgin Asphalt Binder in the New Hot Mix Asphalt

7.1.1. Select the percentage of reclaimed asphalt shingle (P_s) to be introduced into the new hot mix asphalt.

7.1.2. Determine the percentage of shingle asphalt binder (P_{sab}) present in the reclaimed asphalt shingle in accordance with AASHTO T 319, AASHTO T 164 or AASHTO T T170 test procedures.

7.1.3. Determine the expected percentage of shingle asphalt binder (P_{sb}) present in the final blended binder with the use of the following equation:

$$P_{sb} = \frac{F(P_s)(P_{sab})}{(P_{fbb})}$$

Where:

P_{sb} = percentage of shingle asphalt binder present in the final blended binder.

P_s = percentage of reclaimed shingle asphalt in the new hot mix asphalt

P_{sab} = percentage of shingle asphalt binder present in the reclaimed asphalt shingle determined in Section 6.1.2

P_{fbb} = percentage of final blended binder present in the new hot mix asphalt

F = shingle asphalt binder availability factor (determine using the procedure outlined in Section 6.1.8).

7.1.4. Establish the required performance grade (or critical temperature) for the virgin asphalt binder in accordance with AASHTO M 323, Appendix X1, “Procedures for Developing a Blending Chart.” This can be accomplished by constructing a blending chart and plotting the critical temperature of the shingle asphalt binder for 100 percent shingle asphalt binder and the value of P_{sb} on the chart abscissa to determine the critical temperature of virgin asphalt binder that must be used in the new hot mix asphalt, or by utilizing the following equation, which is a mathematical representation of the blending chart:

$$T_{va} = T_{sb} - \frac{(T_{sb} - T_{fbb})}{(1 - P_{sb})}$$

Where:

T_{va} = critical temperature of the virgin asphalt binder
T_{sb} = critical temperature of the shingle asphalt binder
T_{fbb} = critical temperature of the final blended binder
P_{sb} = percentage of shingle asphalt binder present in the final blended binder

7.1.5. To make use of the above-referenced equation, T_{sb} values for high, intermediate, and low critical temperatures for each of the defined properties in AASHTO M 320 must be determined by testing the extracted shingle asphalt binder from Section 6.1.2, above. The value for T_{fbb} is established based on the climatic conditions where the new hot mix asphalt will be used, while the value for P_{sb} is determined in Section 7.1.3. The equation may then be solved for T_{va}.

7.1.6. If the performance grade for virgin asphalt binder as determined in Section 7.1.4 is different from the grade used in Section 7.1.2, then an additional volumetric design for the new hot mix asphalt must be performed in accordance with AASHTO R 35, or an equivalent method approved by the specifying jurisdiction, and a revised design binder content (P_{var}) in the new hot mix asphalt determined.

APPENDIX H:

Endnotes

[1] For a more detailed description of the *CMRA Tear-off Asphalt Shingles Project*, visit the EPA web page and OSWER Innovations Pilot project *Fact Sheet* on this, click http://www.epa.gov/oswer/iwg/pilots/docs/2005_0520_asphalt_formatted_final.pdf

[2] The CMRA informational web page, www.ShingleRecycling.org.

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[27] Recycle America Enterprises, Southborough, MA

[28] Roof Top Recycling, Inc., Boxborough, MA.

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[55] Schroer, Joe, Missouri DOT ongoing mix design approvals

[56] Minnesota DOT and the Solid Waste Management Coordinating Board (SWMCB) have recently convened a technical working group (TWG) to coordinate ongoing shingles recycling research and development. This TWG is scheduled to review recent past and proposed next phases of research on tear-off shingles.

[57] AASHTO has convened a three – state task force of DOT materials engineers to review the existing AASHTO shingles recycling specification and make recommendations for improvement.

[58] Other states are also in various stages of research and development including: Washington (King County), Iowa, Illinois, Indiana and Wisconsin.

[59] See NEWMOA's web page for more information on the beneficial use determination (BUD) database: http://www.newmoa.org/solidwaste/bud.cfm. For more information, contact Jennifer Griffith at jgriffith@newmoa.org.

[60] Henry Justus of Chesner Engineering developed the RMRC's *Draft White Paper for Recycled Asphalt Shingle as an Additive in Hot Mix Asphalt* (April 15, 2003) as part of RMRC's *Project 13 / 14 Recycled Materials Specification* initiative. See the RMRC web page link:
http://www.rmrc.unh.edu/Research/Rprojects/Project13/Specs/RASAC/p13RASAC.asp
and click on the link via the recycling symbol icon hyperlink.

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[64] Owens Corning Fiberglas Technology, Inc. (Summit, IL) U.S. patent application number: 09/715,745; filed: November 17, 2000.

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[68] U.S. Pat. No. 3,572,524 describes an apparatus for charging sludges and other similar waste materials to the feed end of a rotary incinerating kiln using an endless screw-conveyor.

[69] U.S. Pat. No. 4,850,290 to Benoit et al., describes a method for charging drums of solid hazardous waste directly into the central portion of a rotary kiln or into the feed end housing of a kiln.

[70] U.S. Pat. No. 5,454,333, describes a continuous feed method for various waste materials, such as tires or drums of hazardous waste, and describes various other methods for introducing solid hazardous waste fuels into the rotary kilns.

[71] Athena Sustainable Materials Institute (January 2007). *"Enhanced Recovery of Roofing Materials"* Prepared for the Canadian Construction Innovation Council (CCIC).

[72] Chivers; Morgan A. (February 14, 1996) in Fremont, CA. U.S. Patent Office Application number: 08/605,327. For full application text, link to:

http://patft.uspto.gov/netacgi/nph-Parser?Sect1=PTO1&Sect2=HITOFF&d=PALL&p=1&u=%2Fnetahtml%2FPTO%2Fsrchnum.htm&r=1&f=G&l=50&s1=5626659.PN.&OS=PN/5626659&RS=PN/5626659

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[74] Commercial Paving and Recycling Corp. (CPRC), Scarborough, ME.

[75] Omann Brothers, Inc. (MN).

[76] Commercial Paving and Recycling Corp. (CPRC), Scarborough, ME.

[77] Bituminous Roadways, Inc. (Inver Grove Heights, MN) had used the oversized RAS from its finishing screen for aggregate base.[78] Allied Blacktop, Inc. (Eau Claire, WI) had used the oversized RAS from its finishing screen for aggregate base as reported in 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.

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[94] National Asphalt Pavement Association (September, 2000) Special Report 187, Recycling Practices for HMA.

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

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