RECYCLED ASPHALT SHINGLES IN ROAD APPLICATIONS
An Overview of the State of Practice

September, 1999

A literature review was undertaken to identify previous research on the use of waste asphalt shingles in road applications. This review revealed a that a number of states, universities, and public and private organizations have performed relevant research or have experience in the subject. The findings of these studies, particularly as they relate to the individual phases of this project, are summarized below. The principal investigators will continue to research new initiatives throughout the duration of the project.

***Asphalt Shingles*:**

The composition and properties of asphalt shingles are characterized in studies by the states of Minnesota [1] and North Carolina [2], the University of Maryland [3], the National Asphalt Pavement Association [4], asphalt plant manufacturer Astec Industries Inc. [5], and others. There is good correlation in the information presented by the different entities, with only some minor deviation in the details. Based on the studies it can be concluded:

? In the United States, approximately 7 - 9 million tons of old asphalt shingles roofing ("tear-offs") is removed from existing building each year, and about 0.5 to 1.0 million tons of factory rejects and tab cut-outs ("factory scrap") are generated each year.

? The exact composition of a particular shingle depends on the manufacturer and the roofing application, but the shingle manufacturing process is similar in each instance. The process begins with a layer of organic (cellulose or wood fiber) or fiberglass backing felt. The felt is impregnated with liquid asphalt, then coated on both sides with additional asphalt. The asphalt used as the saturant is of a different type than the asphalt used as the coating, but both are harder than asphalt generally used in pavement. Both types of asphalt are "air-blown", or bubbled, during production, a process that incorporates oxygen into the asphalt and further increases the viscosity. Powdered limestone (70% passing the No. 200 sieve) is also added to both types of asphalt as a stabilizer.

Once coated with the appropriate thickness of asphalt, one side of the shingle is then surfaced with granules for protection against physical damage, and damage from ultraviolet rays of the sun. The granules which are exposed in the roofing application are comprised crushed rock coated with ceramic metal oxides, and the headlap granules are coal slag. Both types of aggregate are relatively uniform is size, most ranging from 0.3 - 2.36 mm, and both are hard and angular.

Finally, a light coating of fine sand (< 0.425 mm) is applied to the back surface to prevent the individual shingles from adhering to each other during packaging and transport.

Typical Shingle Composition

Component	Organic Shingles	Fiberglass Shingles
Asphalt	30-35%	15-20%
Felt	5-15%	5-15%
Mineral Filler	10-20%	15-20%
Mineral Granules	30-50%	30-50%

? Tear-off shingles usually contain a greater percentage of asphalt than new shingles, due to the loss of a portion of the surface granules from weathering. The asphalt in tear-off shingles is hardened from oxidation and the volatilization of the lighter organic compounds. Tear-offs are often contaminated with nails, paper, wood, and other debris.

? The American Society for Testing and Materials (ASTM) has set out specifications for roofing shingles. However, the specifications, ASTM D 225-86 (Asphalt Shingles [Organic Felt] Surfaced with Mineral Granules) and ASTM D3462-87 (Asphalt Shingles Made from Glass Felt and Surfaced with Mineral Granules), allow for a fairly wide range of products. Each shingle manufacturer has more detailed specifications for their own roofing products.

- Information regarding the inclusion of asbestos in roofing shingles is inconsistent. Certainly, asbestos is not used in the production of new asphalt shingles, and it is unclear as to what degree asbestos was ever used in shingle manufacturing. The California Integrated Waste Management Board reports that the total asbestos content of asphalt shingles manufactured in 1963 was 0.02 percent; in 1977, it had dropped to 0.00016 percent. [6] The Georgia Department of Transportation relates that asbestos was used in roofing shingles as late as the 1980s [7], while the Iowa Department of Transportation reports the asbestos usage in roofing shingles was discontinued in 1973. [8] The same Iowa DOT study reported that of 368 shingle samples analyzed, only 3 (0.8%) contained asbestos.

  Personal communication with roofers, the Vermont Department of Health, and a Vermont-certified asbestos laboratory indicate that asbestos in roofing is generally confined to commercial "built-up" roofing, older roof coatings, and roofing cement. Asbestos-containing roofing shingles are rare.

Processing Roofing Waste:

- Shingles must be shredded or ground to be used successfully for virtually any road application. For hot mix asphalt (HMA) and cold patch, generally the smaller the shreds, the better they will be incorporated into the mix. In these applications, the shingle pieces must be smaller than ½", and preferably smaller than 1/4". Specifications written for the Texas Department of Transportation requires that 100% of the shingle shreds pass the 19 mm (3/4") sieve, and 95% pass the 12.5 mm (½") sieve. [9] The Georgia DOT requires that 100% of the shingle scrap pass the 12.5 mm sieve. [7] Guidance from the FHWA also recommends shreds sized less than ½". [10]

- Crushers, hammer mills, and rotary shredders have been used with various success to process waste shingles. Often the shingles are passed through the processing equipment twice for size reduction.

- Tear-off roofing is easier to shred than factory scrap. Factory scrap tends to become plastic from the heat and mechanical action of the shredding process. Tear-off roofing is hardened with age and is less likely to agglomerate during processing.

? Water is sometimes added during shredding to both keep the shingles cool and to limit dust, but obviously the added moisture is undesirable in producing HMA. Alternatively, the shreds may be blended with up to 20% sand or screenings that would otherwise be added later in the production of the HMA or cold mix asphalt patching material. [9] The roofing shingle shreds may also be mixed with recycled asphalt pavement (RAP) to prevent clumping of the stockpile.

? Tear-off roofing is much more variable in composition than factory scrap, and is more contaminated with debris which complicates processing. Nail removal is accomplished by magnets after shredding. Paper and lightweight contaminants may be removed by blowers or vacuums.

***Roofing Shingles as Aggregate*:**

? Although the usage of processed roofing shingles as aggregate in road construction or maintenance seems to becoming more common, very little scientific research on its performance was found. Most of the projects are field tests or commercial endevours, with only anecdotal observations as findings.

? Probably the best example is a 1995 Iowa Department of Transportation study on the use of ground shingles as a surface treatment on an unpaved road. [8] Approximately 300 tons of tear-off shingles were ground to pieces less than 1-inch, and approximately 600 tons of tear-off shingles were ground to less than 2-inch pieces. The two sizes of shingles were mixed together prior to use. 500 tons of the processed shingles were applied onto newly lain crushed limestone. The shingles were graded back and forth to achieve a uniform shingle/limestone mixture of about 2.5-inch in thickness. After two years of observations, the study concluded that shingles are very effective for dust control on rural roads, result in better lateral control of vehicles, reduced the loss of granular material into the ditches, and resulted in a quieter and smoother roadway.

Processing the shingles costed $30 per ton, $10 less than the tipping fee at the local landfill, effecting an economic benefit to the project.

? Bituminous Roadways, a Minnesota shingle processor, and the Minnesota Department of Transportation are cooperating on research on using processed scrap shingles as dust suppression on gravel roads. [11] Preliminary feedback has been positive; the shingle scrap resulted in less dust, better driving conditions, and does not need frequent re-application as do conventional dust suppressants. The firm is also exploring the use of processed shingles top-coated with an emulsifier in low volume applications such as driveways and parking areas.

? C.C. Mangum, Inc., of Raleigh, North Carolina, is marketing coarse ground factory scrap shingles as a low-cost driveway and parking area surface treatment. [12] Cost of the material is $9.00 F.O.B. at the Mangum plant.

? Commercial Paving, Inc., Scarborough, Maine, uses tear-off scrap roofing in several different paving applications. [13] Processed shingle material is incorporated in "R&R", a blend of aggregate, crushed and screened demolition waste, virgin aggregates, and an asphaltic emulsifier. "R&R" is manufactured to a variety of specifications, and is used as base and subbase material.

Roofing Shingles in Cold-Applied Asphalt:

? It appears that little applied research has been done with incorporating asphalt shingles into cold-applied paving mixes. The New Jersey Department of Transportation (NJDOT) did pave a small section of a low traffic volume ramp with a "RePave" a shingle based product which is marketed as a pot hole patching material. [14] While the State was pleased with Repave's performance, the product is not available anymore in bulk qunatities.

Button et al., [9] reports that several entities have formulated cold-applied, shingle containing mixtures for light traffic paving applications, but no specific data was available.

- ? Recycled asphalt shingles have been used relatively extensively as an ingredient in cold-applied maintenance mixtures; that is, "cold patch". At least two New England firms; Commercial Paving, Inc., Scarborough, Maine; and American Reclamation Corporation, Charlton, Massachusetts, both produce cold patch in quantities sufficient for municipal and State use. Gardner Asphalt Products, Inc., Tampa, Florida markets "Repave", a blend of ground roofing shingles, aggregate, and emulsifier as pot hole and driveway repair material. RePave is available in 3.5 gallon buckets at home centers and hardware stores for residential use.

  Performance of recycled shingle cold patch material is promising. The combination of hard asphalt, uniform and angular aggregate, and the entrained cellulose or glass fibers apparently make for a quality product that may rival "high performance" cold patch. Results of applications are anecdotal, however:

  - ? NJDOT used "RePave" in a number of maintenance districts in the early 1990s. [14] [15] The NJDOT was pleased with the performance and longevity of the cold patch material, at one time having a sole source waiver to purchase the shingle-based material directly from the vendor.

  - ? The CIWMB reports positive feedback on RePave from a number of New Jersey municipalities, the Washington DOT, and the Placer (CA) County Department of Public Works. [6]

Roofing Shingles in Hot Mix Asphalt (RS-HMA)

By far, the bulk of laboratory and field research on the use of roofing shingles in pavement has been on hot mix asphalt. Testing has been performed, or the material has been used, in Florida, Georgia, Maine, Massachusetts, Missouri, Minnesota, Nevada, New Jersey, New York, Pennsylvania, Maryland, North Carolina, Indiana, Michigan, Tennessee and Texas. [9] An overview of that research, with an emphasis on findings that are germane to Vermont's research project, is presented below.

- ? In 1993, the University of Minnesota conducted research on the use of roofing shingles in a number of bituminous concrete mixtures. [1] From the previous work of others, the researchers noted that the hardness of the asphalt in roofing shingles tended to make a stiffer paving mixture. This stiffness could be problematic in cold climates such as

Minnesota's, so the study focused on cold temperature properties of RS-HMA.

The study evaluated dense-graded mixtures and stone mastic asphalt (SMA) mixtures. The dense graded evaluation included two variations of asphalt cement (85/100 and 120/150 penetration grade), three increments of shingle content (0.0%, 5.0%, and 7.5%) and three types of roofing shingles (fiberglass- backed factory scrap, felt-backed factory scrap, and tear-off). The SMA mixtures were formulated with one grade of asphalt, and one aggregate gradation. The mixtures incorporated either 10.0% fiberglass-backed factory scrap shingles, or 10.0% felt-backed factory scrap shingles. An SMA control mixture contained 0.3% cellulose fiber by weight of mix.

A commercially available RS-HMA was subjected to the same testing procedures.

Among the conclusions were:

? The use of roofing shingles in the mix required less compaction effort to densify.

? A mix using 5.0% of factory scrap shingles resulted in a substantial decrease in cold temperature susceptibility.

? Mixtures containing greater than 5.0% shingles may have a marked decrease in mixture stiffness without a corresponding positive influence on cold temperature susceptibility. This may result in an unacceptable stress at high temperatures and high traffic volumes.

? Moisture sensitivity does not appear to be influenced by the inclusion of shingles in the mix.

? It appeared that the felt-backed shingle mixes would have an increased ability to deform in cold temperatures before thermal cracking occurred. Neither the tear-off or the fiberglass-backed shingle mixes exhibited such behavior.

? Creep compliance analyses led the researchers to conclude that deformation was reduced when shingles were added to a mix prepared with softer (120/150 penetration) asphalt, but that the opposite was true when shingles were added to mixtures using the harder (85/100 penetration) asphalt.

? Concurrent with the University of Minnesota bench study, the Minnesota Department of Transportation (Mn/DOT) constructed three test sections of RS-HMA. [16]

  ? In 1990, Mn/DOT paved a portion of a recreational trail in St. Paul with hot mix asphalt incorporating 6% shingle scrap and 3% scrap tire rubber, and 9% shingle scrap, by weight of aggregate. Both sections have performed well and were in service as of October 1996.

  ? IN 1991, Mn/DOT repaved a portion of a town highway in Mayer using RS-HMA made with factory scrap shingles. The road had last been paved in 1974, and exhibited severe oxidation and longitudinal cracking. The project consisted of a 1.5" leveling course and a 1" wearing course.

    Seven different sections of the road were paved with various amounts (5% and 7%) of shingles in both the binder and wearing courses. Control sections of conventional HMA were also constructed.

    After four years of service, Mn/DOT reported no discernable difference between the shingle scrap sections and the control section.

  ? In 1991, Scott County reconstructed a portion of County State Aid Highway 17, and RS-HMA was used in the base course on 0.5 miles of the northbound lane. Mn/DOT reported that as of December 1995, both the shingle section and control section were in excellent condition.

? As a result of the laboratory and field testing, Mn/DOT has a specification for salvage material in HMA which now includes the use of up to 5% scrap shingles, by weight of aggregate. The shingles can be felt-backed or fiberglass-backed factory scrap; no tear-off roofing is allowed. The manufacturer must certify that the material contains no asbestos.

  Since shingle scrap is an allowable material in HMA, it is the discretion of the contractor to use RS-HMA, and Mn/DOT is not tracking each RS-HMA project. Because there is only one shingle manufacturer and one major shingle processor in the state, the use of RS-HMA is limited to the area served by that particular hot mix plant. [17]

Bituminous Roadways is Minnesota's primary shingle processor. The firm has been processing shingles and producing RS-HMA for about three years. The firm charges the manufacturer $15.00 per ton to accept the shingles. Processing is performed with two Rex "Maxi-grind" rotary drum grinders. Grinding is made easier if the shingles are allowed to age for a year. Just that amount of oxidation hardens the shingles enough to minimize agglomeration of the shreds. RS-HMA produced by Bituminous Roadways is used primarily for commercial and residential paving, such as driveways and parking lots. [11]

? Ross & Associates evaluated the potential use of RS-HMA in North Carolina. [2] The research included laboratory testing of three HMA mixes each utilizing three increments of shingles content (0.0%, 5.0%, and 10.0%). An SMA containing 8.5% shingles and a control SMA containing 0.3% added fiber content were also tested. The results of the testing indicated that:

  ? Tensile strength decreased as the concentration of shingles increased.

  ? The addition of 5% or 10% shingles to the mix significantly hardened the asphalt binder, in some cases more than two penetration grades harder.

  ? The RS-HMA mixes showed decreased susceptibility to rutting based on dynamic creep tests and loaded wheel testing. The authors attribute this benefit to the increased stiffness of the asphalt binder, and the hard, angular granules of the shingle aggregate.

  ? The performance of the shingle-containing SMA was equivalent to the control SMA.

The authors also considered the economics of scrap shingles in pavement. Based on the average cost of asphalt binder and finished HMA in North Carolina in 1997, and a $50.00 per ton shingle processing fee, it was estimated that $1.13 per ton of HMA savings could be realized by incorporating 5% shingles into the mix.

The North Carolina DOT has a specification that allows the use of up to 5% factory scrap shingles in HMA. Currently, one large hot mix producer in North Carolina has an exclusive contract to process all 35,000-40,000 tons of scrap from the CertainTeed Corporation plant in Oxford, NC. [18] The material is incorporated into HMA or used as aggregate.

? The Texas Transportation Institute at Texas A&M University conducted a 1995 laboratory study of incorporating factory scrap and tear-off scrap roofing shingles in HMA. [9] A dense graded mixture and a coarse matrix high-binder (CMHB) mixture were selected as the test mixtures. The shingle material consisted of coarse-ground (-12.5 mm to +4.75 mm) tear-off scrap, fine-ground (-4.75 mm to +180 ?m) tear-off scrap, and (?9.5 mm to -180 ?m) fiberglass-backed factory scrap. After preparation of RS-HMA and control mixtures, the samples were for tested for resilient modulus, indirect tensile strength, moisture susceptibility, and static creep.

The researchers found mixed results for many of the tests, but noted that the incorporation of either factory scrap or tear-off roofing has a negative effect on creep stiffness. The greater the amount of shingle scrap in the mix, the poorer the creep stiffness results. Primarily based on these test results, the researchers do not recommend more that 5% shingle waste be used in HMA until further research has been performed.

The report includes detailed guidelines for shingle processing, RS-HMA mixture designs, mixture production, and RS-HMA placement and compaction. The report also includes an example Texas DOT Specification for "Hot Mix Asphalt Concrete Pavement Containing Reclaimed Roofing Shingles."

? The Georgia DOT has paved two test sections of road using RS-HMA in 1994 [7].

? The first test involved the 1994 widening and reconstruction of the Chatham Parkway in Savannah. A 1500 foot length of the northbound lane was repaved with a 2-inch thick RS-HMA base course, overlain by a 1.5-inch thick RS-HMA wearing course. The fiberglass-backed factory shingle scrap used was generated by GAF, Inc., in Savannah, and shipped to Baltimore for processing. Once processed, the shreds were returned and stored under cover at the asphalt plant. The material was incorporated into the mixture as is convention recycled asphalt pavement (RAP). No special techniques were used in placement, nor were any significant problems encountered.

Mix sampling at the time indicated that the RS-HMA material properties were similar, or slightly improved, as compared to the convention HMA mix. Six core samples (two from the control section, four from the RS-HMA section) were obtained after approximately one year after service; and four additional RS-HMA cores were obtained after 2-1/2 years. Testing revealed that the RS-HMA cores compared well with the job mix formulas and plant mix tests. The only unexpected result was the greater viscosity of the RS-HMA, which may indicate that the shingle modified mix hardens at a faster rate than conventional HMA.

Field observations demonstrate that the RS-HMA is showing little distress, and is performing comparably to the control sections.

? One mile of State Route 21 in Effington County was also repaved with RS-HMA in 1994. This was a simple resurfacing project using the same shingle material and mix parameters as the Chatham Parkway project.

As with the earlier project, mix sampling at the time indicated that the RS-HMA material properties were comparable to the conventional HMA mix. Six cores were taken from the road after approximately two years of service. Those results, and field observations indicate that the RS-HMA is performing well.

? Economic estimates concluded that the incorporation of 5% scrap shingles would reduce the cost of HMA by approximately $1.70 per ton. Disposal cost for the shingles in Georgia was $16.50 per ton; processing costs were about $5.00 per ton, resulting in a significant economic incentive.

Conclusions:

As noted previously, the principal investigators for this project will continue to research new developments on the subject of recycled asphalt roofing shingles in road applications. Research, field testing, and full scale use of scrap shingles in a variety of aggregates, cold applied pavements, and hot mix asphalts is currently occurring throughout the country. Conclusions, at this point, should be then considered as interim. Nonetheless, our research indicates that:

1. The composition and properties of asphalt roofing is well documented, particularly for post-manufacturing “factory-scrap.” Because of age, location, and type of installation, old shingles which were removed from existing buildings (“tear-offs’), are less uniform and more

contaminated.

2. New shingles do not contain asbestos. The percentage of tear-off shingles that contain asbestos is extremely low.

3. Scrap shingle processing techniques and equipment are improving as the processors gain experience. Processing at an asphalt plant with crushers, hammermills, or rotary shredders is the most common technique. Factory scrap is more difficult to process because of the plasticity of new shingles.

4. Roofing shingles processed into aggregate have been used successfully as dust suppression on gravel roads, mixed with natural aggregate as road base material, and as a low-cost "pavement" on driveways and parking areas.

5. Scrap shingles have been incorporated into cold-applied paving asphalt on limited basis. Cold-applied pothole patch is being produced commercially for municipal and State clients, and is available in nationwide in small quantities for residential use. Anecdotal response has been very favorable.

6. Laboratory and field testing of the use of roofing shingles in hot mix asphalt has been ongoing since at least 1987. Pilot projects have demonstrated that shingles can physically be processed and incorporated into HMA. Because shingles contain a high percentage of asphalt, the virgin asphalt content in HMA may be reduced slightly. Laboratory research indicates that RS-HMA performs well for specific situations and mixtures, but as with any pavement, the mix design is critical. Field testing and observations have concluded that RS-HMA has performed as well as control sections of conventional HMA. At least five States (Minnesota, Maryland, Georgia, North Carolina, and Indiana) have standard specifications that allow singles to be incorporated into HMA, generally up to 5% by weight of aggregate, and using factory scrap only.

References:

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

2. Ross, Ben B., An Evaluation of the Use os Hot Mixed Asphalt Pavements Containing Roofing Shingle Material in North Carolina, presented to the North Carolina Department of Environment, Health and Natural Resources, Raleigh, North Carolina, 1997.

3. Witczak, M.W., and Smith, H. A., Recycled Roofing Mixtures in Asphalt Paving Mixtures, University of Maryland, College Park, Maryland, 1994.

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

5. Brock, J. Don, From Roofing Shingles to Roads, Technical Paper T-120, Astec Industries, Inc., Chattanooga, Tennessee, 1996.

6. Asphalt Roofing Shingles Recycling: Introduction, Publication #431-97-031, California Integrated Waste Management Board, Sacramento, California, 1998.

7. Watson, Donald E., et al., Georgia's Experience with Recycled Roofing Shingles in Asphaltic Concrete, Georgia Department of Transportation, Forest Park, Georgia, 1998.

8. Marks, Vernon J., and Petermeier, Gerald, Let Me Shingle Your Roadway, Research Project HR-2079, Iowa Department of Transportation, Ames, Iowa, 1997.

9. Button, Joe W., et al., Roofing Shingles and Toner in Asphalt Pavements, Research Report 1344-2F, Texas Transportation Institute, College Station, Texas, 1995.

10. "Roofing Shingle Scrap," User Guidelines for Waste and By-Product Materials in Pavement Construction, Publication FHWA RD-97-148, Federal Highway Administration, McLean, Virginia, 1998.

11. Personal communication with Mike Jurgenson, Bituminous Roadways, Inc., Minneapolis, Minnesota, August 1999.

12. Personal communication with Shannon Morgan, C.C. Mangum, Inc., Raleigh, North Carolina, August 1999.

13. Untitled information, Commercial Paving Company, Inc., Scarborough, Maine, 1998.

14. Wiessmann, Ross, Recycling Field Research, New Jersey Department of Transportation, Trenton, New Jersey, 1992.

15. Justus, Henry G., New Jersey Department of Transportation Experience with Recycled Materials, New Jersey Department of Transportation, Trenton, New Jersey, 1995.

16. Janisch David W., and Turgeon, Curtis M., Minnesota's Experience with Scrap Shingles in Bituminous Pavements, Minnesota Department of Transportation, Maplewood, Minnesota, 1996.

17. Personal communication with Roger Olson, Minnesota Department of Transportation, St. Paul, Minnesota, August 1999.

18. Personal communication with Marie Sutton, North Carolina Department of Transportation, Raleigh, North Carolina, August 1999.