PERFORMANCE OF RECYCLED ASPHALT SHINGLES FOR ROAD APPLICATIONS

Final Report

September 2002

Carolyn Grodinsky, Vermont Agency of Natural Resources
Nancy Plunkett, Chittenden Solid Waste District
James Surwilo, Vermont Agency of Natural Resources

Foreword

An estimated 10 million tons of waste shingles are generated every year in the United States [1]. Most of these wasted shingles are post-consumer, tear-off roofing shingles; the remainder are factory scraps. Though asphalt shingle recycling is a new industry in the United States, a number of potential markets exist.

Currently, potential end markets for recycled asphalt shingles include: feed stock for hot mix asphalt (HMA) and cold patch, dust and erosion control on rural roads, aggregate for road bases, recycling into new shingles, and fuel. This project, conducted by the State of Vermont's Agency of Natural Resources, focuses on road applications for asphalt shingles including its use as aggregate, cold patch and HMA.

A variety of obstacles exist in the collection, processing and marketing of used asphalt shingles. Asbestos contamination is an ongoing concern. Other contaminants, including nails, need to be thoroughly separated from tear-off shingles during processing before the final product is released.

Of all the potential markets for recycled asphalt shingles, its use in HMA has been the subject of the most national research. Factory scrap shingles are preferred for HMA due to their uniformity and lack of contamination.

A number of states have incorporated recycled asphalt shingles into HMA specifications; these states include Georgia, Maryland, Michigan, Minnesota, New Jersey, North Carolina, Ohio, Indiana, and Florida.

The Vermont ANR designed this research project to be conducted in four phases: Phase I, Literature Search/Waste Shingle Generation in Vermont; Phase II, Evaluate Asphalt Shingles as Aggregate; Phase III, Evaluate Shingles in Cold Patch Asphalt Pavement; Phase IV, Evaluate Asphalt Shingles in Bituminous Concrete. Phase IV was never initiated due to uncertainties regarding funding, suitable project location, shingle feedstock quality, and Vermont Agency of Transportation resources.

Phase I – Literature Search

An Overview of the State of Practice

A literature review was undertaken to identify previous research on the use of waste asphalt shingles in road applications. This review revealed 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 continued to research new initiatives throughout the duration of the project.

Since the initial literature review was completed in mid-1999, the University of Florida – in collaboration with the Construction Materials Research Association, National Roofing Contractors Association, and U.S. EPA Region 5 – has developed a website devoted to asphalt shingle recycling (http://www.shinglerecycling.org/). This website contains a clearinghouse of information on markets, state programs and permitting, and provides links for further literature.

***Asphalt Shingles*:**

The composition and properties of asphalt shingles are characterized in studies by the states of Minnesota [2] and North Carolina [3], the University of Maryland [4], the National Asphalt Pavement Association [5], asphalt plant manufacturer Astec Industries Inc. [6], 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") are removed from existing buildings 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, and 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 that are exposed in the roofing application are comprised of crushed rock coated with ceramic metal oxides, and the headlap granules are coal slag. Both types of aggregate are relatively uniform in 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 established 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. [7] The Georgia Department of Transportation relates that asbestos was used in roofing shingles as late as the 1980s [8], while the Iowa Department of Transportation reports the asbestos usage in roofing shingles was discontinued in 1973. [9] 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 require that 100% of the shingle shreds pass the 19 mm (3/4") sieve, and 95% pass the 12.5 mm (½") sieve. [10] The Georgia DOT requires that 100% of the shingle scrap pass the 12.5 mm sieve. [8] Guidance from the Federal Highway Administration (FHWA) also recommends shreds sized less than ½". [11]

? Crushers, hammer mills, and rotary shredders have been used with various successes 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. [10] 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. Magnets accomplish nail removal after shredding. Blowers or vacuums may remove paper and lightweight contaminants.

***Roofing Shingles as Aggregate*:**

? Although the usage of processed roofing shingles as aggregate in road construction or maintenance seems to be becoming more common, very little scientific research on its performance was found. Most of the projects are field tests or commercial endeavors, 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. [9] 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.

Recycling the shingles was less expensive than disposal. Processing the shingles cost $30 per ton, $10 less than the tipping fee at the local landfill.

? 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. [12] 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. [13] Cost of the material is $9.00 per ton, F.O.B. at the Mangum plant.

? Commercial Paving, Inc., Scarborough, Maine, uses tear-off scrap roofing in several different paving applications. [14] 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 "RePave," a shingle-based product that is marketed as a pothole patching material. [15] While the State was pleased with RePave's performance; the product is not available anymore in bulk quantities.

  Button et al., [10] 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 pothole 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. [15] [16] 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 California Integrated Waste Management Board (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. [7]

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. [10] 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 bench studies on the use of roofing shingles in a number of bituminous concrete mixtures. [2] 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, an advantage in cold climates.

? 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 nor 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. [17]

    - ? 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% factory 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. [18]

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. [12]

? Ross & Associates evaluated the potential use of RS-HMA in North Carolina. [3] 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. [19] 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. [10] 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 mm) tear-off scrap, and (9.5 mm to -180 mm) fiberglass-backed factory scrap. After preparation of RS-HMA and control mixtures, the samples were 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 paved two test sections of road using RS-HMA in 1994 [8].

? 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 was conventional 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 conventional 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 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 (Georgia, Maryland, Michigan, Minnesota, New Jersey, North Carolina, Ohio, Indiana, and Florida) have standard specifications that allow shingles to be incorporated into HMA, generally up to 5% by weight of aggregate, and using factory scrap only.

References:

1. Shinglerecycling.org, <www.shinglerecycling.org>, 2002.

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

3. Ross, Ben B., An Evaluation of the Use of 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.

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

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

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

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

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

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

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

11. "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.

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

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

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

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

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

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

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

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

Phase Ia – Waste Shingle Generation in Vermont

Assumptions:

? Number of Vermont single family and vacation homes = 204,000[a]
? Estimated percentage of homes with asphalt shingles = 0.90[b]
? Average asphalt roofing density = 3.0 lbs/s.f.[c]
? Average roof area = 1850 s.f.[d]
? Lifespan of shingles = 20 years[e]

Therefore,

204,000 ? .0.90 ? (3.0 ? 1850/2000 lb/ton) / 20 = **25,704 tons of waste shingles are generated per year in Vermont.**

Notes:

This figure is a conservative estimate for the amount of asphalt roofing shingle waste generated statewide per year. It does not include commercial buildings, mobile homes, farms and apartments.

---

[a] 1998 Tax Department Figures for single-family and vacation homes.
[b] Estimate provided by four roofing contractors and general contractors.
[c] Average weight from Asphalt Shingle Supplier Directory.
[d] Average roof area from Chittenden Solid Waste District shingle samples to-date (sample size = 20).
[e] North American and Vermont Home Builder Associations and Vermont roofer estimate.

Waste generation estimates will be used in conjunction with the economic data generated during Phase II of the project (shingle collection and processing as aggregate in Chittenden County) to evaluate the feasibility of collecting and processing shingles, statewide, on a permanent basis.

From July 1999 to April 2000, the Chittenden Solid Waste District (CSWD), in conjunction with A. Marcelino and Company, Inc., operated a waste shingle collection program at the Marcelino facility in South Burlington. Participants were not charged a tipping fee. At the time of the collection program, the average Chittenden-area tipping fee was $85.00 per ton.

A form was developed by CSWD to use for enrolling job sites and collecting data. Copies of completed forms were faxed to A. Marcelino. Project participants submitted shingle and tar paper samples from each job site, according to the instructions in the material specifications, to K-D Associates in South Burlington for asbestos content testing. K-D Associates then faxed results of the asbestos tests to CSWD and A. Marcelino, usually within one or two days. CSWD informed the participant of the results.

Participants weighed their loads before delivery. A closed CSWD facility with a truck scale near the A. Marcelino and Company disposal site was available to participants at no charge. Some participants have used other scales in the area.

By April 2000 the goal of collecting 400 tons of waste roofing shingles was nearly reached, and the program was discontinued. The 394 actual tons of shingles were collected from approximately 95 separate roofing projects. A shingle sample from each roofing project was analyzed for asbestos content and only one - from a commercial building - tested positive. A description and spreadsheet of the collection project results is included as *Appendix A1-A5*.

Shingles are no longer accepted for free. For a time, A. Marcelino was collecting waste shingles from area contractors and homeowners but is currently applying for an ANR Solid Waste Management Certification before resuming collection. "Clean" loads of residential shingles were accepted for a $40 per ton fee from May through mid-September 2001, when 74.14 tons of shingles were collected.

Several other firms and public entities have been contacted by the PIs in order to gauge their interest in processing asphalt shingles in Vermont:

?? The Rutland County Solid Waste District owns an Olathe tub grinder. The equipment previously was used to grind mixed construction and demolition waste at the District's facility and at large demolition projects, but is now used exclusively for clean wood, brush and leaf and yard waste. The District once ground asphalt roofing shingles as a pilot test, but found that the material tended to agglomerate as it was processed. Because the District is using the grinder to produce feedstock for composting and fuel for wood-fired boilers, they are not interested in using the equipment for asphalt shingle grinding. The District would embark on a shingle collection program, potentially for shipment to A. Marcelino, if it appeared to be economical.

?? Casella Waste Management, Inc. stockpiles and grinds construction and demolition waste at its regional landfill: Waste USA, in Coventry, Vermont. The grinding is done under contract by a third party, currently Ingerson Transportation, Littleton, NH. Casella has considered landfills in Bethlehem, NH and Clinton County, NY. The decision to perform in-house grinding has not been made, but could include shingles-only grinding.

?? Ingerson Transportation, Littleton, NH, currently performs construction and demolition waste grinding at the Waste USA landfill. The prevailing rate is $3000 per day, plus equipment moving expenses. Ingerson does not believe that their horizontal grinder is suitable for shingles-only grinding.

?? Hammond Lumber, Canaan, NH, grinds construction and demolition (C&D) waste throughout New Hampshire and Maine, and currently grinds C&D for the Hartford, Vermont, solid waste management facility, using a 14' diameter Morbark tub grinder. Fred Hammond, owner, stated that the company would be willing to grind asphalt shingles in Vermont, if economically and logistically feasible.

?? The Addison and Rutland county solid waste districts are considering developing asphalt shingle collection programs, then shipping the collected shingles to Marcelino for processing.

Phase II – Evaluate Asphalt Shingles as Aggregate

The 394 tons of asphalt shingles collected by the CSWD were processed at A. Marcelino for inclusion in a Recycled Asphalt Shingle (RAS)/Recycled Asphalt Pavement (RAP)/gravel mixture for use on unpaved town highways.

The RAP/gravel is produced from a stockpile of waste bituminous concrete and base soils located at Marcelino's South Burlington facility. The material is brought in from Marcelino's own projects as well as from other area contractors. Because of the multiple sources of the bituminous concrete and base soil (state and town roads, parking lots and driveways) the finished material is somewhat heterogeneous. The shingles are double ground to <3/8", the RAP/gravel is crushed to <1½". The mixture is de-nailed by a drum magnet as it travels up the conveyor.

Marcelino believes that the stockpile of RAP and base soil contains approximately 2/3 gravel and 1/3 RAP. Using a bucket loader equipped with a scale, 10% by weight is added to the RAP/gravel mix prior to crushing, to create an approximate 60% gravel, 30% RAP, 10% processed shingle mix. The product exits the crusher's conveyor and falls to the ground for further mixing. The finished RAS/RAP/gravel is then stockpiled or loaded into trucks for hauling.

In the 2000 construction season, RAS/RAP/gravel was placed on two municipal roads:

1. The Town of Hinesburg has utilized 524 tons of a mixture containing 10% RAS, 65% RAP, and 25% gravel on a section of Texas Hill Road (TH 17), a Class 3 Town Highway. The project section of TH 17 begins approximately 0.4 miles east of the junction with SA9 and continues east approximately 0.16 miles. The project section is steeply graded, averaging 14%, and contains a sharp left and right "S" turn. Because of the steep grade, sharp curves, and fairly high traffic volume, the road becomes rutted and "washboard-ed" soon after grading, with a corresponding continual loss of the gravel surface into the roadside ditches. The town must grade the road once every three weeks.

   Prior to resurfacing, the Town re-excavated the ditches along both sides of the road, seeded the exposed areas, and installed jute matting. At the time of the RAS/RAP/gravel installation, grass was beginning to become established. It appears that the road drainage is well managed by the ditches and existing culverts.

   Hinesburg's method of RAS/RAP/gravel installation was to dump, spread, and grade a 3" thickness of the mixture, then roll to compact, then apply calcium chloride. A second 3" thickness was overlain in the same manner so that the result was a 5 - 6" thick, two-lift placement. The Town rented an 11,000 pound front drum/rear wheel vibratory compactor, which was the largest available on short notice. The operator remarked that a heavier and more powerful roller would be preferable, as compaction seemed to be marginal and the machine struggled on the steep grade. The Town applied approximately 100 gallons of liquid $CaCl_2$ per lift. Other than the rental compactor, all work was performed by the Hinesburg Road Crew using Town equipment.

The Town utilized their three dump trucks to haul the material from Marcelino's in South Burlington, which was about a 45-minute round trip. Approximately 100 tons of RAS/RAP/gravel were placed on August 8, about 250 tons on August 9, and the remaining 175 tons on August 10, 2000. The RAS/RAP/gravel mixture was darker and grayer than the normal gravel road surface. Small chunks of RAP were visible in the mixture, but pieces of shingle were difficult to distinguish.

In late October 2000, the road surface was developing washboards from the heavy traffic. According to Hinesburg Road Foreman Mike Anthony, the Town decided to grade the road, but the first grading actually made it rougher. The second grading was done in the rain and the road was very smooth and the material packed well without being rolled. This scenario was corroborated by Nancy Plunkett, Waste Reduction Manager with the CSWD, who lives on Texas Hill Road.

As of June 2001, the Town remained very pleased with the material, believing it required less maintenance than conventional gravel.

The road has remained in good condition through June 2002, developing fewer potholes and necessitating less frequent grading than the control section.

See *Appendix B* for photographs, *Appendix C-1* for location map.

2. On October 2, 2000, 600 tons of RAS/RAP/gravel was placed by the Town of Westford.

The section of road selected for the trial was Town Highway (TH) 3, the Cambridge Road, a Class 2 State Aid town highway. TH 3 extends from Westford village northwest approximately three miles to Fairfax, then continues another one half mile or so to VT 104. Gary Estus, Westford Road Foreman, stated that the road is a popular short cut, and the average daily traffic count was 1500 vehicles. He related that it was difficult to keep a gravel surfaced road in good condition with that amount of traffic.

The project section began at the end of pavement as TH 3 begins from the junction with VT 128 and continued 0.17 miles. The project section begins with a relatively steep down grade to the concrete bridge (B22) over the Browns River then relatively steep up hill with a slight right turn. At mile 0.14, TH 8 intersects on the left side. The project ends in front of the Westford Town Garage.

Prior to commencing the resurfacing program, the Town cleaned and regraded the roadside ditches, and regraded and removed some of the gravel surface. Up to one foot of gravel was removed from the superstructure of the bridge. Mr. Estus stated that a depression would constantly re-form at the bridge approaches from the heavy traffic and the quick change of grade.

The Town contracted with G.W. Tatro, Inc., of Jeffersonville, VT, to haul the shingle/RAP/gravel from Marcelino's in South Burlington. Seven tandem dump trucks were employed, each carrying close to 20 tons of material. Tatro also loaned the Town a Rex SP848 vibratory roller, weighing 16,700 pounds.

The Town's strategy for placement of the material was to dump and grade about a 4" lift, compact the material then apply calcium chloride. The second lift was 2" - 3", and applied in the same manner.

A follow-up telephone call was made to Gary Estus, Westford Road Foreman, approximately six weeks after material placement. Mr. Estus felt that the percentage of RAP and RAS should be increased, and the percentage of gravel decreased. His sense was that the asphalt in the RAP and RAS would cause the mixture to bind better and thus reduce the deformity of the material over time.

On July 25, 2001, a PI viewed the test section and spoke with Mr. Estus. He stated that the road was no better, but no worse than good quality gravel. He did notice a difference in the spring, that the RAS/RAP/gravel road section was ready to be graded earlier than the other roads. Overall, he felt that the road was less muddy and had less drainage problems in the spring, as compared to years past. He also stated that he pays $7.50/ton for gravel and would be interested in RAS/RAP gravel if priced similarly.

As of June 2002, the road contained a number of potholes due to the heavy traffic, but no more so than the adjacent conventional gravel road section. No nails have been found.

See *Appendix C-2* for a location map.

RAS/RAP/gravel was placed on four additional Town Highway test sections during 2001:

1. The Town of Richmond placed 480 tons of RAS/RAP/gravel on Town Highway 31 in mid-July 2001. TH 1 is a flat, low-volume, 0.19-mile "jug handle" off VT 117. Prior to placing the RAS/RAP/gravel, the Town widened the road, replaced culverts and corrected any drainage problems.

   RAS/RAP/gravel was applied to the entire length of the road, 18' wide, and in two 2-inch lifts. Town trucks were used to compact the material, and approximately 130 gallons of calcium chloride was sprayed on the finished surface.

   Peter Gosselin, Richmond Road Foreman, was interviewed in October 2001. Mr. Gosselin stated that he was very pleased about the materials handling characteristics and the finished project. He stated that he had been on TH 31 a few days previous and that the road was in "great shape."

   The road was in excellent condition through June 2002.

   See *Appendix C-3* for a location map.

2. RAS/RAP/gravel was placed on two roads in Huntington. Total tonnage for both projects was 1176 tons.

A 0.31-mile section of TH 4, East Road, was resurfaced with RAS/RAP/gravel on July 9-10, 2001. Based on the USGS topo map, the road rises approximately 200' over the 0.31-mile project length, or an average of 12%. Clinton Alger, Huntington Road Foreman, estimated the average daily traffic at a "couple of hundred" cars per day.

In anticipation of the resurfacing, the town graded the road, installed several new culverts, and cleaned out the roadside ditches. The Town applied a 3 inch lift of RAS/RAP/gravel, sprayed it with calcium chloride, rolled it with a rented vibratory roller, and then repeated the process with another 3" inches of RAS/RAP/gravel. Since Huntington does not have the means to spray $CaCl_2$, the Town borrowed the equipment from the Town of Hinesburg.

In late September 2001, the PIs received notice from the Town that a number of residents were complaining about flat tires on their vehicles from nails acquired on the TH 4 test section. The nearest resident, and only home on the 0.31-mile test section, claimed that she had collected over 100 nails on her daily walks on the road.

In discussing the problem with Alan Marcelino, it appears that at least some of the ground shingles may not have been de-nailed at the time of grinding, rather the RAS/RAP/gravel was de-nailed after blending. If so, the efficiency of the magnet would have been much less, as the nails would need to have been "pulled" from amongst the larger fraction gravel and ground bituminous concrete.

The PIs and Marcelino are exploring ways of rectifying the situation, including removal or replacement of the RAS/RAP/gravel. This appears to be an isolated incident, caused by a change in procedure during material production. No other problems with nails have been reported, including with the second Huntington test section completed a few days later.

Other than the difficulty with the nails, the Town is pleased with the materials performance. The test section has been graded once since installation, as traffic has increased due to a nearby construction project.

The PIs found no nails on a June 2002 site visit. Bill, from the Huntington Highway Department, informed the PI's that the road required less frequent grading than other roads and that he would definitely consider purchasing more of the material if it was commercially available.

See *Appendix C-4* for a location map.

3. The second test section in Huntington was on TH 30, Moody Road. The project location is at an intersection of TH 30 and TH 31 (Carse Road). The test location is steep, with a steep intersection. This combination causes maintenance problems, as gravel is lost through stopping and quick acceleration on the hills. Based on the USGS topo map, the road rises approximately 70' over the 0.13-mile Moody Road project length, or an average of 10%.

This section was completed on July 10 and 11, using the same application method as on TH 4. That is, a 3-inch lift of RAS/RAP/gravel was spread and graded, sprayed with liquid $CaCl_2$, and rolled. The process was repeated for an approximate 6-inch finish thickness. The test section on TH 30 was 710' (and extended 115' up TH 31). No nails were observed on the road surface.

The Town has reported good performance with the RAS/RAP/gravel on this road. As of September 2001, the test section had not needed re-grading.

See *Appendix C-5* for a location map.

4. The Town of Milton applied 1060 tons of RAS/RAP/gravel on TH 54, Watkins Road, on July 30-31, 2001.

Watkins Road is primarily flat. Limited improvements were made prior to the RAS/RAP/gravel application, but overall the road section was in good condition with limited rutting and potholes. Roadside ditching appeared adequate. The RAS/RAP/gravel test section began at the intersection with State Aid 6 and ended at Stewarts Road, which marks the border of Milton and Colchester. Norm Smith, Milton Road Foreman, stated that there were no particular structural problems with the road, and that the road receives a fair amount of residential traffic. The Town is hoping to chip seal this road sometime in the future.

Mr. Smith stated that his crew first spread and graded an approximate 4-inch lift of RAS/RAP/gravel. An approximate 2-inch layer was then placed on top and graded. About 3500 pounds of flaked $CaCl_2$ was spread, and the road section was compacted to a degree with the town trucks. A roller was not used.

In a follow-up interview a month after the installation, Mr. Smith was enthusiastic about the RAS/RAP/gravel. He stated that it "went down well and hardened nicely." The town crew observed no nails or other contaminants. Mr. Smith said he "would like 50,000 tons more."

A PI visited the site on August 29, 2001. The traveled paths where vehicle wheels pass were very hard and flat. The centerline and edges were "loose." Driving on the road was quiet and smooth. The total distance of the test section was 2700 feet (0.51-miles), ending about 0.2-miles from the Colchester town line.

On a site visit on June 2002, PIs learned that test section of Watkins Road had been resurfaced with new gravel due to public complaints of nails mixed in with the RAS/RAP/gravel. The PIs found no nails on the road and Howdy, from the Milton Highway Department, stated that upon inspection, the Highway Department found far fewer nails then the public complaints had lead them to expect.

See *Appendix C-6* for a location map.

5. The Chittenden Solid Waste District used 83 tons of RAS/RAP/gravel at the yard of the Colchester Drop-off Facility.

The Town of Colchester removed the unsuitable soil at the surface and a 6-inch layer of RAS/RAP/gravel was spread over the approximate 75' x 30' area. The material was graded and compacted with a small vibratory compactor.

Lee Tuure, CSWD Operations Manager, stated that he was impressed with the material's consistency and compaction.

As of June 2002, Tuure rated the material 10-15% more compactable/durable than normal recycled pavement. He said that the material was a little dug-up underneath the roll-off containers, but that that was expected, since concrete is the recommended material to use under the containers. He remained very pleased with the material overall. No flat tires or nails have been reported at the Drop-off Facility.

The inclusion of tear-off waste shingles in a gravel/RAP mixture for use as a driving surface on unpaved roads and parking lots appears to have great merit. In all trial applications, the anecdotal responses on performance of the RAS/RAP/gravel have been positive. The 10:30:60 mixture that was used in this project was easy to apply, compacts very well, resists rutting and erosion, and mitigates dust. The equipment to produce the product exists throughout Vermont, and the mixture can easily be modified to road conditions or individual preferences. The persistence of nails in several of the test sections is a problem that would need to be corrected before the material could be marketed.

Phase III – Cold Patch Pavement

Shingle Supply

On November 15, 1999, arrangements were made to purchase 55 tons of double-ground <1/4”, denailed asphalt shingles from Commercial Recycling Systems, Inc. of Scarborough, ME, to be used to create up to 300 tons of cold patch asphalt pavement. Jewell Resources, Lebanon, NH, delivered the ground shingles to Pike Industries, Williston, on November 15, 1999. Inspection of the ground shingles by Pike and ANR personnel (including Buzz Surwilo, VT ANR; Carolyn Grodinsky, VT ANR; Nancy Plunkett. CSWD; and Doug Seyler, Pike) revealed that a substantial amount of nails and staples remained in the shingles. Commercial Recycling Systems was contacted to determine if the load delivered was the correct material; it was. The material had been double-ground and run beneath a magnet after each grind. However, the material had not been screened, something Commercial Recycling Systems usually does before using asphalt shingles to manufacture cold patch. It was decided that cold patch containing such a large amount of such hazardous objects would not be marketable.

Because the binder in cold patch is an emulsion that quickly separates, it must be used within 24 hours of delivery. Unfortunately, due to the nails, the cold patch could not be manufactured within the timeframe and the binder that was delivered for use on November 16, 1999, was returned to the supplier. As a result a second order of liquid binder was placed and arrived on November 22.

On November 20, 1999, the ground shingles were conveyed past the magnet on Pike’s recycled asphalt pavement (RAP) crushing equipment. No nails were found in the several tons of ground shingles that were processed in the trial, and it was decided to convey all 55 tons of ground shingles past the magnet.

Design and Manufacturing

Pike Industries in Williston, Vermont entered into a grant agreement with the State of Vermont Agency of Natural Resources to design, manufacture and then make available to project participants approximately 300 tons of recycled asphalt shingles (RAS) cold patch.

Pike subcontracted the product design to TCG materials, the makers of QPR – a traditional “high performance” cold patch. The typical QPR cold patch design consists of 95% aggregate and 5% liquid asphalt blend. The RAS cold patch mix was determined to be 6% liquid binder (1% more than the standard cold patch), 14% ground asphalt shingles, and 80% aggregate. The cold patch would be heated to 180? F.

274.86 tons of RAS was made on November 22, 1999. Pike stored the material for the ANR and made it accessible to those participating in the testing of the cold patch.

Testing

Beginning in November 1999 letters were sent to those municipalities and VAOT Districts showing interest in the project. By mid-December several municipalities had agreed to test the cold patch. All together, 9 organizations agreed to participate: VAOT Districts 6 and 8, the cities of Barre and Burlington, and the Towns of Shelburne, Essex, Pittsford, Poultney, and Brandon.

Pilot testing began in December 1999 and all 275 tons of the material was used by September 1, 2000 (See *Appendix D-1*). In several instances, particularly towards the end of the project, Pike allowed non-municipalities to obtain the RAS cold patch and these users were not a part of the pilot project. Originally, the PIs developed a log sheet for the participant to record where the material was used, the method of application, consistency, and general comments. As the Phase progressed, the PIs simply solicited verbal comments from the participants about their experience

Several of the organizations have different methods for cold patch application. The following is a description of some of the varying methodologies:

1. Application process used by VAOT District 6:
    - ? Determine potholes to fill
    - ? Broom out the water
    - ? Heat and further dry the pothole
    - ? Fill pothole, tamp with shovel back, cover with sand to prevent from adhering to vehicles tires. Normally, also compact the cold patch with the truck

2. Application process used by Burlington's Department of Public Works
    - ? Applied where necessary, no hot box
    - ? Compacted by driving truck over the pothole

3. Application by the City of Barre
    - ? The morning of or evening before expected use the RAS is heated in the Town's "hotbox" at temperatures between 180?F to 220?F, this improves the materials consistency
    - ? The material is not kept under cover
    - ? Pothole application is "throw and go"

The most representative test of Recycled Asphalt Shingle (RAS) cold patch pavement occurred on VT 109 in Waterville.

The subject project was the repair of a culvert located under VT 109 just north of the intersection with Town Highway (TH) 13, in Waterville. The VAOT District 8 crew had repaired the freeze-prone culvert the previous day. The ensuing repair was about five inches deep, by five feet wide, by the width of the road - about 24 feet. Traffic is light on this section of VT 109, with an Average Annual Daily Traffic (AADT) count of 960.

For a basis of comparison, the strategy was to repave one traveling lane with conventional QPR cold patch, and repave the other travel lane with the RAS cold patch. The conventional cold patch was placed first, on the northbound lane. First, the upper ?5" of soil was removed, and the edges cleaned, of the area to be paved. Then the estimated amount of cold patch material needed for a first (?3") lift was dumped from the truck, roughly spread with a backhoe, then smoothed with shovels and rakes. Finally, the VAOT truck was then driven over the loose cold patch to compact it. The dumping, smoothing, rolling process was repeated for the finished grade.

The conventional cold patch had a very loose, pliable consistency. The pile that was dumped from the truck onto the road tended to slump and spread outward. The material appeared quite "wet". The crew foreman, "Mark", characterized the cold patch as somewhat "self-leveling", and indeed it appeared to be. The material contained no appreciable clumps, and was easily worked with hand tools. The finished surface was quite smooth and level after having been rolled by the dump truck, and passing traffic did not seem disturbed while traveling over the patch.

The RAS cold patch was used on the southbound lane. Again the upper ?5 inches of soil was removed, and the edges cleaned of the area to be patched. The second truck, containing the RAS cold patch, was brought into position. The body was lifted to its full height before the RAS cold patch moved, and when it did, the entire contents of the truck slid out; substantially more than what was needed. Even after being dumped, the pile contained many clumps, up to 12" in the longest dimension. The excess cold patch was reloaded into the truck by the backhoe. The RAS cold patch remaining on the area to be repaired was graded with the backhoe, and it was obvious that that was difficult to do. The RAS was much stiffer, much dryer, and was aggregated into clumps that were difficult to break up. A crew member characterized the material as "*dryer than a popcorn fart*." The material resisted leveling with hand tools. Foot pressure on a clump would cause it to break apart, but not for a few seconds. The material could not be smoothed as well as the conventional material and that characteristic was readily apparent after rolling. Although not unacceptably rough, the finished road surface had a noticeably rougher texture and had slighter up and down contours than the northbound lane.

In conclusion, the conventional cold patch is more easily applied because of its pliable, more liquid, consistency. The RAS cold patch was dryer and harder, which resulted in difficulty machine- and hand- working the pavement. The VAOT crew expressed deep concerns about using the RAS pavement on smaller, shallow repairs, such as a typical pothole. Even in this application, there were concerns about long term cracking and loss of adhesion.

See *Appendix B* for photographs, *Appendix C-7* for project location.

Results

The results from the cold patch have been mixed, and at times even contradictory. Barre has found the material to work very well, have long sticking power, and be easy to use. In contrast, the VAOT District 6 has found the material too stiff to work with and of low quality and stopped using it in mid February.

Comments from Participants

1. Todd Law, Essex Town (June 5, 2000)
   "The cold patch was not utilized, as it contained many 1"- 1 ½" roofing nails creating a hazard/concern for tire puncture/damage.

2. Neil Boyden, Williston, Department of Public Works (April 20, 2000)
   Picked up three 5-gallon pails of RAS cold patch from Pike, then let the material sit in the heated garage for several days. The material did not soften enough so that they would be comfortable using it. They are not planning on taking a greater quantity.

3. Ray Cyr, VOT 6 (March 24, 2000)
   "Testing of the product has ceased, because it is not performing in a manner that dictates further use. The material is dry and chunky; thus it is difficult to use. The dryness has been the direct cause of its not staying in the potholes. The material shows signs of being brittle and spider cracking is evident."

   The construction crews did not like the cold patch at all. They found it very hard to work with.

4. Pat Lefevre, Burlington Department of Public Works
   They have had mixed results with the material. A number of nails were found in the RAS cold patch mixture. The mixture was also fairly stiff making it difficult to work with.

   "Mike" some nails were present in the mixture, however, not enough to really cause concern. The material was stiff which made working with it difficult. Yet, Mike believed if the cold patch was heated it would be significantly more malleable. He thought that using the hot box would help.

Conclusions

There are several theories as to why the RAS cold patch mix was less than satisfactory. Pike cited three possible factors. First, the 55 tons of RAS supplied by Commercial Recycling Systems may not have been of the same quality as the sample, which was submitted for testing some months earlier. If nothing else, the initial sample was free of nails which was not true of the RAS delivered for the cold patch pavement. Second, the 15% shingle content may have been too great. Third, the aggregate in the shingles is of a smaller particle size than the natural aggregate. For that reason, the liquid asphalt content was increased from 5% to 6%, but the increase may not have compensated for the additional surface area of the shingle aggregate. The smaller aggregate may have absorbed more liquid asphalt, resulting in a drier and stiffer mix.

VTrans Bituminous Engineer Timothy Pockette had similar opinions. Mr. Pockette's interpretation was that the finer aggregate and the cellulose or glass fibers in the RAS provided additional surface area for the liquid asphalt to coat. The 1% increase in the asphalt content may not have been adequate to properly coat the 3/8" aggregate, the shingle aggregate, and the fibers in the shingles, resulting in a stiffer mix. Further, the asphalt in roofing shingles is harder than that used in bituminous pavement and this asphalt may not have completely liquefied in the cold patch manufacturing process. The semi-melted asphalt may have bound to pieces of the 3/8" aggregate, causing large globules to form.

See *Appendix D-2* for Pike Industries' evaluation of the product.

The PIs believe that cold patch made with recycling asphalt shingles is viable in Vermont, but that additional mix design research would need to be undertaken before such a material could be commercially marketed.

Phase IV – Asphalt Shingles in Bituminous Concrete

Phase IV consisted of the use of a predetermined quantity of <1/4" ground Recycled Asphalt Shingles in the manufacture and installation of bituminous concrete. The work tasks were scheduled for the 2001 construction season. Originally, it was believed that RAS meeting the <1/4" standard could not be produced locally and that the finely ground material would need to be imported from out of Vermont (and likely from Commercial Recycling Systems). With the experience gained collecting and grinding asphalt shingles since July 1999, A. Marcelino reported that they were capable of producing the shingle feedstock and had the necessary quantity of shingles stockpiled.

In April 2001, the PIs met on several occasions with representatives of VTrans and Pike Industries to discuss Phase IV. The budget, mix design, and project location were discussed. It was agreed that:

? The application that would be most beneficial to the body of research on RAS pavement would be a State Highway pavement project, optimally on a low traffic volume road. Quality control and quality assurance on such projects is much more stringent than on town highway paving projects.

? As a consequence of the dubious results of the RAS cold patch, additional effort should be made in formulating the mix design for the HMA. VTrans could perform the mix design.

? VTrans will locate a suitable test section.

PROPOSED BUDGET

Acquire 64 tons of 1/4" RAS	$2,560
Mix Design, Trial Drop, Binder Testing (if done by Pike)	$20,000
“ ” “ ” “ (if done by VTrans)	?
Produce, Haul, Place 1273 tons of RAS-HMA	$70,000
Testing after placement	$1,200
TOTAL	$93,740

Based on a March 8, 2002, meeting, the uncertainties regarding funding, a suitable project location, shingle feedstock quality, VTrans commitment, and the PIs own lack of expertise in the subject matter has led to the decision to discontinue this final phase of the research project. Further, the PIs believe that blending ground shingles with gravel and/or recycled asphalt pavement (RAP) will ultimately prove to be the most effective use of this waste in Vermont road applications.

Conclusions

Upwards of 10million tons of waste asphalt shingles are disposed of in the United States each year, with an estimated 25,000 tons being disposed of in Vermont alone. Because of the similarity in composition to bituminous pavement, research on the various uses of waste asphalt roofing shingles in road applications has been ongoing at a number of universities, States, and public and private institutions. The focus of the research has primarily been on incorporating recycled asphalt shingles into hot mix asphalt. Based on this research, at least nine States allow some usage of RAS in HMA.

Phase II of this project consisted of the collection of waste shingles, then the design, manufacture, and use of unpaved road driving surface material. This phase demonstrated that contractors and homeowners were willing to separate shingles from other wastes in exchange for reduced disposal cost. The finished product consisted of approximately 10% RAS, 60% gravel, and 30% recycled asphalt pavement. The material was provided free of charge to municipalities in the Chittenden County area. The material was primarily attempted on high maintenance road sections. The RAS/RAP/gravel performed very well according to the municipal officials, resulting in less road maintenance, less dust, and a smoother road surface.

RAS/RAP/gravel can be manufactured by a number of entities throughout the state. The material requires less capital investment to make than either cold patch or HMA, and the inevitable variability of the waste shingle feedstock should not affect the quality of the final product. With satisfactory nail removal, RAS/RAP/gravel will be a superior, economical rural road surface treatment.

Although the results for the pilot cold patch mix were unsatisfactory, the PIs believe that cold patch material can successfully be manufactured using recycled asphalt shingles once the appropriate mix is designed.

Phase IV was not attempted, but the literature suggests that a well-designed HMA containing 5%-7% ground recycled asphalt shingles may perform as well as conventional HMA.

CSWD

CHITTENDEN SOLID WASTE DISTRICT
1021 Redmond Road ◆ Williston, VT 05495-7729
802-872-8100 ◆ Fax: 802-878-5787 ◆ Web: www.cswd.net

1999-2000

**PARTICIPATE IN PILOT PROJECT:
FREE ASPHALT SHINGLE DISPOSAL!**

Dear Roofing and Building Contractors, Waste Haulers, and Homeowners:

The Chittenden Solid Waste District (CSWD), in partnership with A. Marcelino and Company, Pike Industries, VT Agency of Natural Resources, VT Agency of Transportation and VT Local Roads Program, is researching alternative uses for asphalt shingle waste. Three pilot projects will be conducted over the next few years to evaluate the performance of ground shingles in aggregate, cold patch, and hot mix asphalt road applications. The economics of diverting asphalt shingles from landfill disposal in these ways will also be examined.

The first pilot project is underway. We are seeking to collect 400 tons of shingle waste that meet the specifications on the back of this letter. The collection site is located in South Burlington off Patchen Road. **If you deliver shingles that meet the specs, you will not be charged any tipping fee**. We'll take them for **FREE** until we have the supply we need. Shingles that do not meet the specs will not be accepted and must be disposed of properly.

If you are interested in participating in this project or have questions about it, please call me at 872-8100, ext. 222.

Sincerely,

Nancy Plunkett
Waste Reduction
Program Coordinator

OVER

ASPHALT SHINGLE RECYCLING PILOT PROJECT 1999-2000

Specifications for Asphalt Shingles to Be Accepted for Recycling

TO SIGN UP FOR THE PROJECT, CONTACT:
Nancy Plunkett, CSWD, 872-8100, ext. 222; 1021 Redmond Rd, Williston, VT 05495

TYPE OF MATERIALS ACCEPTED
Non-asbestos asphalt shingles of any size, shape or color will be accepted. Tar paper backing and nails are okay. Loads shall be free of contamination such as wood, metal flashing, cans, paper and other types of debris. Loads with contamination will be rejected.

ASBESTOS TESTING
The VT Agency of Transportation (AOT) requires that asbestos testing be conducted on shingles and tar paper backing that will be used in the road aggregate. **AOT will pay for the tests**. For each job site, the following samples will be needed: 1) two 2" squares of shingle samples collected from different locations of the roof (from each layer if more than one), 2) one 2" square of the roofing tar paper, and 3) one 2" square of patching material if present. The samples should be combined in one zip lock bag or other small plastic bag and delivered or mailed to K-D Associates, 1350 Shelburne Rd, Suite 209, So. Burlington, VT 05403 (800-639-2035). On paper inside the bag or attached to the bag, you should include the name of your company, your phone number, the address of the job site, and the words: "Asphalt Shingle Recycling Project". Test results are normally available within 24-48 hours. Test results will be faxed to A. Marcelino and Company and CSWD. Nancy Plunkett at CSWD will call you when she receives your test results. Only asbestos-free shingles will be accepted for recycling.

WEIGHING
In order to track the amount of shingles received for this project and to help estimate total local quantities available for future projects, loads must be weighed before delivery to A. Marcelino and Company. Anyone hauling shingles for the project may use, at no charge, the scale at the Biosolids Processing Facility behind the South Burlington's Wastewater Treatment Facility on Airport Parkway (first driveway on the left after Budget Car Rental if traveling north). The scale is on the right side of the parking area and the read-out is visible through the picture window next to the entrance. The total weight should be written down and provided at the time of shingle delivery along with the name and address of the job site. If you don't know your vehicle's empty weight, reweigh it and report the tare weight to the shingle delivery site. Other scales may be used. If another scale is used, a weight slip must be provided at the time of delivery. If you use a private hauler to transport your shingles, discuss this weighing requirement with him or her.

DELIVERY
Shingles may be delivered to the A. Marcelino and Company site at the end of Landfill Road off Patchen Road in South Burlington behind the South Burlington Drop-Off Center. Loads will be inspected. Any load not meeting the specifications stated above will be rejected. Hours of operation are: MON – FRI, 7:00 AM – 4:00 PM.

FEEDBACK
Participants will be asked to answer a short survey at the completion of the pilot project.

PROJECT PARTNERS
Roofing Contractors, Roofing Waste Haulers, A. Marcelino and Company, Chittenden Solid Waste District, Pike Industries, VT Agency of Natural Resources, VT Agency of Transportation and VT Local Roads Program.

RECYCLED ASPHALT SHINGLE PROCESSING

Chittenden Solid Waste District's grinder processing some of the 394 tons of waste asphalt shingles collected from April 1999 to July 2000.

Stockpiled asphalt shingles at A. Marcelino and Company, South Burlington.

Packer Industries demonstrating their rotary drum grinder on collected asphalt shingles at A. Marcellino

9/20/99

A Marcellino shingle processing equipment, South Burlington.

RECYCLED ASPHALT SHINGLE COLD PATCH

Newly manufactured recycled asphalt shingle (RAS) cold patch at Pike Industries, Williston, Vermont

11/22/99

VTrans trial location for RAS cold patch, VT 14, South Barre, VT

2/22/00

Drying potholes prior to cold patching. VT 14, South Barre

2/22/00

Pothole filling with cold patch, VT 14, South Barre.

2/22/00

Appendix B

VTrans culvert repair, VT 109, Waterville. Northbound lane of road paved with conventional cold patch (complete, to the left) and southbound lane (shown prepared for paving) paved with RAS cold patch.

3/24/00

Culvert repair, VT 109, Waterville. Spreading conventional cold patch with backhoe

3/24/00

Appendix B

Culvert repair, VT 109, Waterville. Compacting RAS cold patch with dump truck.

3/24/00

VTrans culvert repair, VT 109 Waterville. Completed cold patch paving. Conventional cold patch in background, RAS cold patch in foreground.

3/24/00

Appendi
x B

RECYCLED ASPHALT SHINGLES / RECYCLED ASPHALT PAVEMENT / GRAVEL

Placement of a lift of RAS/RAP/gravel on Texas Hill Road, TH17, Hinesburg. A total of 524 tons were placed over 0.17 miles.

8/9/00

Placement of RAS/RAP/gravel on Texas Hill Road, TH17, Hinesburg. A total of 524 tons were placed over 0.17 miles.

8/9/00

Appendi
x B

Completed section of TH 17, Hinesburg, RAS/RAP/gravel. Material was placed in (2) 3" lifts, compacted, and sprayed with calcium chloride.

8/9/00

Transition from control section (background) to RAS/RAP/gravel (foreground), TH 17, Hinesburg. Six weeks after construction, gravel section is noticeably rougher, with potholes and washboards appearing.

9/17/00