SPECIFICATIONS RELATED TO PROJECT SELECTION

Richard C. Ingberg, P.E., Minnesota Department of Transportation

This paper discusses the work done by Mn/DOT in the last several years to develop specifications designed specifically for the maximum use of salvageable materials in the rehabilitation of pavements. It describes the steps leading to recent specifications for hot-mix recycling, the benefits derived, and the anticipated future of such projects. It also lists the problems involved with these specifications because of the general lack of historical information on projects involving recycling and/or rehabilitation. This report also presents information on Mn/DOT's sulfur extended asphalt projects including a sulfur extended asphalt-recycled project. The author recommends the changes that must be made before a specification is developed that allows competition between heater scarification, hot-mix recycling, and conventional hot-mixing. Other areas touched on are; removal, processing, storage and ownership of salvaged materials; different types of specifications; how to write new specifications; and the development of new specifications. The report contends that the design of a specification is so crucial that the very life of the concept (in this case, recycling and/or rehabilitation) may depend on it. One of the final conclusions is that the proper specification can lead to substantial savings. An example is offered where a savings of about 35% was experienced because a contractor was given the option of two specifications.

It is in the public interest for engineers, material suppliers and contractors to conserve resources such as aggregates and asphalt cement so that maximum use may be attained from the available supply. A large source of this supply has been processed and placed in our present pavement structures. Their usefulness as a pavement structure has deteriorated to the point that vehicle operating costs and pavement maintenance costs have increased so that the pavement is no longer efficiently serving it's intended purpose. Sound conservation practices demand that we design specifications to allow the maximum use of these salvageable materials to rehabilitate our pavements as long as their use is compatible with engineering and economic considerations. This paper will discuss some of the experiences in Minnesota to maximize the benefits of recycling salvageable materials. Most of our experience has been with hot-mix recycling. The design of recycling and rehabilitation specifications is crucial to whether or not the recycling of salvageable materials will be economical or even be accomplished at all. Our experience has shown that good specifications result when the interests of the user agency and the contracting industry are integrated and harmonized to produce maximum benefits.

Experience with Hot-Mix Recycling

Maplewood-Urban
1976 20,000 Tons 50-50;40-60 Blends Batch Plant

Minnesota's first hot-mix recycling project was constructed in Maplewood, Minnesota, in 1976. (1, 2, 3) This is the project that gave birth to the heat transfer concept of hot mix recycling. The existing aggregate base and asphalt pavement were processed into recycled base and binder courses. The major specification modifications were to process the salvaged asphalt material to a size smaller than 1½ inches, a provision that the salvaged asphalt mixture would not have to go through the dryer, and the temperature of the clean aggregate in the dryer could exceed the standard specification maximum. We learned that with the addition of 120-150 penetration virgin asphalt cement the penetration of the recovered asphalt cement from the recycled mixtures (new and old) was approximately equal to the penetration obtained by the thin film oven test of the virgin asphalt cement. We also found, in this case, that it was not cost effective to haul salvaged aggregate base material long distances back to the hot-mix plant site due to the low cost of new aggregate material. We were extremely pleased at the minimal cost for modification, the quality of the recycled mixture and the ease of laydown and compaction operations.

Fergus Falls-Rural
1977 50,000 Tons 50-50;60-40 Blends Drum

The following year, 1977, we reconstructed asphalt shoulders on Interstate 094 near Fergus Falls. (2, 4, 5) This was our first rural project and our first dryer drum recycling project accomplished using the heat transfer concept. The salvaged asphalt material was fed into discharge end of the drum with a slat conveyor. We recycled a blend of

salvaged asphalt and salvaged aggregate material from 50-50 to 60-40 without excessive opacity at an acceptable production rate of 300 tons per hour. Although we were able to recycle the salvageable materials in the dryer drum, a continous mix pug mill was placed between the drum discharge and the storage tower in case the drum concept did not work. As the penetration of the old asphalt shoulder was very low (avg. 20) we experimented with adding 200-300 penetration asphalt cement in lieu of the 120-150 penetration asphalt cement we normally use. Even then, we had lower penetration on the extracted asphalt of the recycled mixture than we had anticipated. We believe the lower penetration possibly was due to the recycled material passing through the continous mix pug mill. We were satisfied with the mixture quality and pleased that the heat transfer concept was successful in a dryer drum plant.

Litchfield
1978 100,000 Tons 60-40 Blend Drum

In 1978, we recycled the old bituminous pavement and shoulders on a large rural project between Litchfield, and Atwater, on T.H. 12 (2, 6). On this project we did not specify the size of salvaged asphalt materials entering the drum mix plant. We did specify that the recycled mixture must pass the 2" sieve or one half of the course thickness when deposited into the truck at the plant site. All salvaged asphalt material was processed by dozers running over the stockpile and the use of scalping screens. The contractor would not use this method again due to the cost involved. The recycled mixture was produced at a 60-40 blend of salvaged bituminous material to virgin aggregate at an average production rate of over 450 tons per hour. The salvaged asphalt material entered the drum at the midpoint (center feed). All existing aggregate base was left in place in the roadbed. Base, binder and shoulder wearing courses were constructed with salvaged asphalt material and new virgin aggregate.

Additional Projects 1978
200,000 Tons 60-40;50-50;25-75 Blends

The above project was only one of several hot-mix recycling projects in Minnesota in 1978. We were encouraged by the variety of these projects, two state projects, two city projects, and two airport projects. We thought we were on our way with recycling in Minnesota. What we didn't realize was the amount of effort we were spending lining up specific projects for recycling. We also were unaware that recycling would fall off considerably in 1979.

Projects 1979

1979 was a disappointment for hot-mix recycling in Minnesota. We had very limited tonnage. We were using a permissable specification for recycling on several projects, however, no contractors were producing recycled mixtures on these projects. Because of this, we modified our specifications to pay for the old asphalt in the recycled mixture.

Projects 1980
30-70;40-60;50-50;60-40;70-30 Blends

This year, 1980, Specification 2332 (7) permissable hot-mix recycling produced recycled mix on several projects. We have a large airport runway project, an interstate project, and two trunk highway projects. We have turned the corner in hot mix recycling. Every contractor has the incentive to look at every project and weigh the costs and benefits of recycling vs. conventional mixtures. This specification is a part of all MnDOT projects. (8) No longer do we have to specify hot-mix recycling for specific projects. The contractor decides when and how to recycle and bids accordingly. We recently let a project which included the revised permissable hot-mix recycling specification. The contractors bid for the recycled hot mix portion of the project including mobilization was $547,163.03 compared to the engineers estimate based on conventional construction, of $837,970.85 for the same items. This represents a savings of approximately 35%. The first two bidders bid $65.00 and $66.00 per ton for asphalt cement compared to the engineer's estimate of $163.50/ton. The free market mechanism is working in Minnesota.

Experience with Heater Scarification

We have had limited experience with hot surface recycling in Minnesota. In 1978, we evaluated a project in Fridley. This method used heater scarification, then application of a rejuvenator. A hot mix wearing course was placed on the scarified layer several days later. In 1979, due to a shortage of funds, the state let a maintenance contract to provide a short term solution for a four lane expressway scheduled for reconstruction. This heater scarification procedure used a lead heater scarifier unit followed by a heater scarifier paver combination. Both units had the ability to heater scarify and add emulsified asphalt or rejuvenator. A hot-mix wearing course mixture was placed over the hot heater scarified pavement surface by the trailing unit. Earlier this year (1980) we used heater scarification on a portion of an experimental project using the same method as in Fridley, on a heavily travelled portion of Interstate 094 northwest of St. Cloud. The heater scarifier process was included as part of three 1-mile test sections which were developed to find an economical solution to our thermal cracking problem in the 1½" wearing course and the 2" binder course. The two other sections called for removal of the wearing course and both the wearing and binder courses with subsequent placement of new material. We have made several observations to date. At least on the more heavily travelled pavements, the heater scarification train using a trailing unit to place the hot mix wear course over the hot scarified material shows better pavement performance.

We would like to prepare alternative designs and specifications to allow competition between heater scarification, hot mix recycling, and conventional hot-mix. However, before we can accomplish this we feel some changes in the heater scarification specifications are necessary:

1. We have been unable to find any reference to density or void requirements for the old heater scarified material. We believe this should be required.
2. We also have experienced segregation of the heater scarified material.
3. Another problem is the addition of emulsified asphalt or rejuvenators to the scarified mat. The first problem that comes to mind is the water you are adding to the heated mat. This has to have a cooling affect and we don't believe water has any place in an asphalt pavement.
4. Another question? How do we insure uniform mixing of soft asphalt cement or rejuvenators with the hot scarified mixture.
5. We feel that in Minnesota a 3/4" depth of scarification of the old mat is the practical limit.
6. Many user agencies feel that heater scari-

fication procedures acts as a stress relieving interlayer to reduce reflective cracking. In the past we have not had any success with stress relief interlayers of any type. This does not include recent installations not yet evaluated.

It appears that the train method with the trailing unit (with integral paver) placing a new hot mix wearing course could be modified to produce a pavement structure that would be equal to recycled or conventional hot-mix if we would:

1. Require density and voids similar to those of hot-mix.
2. Insure a uniformly graded mixture without segregation.
3. Insure distribution of soft asphalt cement or rejuvenator in the scarified mat.

With these modifications we could take care of the rideability problem and produce a durable wearing course similar to a hot-mix overlay. This could also eliminate hauling of material to and from the hot mix plant.

Heater scarification could be an alternate to levelling and overlay if the pavement is structurally adequate and used with an overlay.

Experience with Sulphur Extended Asphalt and Sulphur Extended Asphalt-Recycled

1979 was a year we forgot about hot mix recycling. We experimented with two sulphur extended asphalt projects (9). One was a rural project incorporating approximately 44% sulphur to 56% asphalt cement by weight as binder. Gulf Canada provided the blending equipment and expertise. We were pleased with the results. The other project was a sulphur extended asphalt recycled, with salvaged asphalt material as a component as the paving mixture along with sulphur and new asphalt cement. Sulphur Development Institute of Canada provided the blending equipment and expertise. This project assured us that we could combine sulphur with recycled salvaged asphalt material without any problems.

Salvaged Materials

Source of Salvaged Material for Reuse

Where does the material come from to produce recycled pavements? Unless a contractor owns an aggregate supply or some other structure containing reclaimable materials, his source of reclaimed material must be provided by private industry or public agencies. A point to keep in mind is that it is not important where materials are obtained for producing paving mixtures. The quality and gradation of these materials is important as this will determine how they will perform in the pavement structure. Urban projects will differ from rural projects (10). Most of these materials will be derived from existing pavement structures. On large rural projects, the characteristics of these materials can be determined prior to design and construction and will in most cases, be salvaged and recycled into the new pavement structure. On urban projects, due to their relatively small size, the materials removed from the project can not easily be recycled and returned to the same project. Therefore, on urban projects, the quality of the material will be determined from the previously stockpiled material from many and varied sources. However, keep in mind that the characteristics of the materials incorporated into the paving mixture are the important aspects to be concerned about.

Removal of Salvageable Pavement Materials

Asphalt Pavement structures can be removed by ripping, scarifying and then processed for re-use. This is only practical when removing the entire structure. Prior to incorporating this material into a recycled mixture, crushing or processing to a smaller size will be necessary. This can be accomplished with conventional aggregate crushing equipment. The most popular seems to be a jaw with two rolls. The first roll will produce pancakes with the second roll breaking up the pancakes into small fragments. A cone crusher will require the addition of grouser bars on the cone to break up the pancakes into small fragments. Hammermills can be used on recycling projects that require ripping and scarifying. Hammermills most likely will be used for full depth inplace recycling.

Planing, either hot or cold, is capable of removing asphalt pavements to a specified grade or can remove the entire structure. This virtually eliminates the need for a crusher in the recycling operation. Up to 15% oversized material (over 2") can easily be crushed with a dozer at the plant site. It is also possible depending on the expertise and method of recycling to utilize fragments larger than 2" nominal size if the final mixture meets specifications.

Storage and Ownership of Salvaged Material

The entity responsible for producing the recycled mixture should be responsible for the removal, processing and recycling of these materials. For example, some user agencies have specified removal and stockpiling of asphalt pavement structure as a part of a separate grading contract. One of the basic problems in doing this is the lack of interest in retaining the inherent quality of the pavement removed and stockpiled. Experience has shown that deleterious and objectionable material have contaminated the stockpile thereby insuring an inferior recycled mixture with a large potential for premature failure of the recycled pavement structure. It also has allowed time for moisture contents to build up in the stockpile thus requiring fuel for drying, making pollution control more difficult, and reducing the rate of plant production of recycled mixtures. This adds unnecessary expense to the user. A simple way to eliminate this unnecessary expense is to make the removal, processing and stockpiling of salvaged material the responsibility of the persons producing the recycled mixture. Contractors who have this responsibility have the incentive to carefully remove process and stockpile these materials and keep costs to a minimum. This year contractors in Minnesota cover or construct their salvaged asphalt material stockpiles to prevent or reduce moisture buildup. With the price of liquid fuel near $1.00/gallon each 5% of moisture per ton of mixture will require $1.00 per ton to remove the moisture. Many unprotected stockpiles have moisture contents ranging from 5-15%. The user agency should not retain the ownership of salvaged materials unless they are willing to protect its quality. Ownership should go to the person controlling the end use of the material.

The user agency should pay for the removal of materials on a project. These materials will then become the property of the contractor to dispose of as he sees fit. This is what we have been doing with materials removed from all our projects in the past. The only difference was that most of these materials were being hauled to a landfill for disposal or disposed of within the right of way and not used in the pavement structure.

The user agency should allow the contractor to incorporate these potentially valuable materials into recycled mixtures for payment equal to conventional mixtures. In other words, these salvaged materials would continue to be hauled to landfills unless we were willing to use and pay for the recycled mixtures that could be produced from these materials.

By allowing the use and payment for salvageable materials in lieu of conventional materials, the user has established value for salvageable material. Unless this is done, salvageable materials will either be hauled to a landfill or as some enterprising contractors are doing, they will be incorporated into recycled asphalt mixtures for the private market sector.

Development of Permissable Hot-Mix Recycling Specifications

The first step in developing specifications for recycling were the special provisions used for the Maplewood project. We used the maximum size requirements from other recycling projects in Texas and Nevada. We designated the thickness of aggregate base to be salvaged. The gradation of the salvaged aggregate was required to be reasonably uniform from fine to coarse with 100% passing the 1½" sieve. The gradation of the processed salvaged bituminous material was required to have as reasonably uniform gradation from fine to coarse with 100% of the material passing the 1½" sieve.

The salvaged materials were measured and paid for by the ton. They were to be placed in separate stockpiles. We also allowed up to 20% salvaged aggregate to be incorporated into the salvaged bituminous to facilitate crushing or processing.

The standard plant mixed bituminous pavement specifications were modified as follows:

1. The contractor was required to submit an acceptable proposal for preventing or eliminating excess air pollutants.
2. A means for adding the salvaged bituminous material to the heated aggregate after the aggregate has left the dryer. Also positive control on proportioning the salvaged material into the mixture.
3. When adding salvaged bituminous mixture for the bituminous base and binder courses it may not be necessary to run the salvaged bituminous material through the dryer.
4. We gave the approximate mixture proportions which ranged from 20-40%, for salvaged bituminous and 60-80% for the salvaged aggregate.
5. Aggregate leaving the dryer could be heated in excess of 325 degrees F.
6. Costs for equipment modification at a lump sum bid not to exceed $15,000. Also required was the itemized cost for modification.
7. Payment similar to conventional mixtures except there was no payment for old asphalt cement in the salvaged bituminous material.

Our first change to the above special provisions occurred in 1978 when we deleted the 1½" maximum size in the salvaged bituminous material. The maximum size requirement applied to the recycled mixture after being processed through the hot mix plant and deposited into the transport vehicle.

Up to this point in time almost all our projects had been specifically designed for recycling. If recycling was ever going to reach its potential, we had to provide a permissable specification for allowing recycled mixtures in lieu of conventional mixtures on all projects. We also were spending to much engineering time setting up projects for recycling without really knowing for sure, in some cases, whether recycling was cost effective.

Therefore, in 1978, we began the development of a permissable hot mix recycling specification to allow the contractor to use recycled mix in lieu of conventional mix. As a part of this specification, we made several significant changes. The most important change was to establish mix design criteria from recycled mixtures. They are as follows:

Using the representative samples submitted and the proposed proportion of each, trial mix tests will be run to determine the percentage of asphalt, by weight to be added. The following criteria will be used to determine the percentage of added asphalt required:

1. *Marshall Stability (50 below)
   - Minimum..... 500 lbs.
   - Maximum.....3,000 lbs.
2. *Voids in Mix
   - Minimum..... 4%
   - Maximum..... 6%
3. *Cold Water Abrasion Loss
   - Non Wearing..... 15% Max.
   - Wearing..... 10% Max.
4. In no case shall the percentage of salvaged asphaltic concrete in the recycled mixture exceed 70 percent by weight.

* Test procedures on file in the Department of Transportation's Materials Engineering Laboratory at the Transportation Building in St. Paul.

No recycled mixture shall be produced for use on the project until the amount of asphalt material to be added with the appropriate blend has been established.

After the percentage of added asphalt has been determined, it and the proportions of the other materials used in making that determination shall remain in effect until modified in writing.

Another change was establishing a job-mix formula if virgin aggregate was used in recycled wearing course mixtures. The requirements are the same as those required for conventional wearing course mixture. The job-mix formula applies only to the virgin aggregate portion of the recycled wearing course mixtures. The virgin aggregate portions of recycled base and binder courses must meet the broad gradation bands similar to conventional base and binder course mixtures. We do not do design mixes for conventional base and binder mixtures.

This specification was included in many projects to be let in 1979. However, contractors were not using the specification, therefore, the volume hot-mix recycling did not meet our growth expectations. It did not take long to realize that the way our pay items are set up in Minnesota, if we were to continue not paying for the old asphalt cement in our recycled mixtures there would be little, if any, recycling.

This led to our most important and controversial change in our specifications, paying for the old asphalt in the salvaged bituminous material. Several engineers in Mn/DOT did not agree with the philosophy of paying for asphalt cement we already owned. However, the free market mechanism compensates for this in the competition bidding process.

An explanation of why it is necessary to pay for old asphalt cement is best accomplished by the following. The first step before a contractor can build a project is to be the lowest successful bidder. Our permissable recycling specification allowed recycled mixtures in lieu of conventional mixtures. However, if the contractor was the successful bidder and decided to recycle he would

get payment only for the new asphalt cement added to the recycled mixture. For example, if the project called for 20,000 tons of asphalt mixture at a bid price of $10.00 per ton and 1000 tons of asphalt at a bid price of $100.00 per ton, the contractor would be paid $300,000 for the constructed pavement. Remember, first of all, he had to bid low to get the job. Then, if he decided to recycle he would get the bid price for the asphalt mixture and if he saved 500 tons of asphalt cement by recycling he would be paid a total of $250,000 which produces a loss of $50,000.

You can see the contractor had no incentive to recycle. So we had to find a way to compensate the contractor for the value of the asphalt cement in the mixture. The method chosen was the Colorado Extraction method applied to the final recycled mixture. Under the revised specifications the contractor is paid for the amount of virgin asphalt added to the mixture plus the amount of old asphalt in the mixture.

This has been the key to establishing hot-mix recycling in Minnesota as a standard operating procedure. In 1979, we had one supplemental agreement where a contractor used the new specifications. This year, 1980, the permissable specifications are being used on all projects. (7)

Selection of Alternative Recycling and Rehabilitation Procedures

When writing specifications for recycling and rehabilitation procedures, keep in mind who is best able to make the decisions that will maximize the benefits of recycling and rehabilitation procedures. The designer and the staff specialists such as the bituminous engineer, materials engineers, research engineers, planner, etc., have a very important role to play in determining the present condition of the pavement and what the pavement will be expected to provide in the future. A very important factor today is the lack of funds to most cost effectively provide an acceptable transportation system. Funding levels will have a heavy impact on the best available solutions which will provide the most appropriate level of service to the public. Another problem facing us is the lack of a defensible service life of various rehabilitation procedures. In absence of long term evaluation for durability a best estimate of service life must be determined. This is best accomplished by a team of experts. From this best estimate future modification to the estimate will be forthcoming as time and testing provide more precise answers to service life. We are beginning the process of establishing service lives for recycling and rehabilitation procedures in Minnesota. The Federal Highway Administration is also establishing a data bank on recycling projects. This should help guide us in the future.

Method Vs. End Result Specifications

There are basically two types of specifications. Method specifications, which specify exactly how to do the work, what equipment to use, how to use it, and to some extent, what the end result should be. End result specification leaves it up the contractor to provide the end result without instructing him how to produce that end result.

The most practical specification is a combination of method and end result specifications that combines the expertise of the user agency, contractors, material suppliers and equipment manufacturers to produce a good end product almost all of the time at a reasonable cost.

Energy

The engineer need not concern himself with the energy saved or consumed for any design alternative provided the cost of energy is reflected by free market condition and so long as the specifications permit realistic alternatives to the bidders.

Development of Specifications

As you can see, the thrust in Minnesota is to develop permissable recycling specifications along with alternative rehabilitation procedures which will allow the contractors as much latitude as possible. However, this cannot be accomplished unless we find a way to make recycling a standard operating procedure. Each user agency must develop their own standard specifications for hot, cold and surface recycling. In most cases, the state user agency should be the leader in establishing these specifications.

The question then becomes, how do we transition from our past practice of almost exclusively building pavements out of new materials to one of utilizing salvaged or reclaimed materials for reconstructing or maintaining our pavements. This is a new and challenging field. More challenging than new design and construction because we have to find new ways of evaluating recycling methods and materials and predicting their future performance. If you thought performance of our old designs were difficult to determine, recycling procedures are infinitely more difficult to predict. However, we have no choice. We have to make intelligent decisions based on past experiences until more definite data is available for modifying our initial performance predictions. The initial answer will be to look at the properties of these salvaged materials in comparison to the materials used in the past. This is what we have done with hot-mix recycling. This is what we are doing with sulfur-extended asphalt mixtures. (11). As with any new product or procedure, we measure its properties and performance in relation to what we have done in the past.

We cannot wait another 15-20 years to determine the actual service lives of recycling and rehabilitation procedure. By waiting, millions of tons of potentially reclaimable material will be wasted and forever lost at a tremendous cost to the public. Also keep in mind that recycled pavements can have an added bonus of costing less than our conventional pavements. Another important benefit is less demand for new aggregates and asphalt cement, both non-renewable resources. Another important benefit is that landfills in our urban areas will take longer to fill and reduce the demand for new landfill sites further and further from the source of waste material thus reducing the cost of transportation.

Each area of the country must start with the specifications they are now using and begin to modify them by comparison with the practices a number of experienced agencies as expressed in their specifications. There are many specifications to study and evaluate when writing your own specifications. Your specialists responsible for writing your specifications know your area of the country and are best equipped to modify or create specifications that will fit your area. In addition, you should involve the contracting industry to assist and help you write specifications that will allow the free market mechanism to work. There should

be as many alternatives as possible to allow maximum competition which will produce the desired product at the least cost.

In summary, the user agency should:

1. Be responsible for the adequacy of design alternatives.
2. Write simple straight forward specifications which clearly state what is expected.
3. Permit the contractor to select the materials and methods which will accomplish the end result.
4. Use standard specifications familiar to the contractors.
5. Modify standard specifications only as necessary to obtain the end result.
6. Focus on end results by allowing the contractor flexibility in choosing the most economical methods and procedures to accomplish the work.

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