

## Section 8

# RECYCLING OF ASPHALT PAVEMENTS

## 8.1 HOT MIX RECYCLING

Asphalt recycling is not a new idea, since the concept of recycling of asphalt pavements has been around for many decades. However, with increasing economic and environmental needs, asphalt recycling has become a more viable alternative. Aggregate, asphalt binder and fuel costs can be significantly reduced. Depending on the method of milling, the availability and quality of Reclaimed Asphalt Pavement (RAP) material, location of the plant relative to the project, the type of plant used and the amount of moisture in the RAP, a 20% to 40% savings may be realized. Also, in most cases where milling is specified, the Contractor retains the RAP material, which has no cost other than milling, processing and hauling. In addition to recycling of asphalt pavement material, the specifications allow and some contractors are now recycling post manufacturing waste Reclaimed Asphalt Shingle (RAS) material, recycled concrete, tires, glass, slag, and other items.

Article 610-3 and Subarticles 1012-1(F) and 1012-1(G) of the NCDOT Standard Specifications addresses the requirements and policies concerning recycling of asphalt pavements and shingle material. The Contractor has the option to use a recycled plant mix in lieu of virgin plant mix. However, all provisions of the Specifications for virgin mixes apply to recycled mixes. This means that the same tests, test frequencies, and quality control requirements will apply to these mixes. Use of reclaimed asphalt pavement materials is allowed on all standard plant mixes except Open Graded Asphalt Friction Course (OGAFC) mixes and Permeable Asphalt Drainage Course (PADC) mixes.

Recycled pavements can vary widely in their content of reclaimed materials, new aggregates, asphalt binder and recycling agents. Asphalt mixtures containing any amount of reclaimed asphalt pavement (RAP) and/or reclaimed asphalt shingle material (RAS) is considered to be a recycled mix. In current NCDOT recycling specifications the Contractor is allowed to use up to a maximum of 50% reclaimed asphalt pavement (RAP) in the total recycled mixture with the exception of RS9.5D and RS12.5D mixes (maximum 20% allowed). However, the majority of the recycled mixtures incorporate 20% or less RAP in the final mixture. This is due to the fact that NCDOT Specifications generally allow the use of the PG asphalt binder grade typically required for a given mix type when 20% or less RAP is incorporated into the total mix. This allowance is subject to certain viscosity requirements on the asphalt binder in the completed recycle mix. Considering that the asphalt binder contributed from RAP is aged, oxidized and stiffer, a softer, less viscous virgin asphalt binder grade may be required when more than 20% RAP is used to compensate for this increased stiffness. When the amount of RAP is between 20% and 25%, the specifications require the use of a PG binder grade one grade lower (both high and low temperature grade) than the grade normally specified for that mix type. When the RAP percentage is greater than 25 %, the grade determination will be made during the mix design process. The procedure for making this determination is available from the Asphalt Design Engineer located in the Department's Materials and Tests Unit. This procedure is based on information included in the Asphalt Institute publication SP-2 "Superpave Mix Design" (Third Edition). (See Article 610-3 of the Standard Specifications.)

## **8.2 HOT-MIX RECYCLING METHODS**

Recycled mixtures are produced successfully in both batch and drum-mix plants with some plant modifications required for both. All hot-mix recycling of RAP/RAS is done by the "mixer heat transfer method".

In batch plant recycling, the RAP/RAS is fed either into the plant weigh box or into the hot elevator at stockpile ambient temperature. This is accomplished by use of a system made up of stockpiles, feeding bin, feeder and conveyor system. The virgin aggregate is processed as normal through the regular plant feeding system, dryer, elevator, and tower. The virgin aggregate is superheated in the dryer and transfers its heat to the cold RAP material either in the weigh box and plant mixer, or in the hot elevator, hot bins, weigh box, and plant mixer, depending on which type RAP/RAS introduction method is used. Additional asphalt binder is added into the plant mixer unit.

Drum mix plants are more suited for recycling. The most common technique used is the center inlet method, where the virgin aggregate enters into the burner end of the drum and the RAP material enters at approximately the center of the drum. The virgin aggregate has time to cool down the exhaust gases to prevent smoking of the recycled material. As higher percentages of RAP material are used, less virgin aggregate enters the drum, which increases the temperature exposed to the RAP material. Generally, the asphalt line is moved further down in the drum to a cooler zone to prevent excessive smoking of the recycled mixture. Probably the most complex problem of recycling with drum mix plants is air pollution. Smoke should be eliminated and if dust is generated, it should be captured in either a wet wash system or a baghouse. Both of these systems work fine, although certain precautions must be taken with baghouses. Generally, all of the minus  $P_{0.075}$  particles in the RAP material are coated and cannot absorb unburned fuel oil or light ends from asphalt as the virgin fines do. This results in a slow buildup of a sticky cake on the bags and these bags have to be replaced more often. To reduce this problem, highly efficient combustion should be obtained and high quality asphalt should be used which does not emit excessive light ends.

In an attempt to control this air pollution problem, some drum mix manufacturers have modified their plants to further prevent the RAP and/or asphalt binder from direct exposure to the burner flame. Some drum plants utilize a coater box, located past the discharge chute to do this, while others use an inner and outer drum system to accomplish this objective. With the addition of a coater box to a drum plant, the RAP can be introduced further down in the drum and the asphalt binder can be added into the coater box. With the inner and outer drum system ("double barrel drum"), the RAP and asphalt binder are introduced between the two drums. Both of these methods will reduce pollution problems by reducing the amount of RAP and/or asphalt binder exposure to the heat source.

The RAP material is fed to the plant with a conventional cold feeder, although the bin should have a relatively small capacity with steep sides and a wide and long bottom opening for easy discharge and minimal sticking problems. To prevent further compaction of the RAP material, vibrators should not be used on the bin and the RAP should be fed slowly into the bin. Air cannons on the cold bin can satisfactorily prevent RAP consolidation. The belt or slat feeders used to transport the RAP to the weigh hopper or drum should be fairly wide and have sufficient horsepower to be used in a start-stop operation. The RAP feed system should be such that it will provide a good uniform flow of RAP to the mixer unit at all times.

NCDOT Specifications require that the RAP/RAS be automatically weighed and proportioned into the mix, whatever the type plant and/or method of RAP/RAS introduction being used. Batch plants that introduce the RAP into the weigh box accomplish this by simply weighing the RAP in the weigh box the

same as it does the virgin aggregates. Batch plants which feed the RAP into the hot elevator, and all recycle drum mix plants normally will have a belt scale on both the RAP conveyor belt and the virgin aggregate conveyor belt which monitors the weights of these materials. These two belt scales must be interlocked to automatically adjust to the correct percentages. These belt scales should be checked quarterly to insure 0.5% accuracy, and more importantly that the correct proportions of RAP/RAS and virgin aggregates are being maintained.

The amount of RAP/RAS which can be used in a recycled hot mix is controlled by:

- 1) the type plant being used;
- 2) the method of RAP/RAS introduction being used;
- 3) the desired grade of asphalt binder to be used;
- 4) the viscosity and penetration of the RAP/RAS asphalt binder;
- 5) the moisture content of the RAP/RAS;
- 6) the stockpile temperature of the RAP/RAS;
- 7) the temperature to which the virgin aggregate must be heated; and
- 8) the required temperature of the completed mix.

When recycled mixtures are being produced where more than one grade of asphalt binder is required, at least one tank will be needed for each grade of binder or the tank must be completely emptied before a different grade is added. ***Different grades of asphalt binder shall not be mixed.***

### **8.3 COMPOSITION OF RECYCLED HOT MIX ASPHALT (MIX DESIGN & JMF)**

Article 610-3 and Subarticles 1012-1(F) and 1012-1(G) of the NCDOT Standard Specifications addresses the requirements and policies concerning recycling of asphalt pavements and shingle material. The Contractor has the option to use a recycled plant mix in lieu of virgin plant mix. However, all provisions of the Specifications for virgin mixes apply to recycled mixes. This means that the same design criteria tests, test frequencies, and quality control requirements will apply. Use of reclaimed asphalt pavement materials is allowed on all standard plant mixes except Open Graded Asphalt Friction Course (OGAFC) mixes and Permeable Asphalt Drainage Course (PADC) mixes.

For Type RS9.5D and RS12.5D mixes, the maximum percentage of reclaimed asphalt material shall be 20% and the virgin asphalt binder shall be PG 76-22. For all other recycled mix types, the virgin binder PG grade shall be as specified in Table 610-2 of the Standard Specifications for that mix type. When the percentage of RAP is greater than 20% but not more than 25% of the total mixture, the virgin binder PG grade shall be one grade below the specified grade (both high and low temperature grade) for the specified mix type. When the percentage RAP is greater than 25% of the total mixture, the Engineer will establish and approve the asphalt binder grade to be used.

Reclaimed asphalt shingle (RAS) material may constitute up to six (6) percent by weight of total mixture. When both RAP and RAS are used, do not use a combined percentage of RAS and RAP greater than 20% by weight of total mixture, unless otherwise approved. When the percent of binder contributed from RAS or a combination of RAS and RAP exceeds 20% of the total binder in the completed mix, the virgin binder PG grade must be one grade below (both high and low temperature grade) the binder grade specified in Table 610-2 for the mix type.

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The JMF will indicate the total percentage of asphalt binder required for the mixture (by weight of total mixture), the actual binder grade to be used and the percentage to be added to the mixture as required above. The "Pay Item" binder grade for the mix will be as specified in Table 610-2 for the appropriate mix type.

Anti-strip additives are required in all NCDOT Superpave mixes. Depending on TSR test results, different percentages may be necessary and will be indicated on the JMF. The minimum percentage is 0.25% liquid chemical additive (based on the percentage of new or additional binder) or 1.0% hydrated lime (by weight of total dry aggregate). The JMF will indicate the type, percentages, and sources to be used. See Section 4.8 for additional information.

Samples of the completed recycled asphalt mixture may be taken by the Department on a random basis to determine the PG grading of the recovered asphalt binder. If the grading is determined to be out of the specified range, the Engineer may require the Contractor to adjust the additional asphalt binder formulation and/or blend of reclaimed material to bring the grading within the desired range.

Should a change in the source of RAP/RAS be made, a new mix design and/or job mix formula may be required as outlined above.

#### **8.4 PLANT CALCULATIONS AND CONTROL FOR RECYCLED MIXES**

Depending on the type plant being used and the method of RAP introduction into the plant, some plant adjustments may be necessary in such areas as cold feed percentages and hot bin pull percentages.

The RAP is normally fed through a separate cold feed bin from the series of bins handling the virgin aggregates. Because of this, the blend percentages shown on the JMF can not be used in setting and/or checking virgin cold feed bin percentages alone. A recalculation of the virgin aggregate percentages, excluding the RAP aggregate, must be performed. These percentages can be used for setting and checking the virgin aggregate blend by itself. The RAP cold feed percentage is then controlled by either weighing in the correct percentage into the weigh box, or by use of interlocked RAP and virgin belt scales which automatically proportions the correct RAP/Virgin percentage. This depends on the type plant and method of RAP introduction being used.

During production of a recycled mixture, adjustments in the virgin aggregates blend percentages shown on the JMF are occasionally needed; however, the % RAS, % RAP and % Additional binder shall not be changed without the specific approval of the Pavement Construction Engineer or his representative.

Since drum mix plants do not have hot bins, naturally there will be no hot bin pull percentage adjustments necessary. The recycled mix gradation is controlled by the cold feed bin percentages and the aggregate (virgin and RAP) gradations. Neither will there be any hot bin percentage adjustments at a batch plant where the RAP is fed into the hot elevator. Since the RAP passes over the hot bin screens, along with the virgin aggregates, and is sized into different hot bins with the virgin aggregates, the hot bin pull percentages will be computed the same as for a virgin mix. Batch plants that incorporate the RAP into the mix by weighing it directly into the weigh box will require some adjustments to the hot bin pull percentages. The virgin aggregate batch weight must be reduced by the RAP batch weight and the hot bin percentages adjusted based on the effective gradation yield of the RAP. The virgin aggregate batch weight is calculated by subtracting the total of the percent aggregate of mix in the RAP, the percent binder of mix in the RAP, and the percent new binder, from the total batch weight of the mix. The hot bin pull percentages are then determined in the same manner as outlined for virgin mixes, except that the effective gradation yield of the RAP must be considered before determining these percentages. The effective gradation yield of the RAP is computed by multiplying the percent of RAP aggregate only in the mix times the gradation of the RAP.

This effective gradation yield will be provided into the mix in addition to the virgin aggregate gradation, which is controlled by the hot bin pull percentages. Therefore, this effective yield gradation of the RAP must be deducted from the desired JMF gradation requirements prior to determining the virgin aggregate hot bin pull percentages. When determining these percentages using this method, the figures derived will include both the virgin aggregate and the RAP. It may then be necessary to convert the virgin percentages to equivalent percentages for virgin aggregate only. This would be done simply by totaling the virgin aggregate percentages and dividing each individual percentage by that total. This conversion is necessary because the virgin aggregate batch weight is separate from the RAP batch weight and the combined virgin aggregate gradation can be better controlled by this method. The hot bin batch weights are then computed by multiplying the virgin aggregate hot bin percentages times the virgin aggregate batch weight. The RAP and new binder in the mix will be computed separately by multiplying those percentages times the total batch weight of the mix. The scales settings will be accumulative with the virgin aggregate and RAP weight set on the aggregate scales and the new binder weight set on the binder scales.

The QC technician is responsible for determining Hot Bin pull weights. QC technicians should refer to Section 7 of this manual for allowable adjustments in blended aggregates and Hot Bin pull percentages.

## **8.5 QUALITY CONTROL, HANDLING AND PROCESSING OF RAP/ RAS MATERIAL**

Recycled mix quality is directly dependent on the RAP/RAS quality, handling and processing. Only uniform, good quality reclaimed asphalt materials should be used in recycled mixes. The RAP/RAS stockpiles should not be used as disposal sites for all types of unwanted materials. Good quality control is needed to keep contaminants in the RAP/RAS material to a minimum. Prior to stockpiling the RAP/RAS, the area should be cleared and leveled to provide a firm and level base. As with different types of aggregates, each different type of RAP/RAS material should be stockpiled separately. The lowest stockpile height that space will permit should be used and vehicle operation on the RAP/RAS stockpiles should be kept to a minimum to prevent consolidation. While not a specification requirement, it is highly recommended that the RAP/RAS stockpiles be covered to keep the material as dry as possible so that less fuel is needed to evaporate the excess moisture. The RAP/RAS material should be pre-screened before crossing the belt scales on a drum plant or modified batch plant, or before entering the weigh box in a batch plant. Current NCDOT Specifications require that the RAP be such that it will pass a 2 inch sieve prior to introduction into the mixer unit. RAS material must be ground such that it will pass a ½ inch sieve prior to being introduced into the mixer.

It is the Contractor's responsibility to monitor the RAP/RAS stockpiles and verify that the gradation and asphalt content of the RAP/RAS being used is consistent and reasonably close to that of the RAP/RAS used when the recycled mix was originally designed. Recycled mixes are originally designed using samples of RAP/RAS stockpiles that the Contractor has on-hand at that time. These mix designs are considered current and may be usable for several years provided the RAP/RAS remains reasonably consistent and mix quality can be maintained. Although the Contractor's RAP/RAS source may change numerous times during that period, it would be almost impossible and very impractical to redesign these recycled mixes each time the RAP/RAS source changes. The primary concern should continue to be that of maintaining mix quality.

Certain QC field tests must be performed on RAP/RAS stockpiles (See Section 609-5 of the Standard Specifications). Once a stockpile of RAP/RAS has been sampled and these samples used in the mix design process, no other new source of RAP/RAS should be introduced into that same stockpile without prior testing. If the RAP/RAS is from a source other than the mix design source, test must be

performed to verify possible use into an existing job mix formula (JMF). Refer to Table 1012-2 of the Standard Specifications for new source RAP field binder content and gradation tolerances. RAP/RAS from the same source may continue to be placed into that stockpile. Normally this means that a different source of RAP/RAS should be stockpiled separately and tested prior to its use, provided there is a sufficient quantity of RAP/RAS to justify a separate stockpile. It is permissible to combine RAP/RAS from different sources, provided that it is processed and/or uniformly blended during stockpiling and prior to its sampling and testing.

If a Contractor desires to use a new source RAP/RAS in an existing recycled mix, he shall submit evidence of the gradation and binder content to the Department's QA Supervisor. The QA Supervisor may elect to run his/her own gradation and binder content test on the RAP/RAS. If the gradation and binder content are within the specified tolerances given in Table 1012-2, the QC technician may use the new source RAP in a mix subject to satisfactory volumetric tests results on the mix. Once mix production begins, normal random sampling of the mix shall be done. If a new source RAP stockpile is approved for use, the QC technician will perform binder Content and gradation tests weekly to verify that it meets the requirements of Table 1012-2. This procedure applies to all recycled mixes. All required tests shall be performed. If these test results meet the Specification requirements for the existing JMF, the new source RAP may continue to be used in the mix. If any of these test results are unsatisfactory, the QC technician shall contact the QA Supervisor.

If the QC gradation and/or binder content is not within the specified tolerances of Table 1012-2, the Pavement Construction Section should be notified. The QA Supervisor may investigate to determine if the QC test results are correct. A new mix design may possibly be required prior to any further use of RAP that doesn't meet requirements of Table 1012-2. The Pavement Construction Engineer will make this determination.

**New Source RAP Gradation and Binder Tolerances**  
**Table 1012-2**

MIX TYPE	Base	Inter.	Surf.	Base	Inter.	Surf.	Base	Inter.	Surf.
	(0 - 20% RAP)			(20+ - 25% RAP)			(25%+ RAP)		
Binder %	+/- 0.7%			+/- 0.4%			+/- 0.3%		
25.0 mm	+/- 10	-	-	+/- 7	-	-	+/- 5	-	-
19 mm	+/- 10	+/- 10	-	+/- 7	+/- 7	-	+/- 5	+/- 5	-
12.5 mm	-	+/- 6	+/- 6	-	+/- 3	+/- 3	-	+/- 2	+/- 2
9.5 mm	-	-	+/- 8	-	-	+/- 5	-	-	+/- 4
4.75 mm	+/- 10	-	+/- 10	+/- 7	-	+/- 7	+/- 5	-	+/- 5
2.36 mm	+/- 8	+/- 8	+/- 8	+/- 5	+/- 5	+/- 5	+/- 4	+/- 4	+/- 4
1.18 mm	+/- 8	+/- 8	+/- 8	+/- 5	+/- 5	+/- 5	+/- 4	+/- 4	+/- 4
0.600 mm	+/- 8	+/- 8	+/- 8	+/- 5	+/- 5	+/- 5	+/- 4	+/- 4	+/- 4
0.300 mm	-	-	+/- 8	-	-	+/- 5	-	-	+/- 4
0.075 mm	+/- 4	+/- 4	+/- 4	+/- 2	+/- 2	+/- 2	+/- 1.5	+/- 1.5	+/- 1.5

NOTE: Tolerances shall be applied to the RAP gradation shown on the mix design currently being used (M&T Form 601). New source RAP sampled and tested within these tolerances may be used in an existing JMF subject to satisfactory Gyratory and maximum specific gravity test results on the new mix.

## **8.6 COMPENSATION FOR RECYCLED HOT MIX ASPHALT PAVEMENTS**

Current NCDOT Specifications allow a Contractor to furnish a recycled mixture in lieu of a standard virgin mixture, unless otherwise stated in the contract. It should be noted that the contract line code bid items do not distinguish between recycled mixes and standard mixes. Payment for a given type of mix will be at the same unit prices for both mixture and asphalt binder, regardless of whether or not a recycled mixture is used. This method of payment for the mix is used with the assumption that if a Contractor plans to use recycled mixes on a project, he will submit a cheaper bid price than if using virgin mixes, which should result in a cost savings to the Department.

Payment for asphalt binder in recycled mixes will include the total quantity of virgin and reclaimed asphalt binder. The quantity to be paid for will be the theoretical number of tons (metric tons) of the grade of asphalt binder required by the applicable job mix formula based on the actual number of tons (metric tons) of plant mix completed and accepted on the job. The theoretical number of tons (metric tons) will include additional new asphalt binder, salvaged asphalt binder from the reclaimed asphalt pavement material, and salvaged asphalt from the reclaimed shingle material.

Unless otherwise agreed to in writing, the grade of binder to be paid for will be the grade specified for that mix type in Table 610-2 regardless of the grade actually used due to use of higher percentages of RAP. For example: The contract requires a S12.5C mix type. For S12.5C mix, the specifications require a PG 70-22 binder. The Contractor is using 22% RAP in the mix. The contractor must now lower the virgin binder grade actually used to PG 64-28 (one grade lower on high and low end of temperature range). However, the Contractor will be paid at the contract unit bid price for PG 70-22.

Any price adjustments made to the asphalt binder unit bid price due to binder price fluctuations will be applicable to the total binder percentage shown on the JMF, including both additional binder and reclaimed binder. All price adjustments will be based on grade PG 64-22 average FOB selling prices, regardless of grade used or required.

No separate payment is made for anti-strip additive. Compensation is considered incidental to the mix and/or binder price.

## **8.7 MILLING OF ASPHALT PAVEMENTS**

Section 607 of the Standard Specifications addresses Asphalt Pavement Milling. It is important to understand that milling (pavement removal) is a separate entity from hot mix recycled pavements. Milling may or may not be done in conjunction with the production of a recycled mixture. Also, milled pavements may or may not be overlaid with a recycled hot mix. The connection between the two is that the RAP from a milling operation may be used in a recycled mix, within certain restrictions. The purpose of milling is not necessarily that of producing RAP solely for use in recycled pavements. The purpose(s) may include other factors and objectives as discussed below.

Section 607 of the NCDOT Standard Specifications covers milling of asphalt pavements; however, very often milling is covered by project special provisions in contracts. These project special provisions should always be checked since the method of measurement and payment may be different from the Standard Specifications.

When existing asphalt pavement is to be removed, the removal may be done by cold milling with equipment ("milling machine") that has been designed and built exclusively for pavement milling operations.

There are many advantages of milling versus other pavement removal methods. The pavement can be removed quickly with minimum interruption to traffic flow and in some cases the restored pavement can be opened immediately to traffic. Milling is a safe system that involves very few hazardous obstructions in the roadway and is relatively pollution free. The removal of asphalt pavement by milling is not limited to interstate or primary highways, but is also affordable by cities and smaller communities as well as Federal and State agencies. The milling procedure consumes substantially less energy than other methods of pavement removal and the removed material can usually be used again without further processing.

Milling can correct several pavement problems while saving time and money by not having to adjust adjacent structures or geometric designs. Some of the problems which can be corrected by milling are rutting, washboarding, pushing, shoving and bleeding of asphalt pavements. Milling improves the texture for bonding of additional asphalt pavements and retains guard rail heights, curb heights, and bridge clearances. On multi-lane highways, the distressed lane can be milled with limited inconvenience to the traveling public. Also, the desired profile and cross-sections of roadways can be restored so that drainage systems can function properly.

The specifications require the use of milling machines equipped with an electronic control system which will automatically control the longitudinal profile and cross slope of the milled pavement surface through the use of a mobile grade reference(s), an erected string line(s), joint matching shoe(s), slope control systems, or other methods or combination of approved methods. An erected fixed stringline must be used when required by the contract. Unless stated otherwise, a mobile grade reference system capable of averaging the existing grade or pavement profile over a minimum 30 foot distance or by non-contacting laser or sonar type ski systems with at least four referencing stations mounted on the milling machine at a minimum length of 24 feet must be used. Locate the position of the grade control system such that the grade sensor is at the approximate midpoint of the mobile reference system.

A machine capable of leaving a uniform surface suitable for handling traffic without excessive damage to the underlying pavement structure must be used. Use a milling machine and other loading equipment capable of loading milled material to be used in other parts of the work without excessive segregation.

The existing pavement must be milled in a manner which will restore the pavement surface to a uniform longitudinal profile and cross section in accordance with typical sections shown in the plans. Where indicated in the plans or project special provisions, remove pavement to the specified average depth and specified cross slope. Establish the longitudinal profile of the milled surface by a mobile reference system on the side of the cut nearest the centerline of the road. Establish the cross slope of the milled surface by an automatic cross slope control mechanism or by a second skid sensing device located on the opposite edge of the cut. The Engineer may waive the requirement for automatic grade and/or cross slope controls where conditions warrant.

Thoroughly clean the milled pavement surface of all loose aggregate particles, dust, and other objectionable material. Disposing or wasting of oversize pieces of pavement or loose aggregate material will not be permitted within the right of way.

Pavement removal operations must be conducted in a manner that effectively minimizes the amount of dust being emitted. Plan and conduct the operation so it is safe for persons and property adjacent to the work, including the traveling public.