CHAPTER 8. HOT MIX ASPHALT RECYCLING (CASE HISTORY AND QC/QA)

INTRODUCTION

The purpose of this chapter is to present a selected case history of hot mix asphalt recycling, and a summary of Quality Control/Quality Assurance (QC/QA) practices. The first part of the chapter presents a case history and the second part presents the specifications, and QC/QA practices.

CASE HISTORY

A summary of performance results from several states was presented in chapter 2 "Performance Data of Recycled Mixes." Hot mix asphalt recycling is no longer considered an experimental process. It is routinely used by most states in the U.S. The following is a selected typical case history which gives development of recycled mix design, mix production, and construction.

A hot mix recycling job was done on Traffic Route 72 (Lebanon County, Pennsylvania) in 1982. This stretch of the pavement had an average daily traffic (ADT) count of about 5,000, with approximately 10 percent truck traffic. A control section was also constructed with conventional rehabilitation technique. The recycled project consisted of using recycled hot mix asphalt in the base course. The recycled asphalt pavement (RAP) material was obtained from Traffic Route 22 by milling to a depth of 40 mm (1½ in). The RAP was taken to a hot mix plant for recycling as a base course. The RAP stockpile was sampled at ten locations. The ten samples were subjected to extraction test to determine the average asphalt content and gradation of the RAP. The average asphalt content was determined to be 5.4 percent. The average gradation of the RAP, virgin coarse aggregate (AASHTO 57), and virgin fine aggregate (F.A.) are given in table 8-1. It was decided to use 20 percent RAP in the recycled mix. The proportions of coarse and fine aggregate were determined so that the total blend met the Pennsylvania DOT specification for bituminous concrete base course (BCBC) as shown in table 8-1. It was assumed that the total asphalt content in the recycled mix was equal to that used in 100 percent virgin base course mix, which was 4.0 percent. The percentage of new asphalt binder was, therefore, calculated as follows:(1)

Table 8-1. Average gradation of RAP and Pennsylvania DOT specification for bituminous concrete base course. (BCBC).

Sieve	RAP 20.0%	AASHTO 57 63.3%	F.A. 16.7%	Total Blend	Spec.
38 mm (1-1½")	100	100	100	100	100
12.5 mm (½")	100	50	100	68	40-75
4.75 mm (No. 4)	84	4	100	36	20-47
2.36 mm (No. 8)	65	2	76	27	15-37
75 mm (No. 200)	18	0.3	6.5	4.9	2-6

$$P_{nb} = \frac{(100^2 - rP_{sb})\,P_b}{100\,(100 - P_{sb})} - \frac{(100 - r)\,P_{sb}}{100 - P_{sb}}$$

where:

P_{nb} = Percent of new asphalt binder in recycled mix (plus recycling agent, if used), expressed as whole number

r = New aggregate expressed as a percent of the total aggregate in the recycled mix expressed as a whole number

P_b = Percent, estimated asphalt content of recycled mix assumed to be the same as that of 100 percent virgin HMA mix or determined as an approximate asphalt demand of combined aggregates

P_{sb} = Percent, asphalt content of reclaimed asphalt pavement (RAP)

The percentage of new asphalt binder, P_{nb}, was determined as follows:

$$P_{nb} = \frac{(100^2 - 80 \times 5.4)\,4}{100\,(100 - 5.4)} - \frac{(100 - 80)\,5.4}{100 - 5.4} = 2.9\%$$

Therefore, percent virgin or new binder in the total binder = $\frac{2.9}{4.0} \times 100 = 72.5\%$

Asphalt cement was recovered from the RAP by the Abson method and its viscosity was measured at 60ºC. The viscosity was 60,000 poise. The blending chart in figure 8-1 was used to determine the grade of the virgin asphalt cement to be used in the recycled mix. According to the blending chart, the virgin asphalt cement should have a viscosity of about 800 poise. Therefore, an AC-10 asphalt cement with a viscosity of 1,000 ± 200 poise was selected.

HMA mixture containing 20 percent RAP and 2.8 percent AC-10 asphalt cement was prepared in the laboratory and tested for volumetric properties (such as air voids and VMA) and Marshall stability and flow. The mix met the Pennsylvania DOT specifications and, therefore, approved for use.

A batch plant was used for producing the recycled base course mix containing 20 percent RAP. The RAP was directly introduced to the weigh hopper of the batch plant. The RAP was fed into the RAP bin with a front end loader. A RAP feeding bin of small size, with steep sides, wide and long bottom opening was used to facilitate easy discharge of material and reduce sticking of RAP at the sides. No vibrator was used in the bin. A grizzly screen was used to scalp off + 50 mm (+ 2 in) material. The operation of the conveyor belt was interlocked with the operation of the RAP bin feeder. This enabled the simultaneous stop/start operation of conveyor and the RAP bin feeder. The mix was transported to the Traffic Route 72 site with trucks and laid with conventional paver. The compaction was done with a vibratory roller. Quality control tests on the recycled HMA mixture (such as asphalt content, gradation and volumetric properties) showed that the recycled mix met all the Pennsylvania DOT specification requirements for 100 percent virgin mix. Table 8-2 shows average test data (31 samples) on the percentage of material passing 2.36 mm (No. 8) and 0.075 mm (No. 200), percent asphalt content, and percent air voids in compacted Marshall specimens. The test data is quite consistent and is equal to or better than that of a 100 percent virgin mix. Control charts depicting the mix composition and volumetric properties of the HMA were also maintained during the production of the recycled mix.

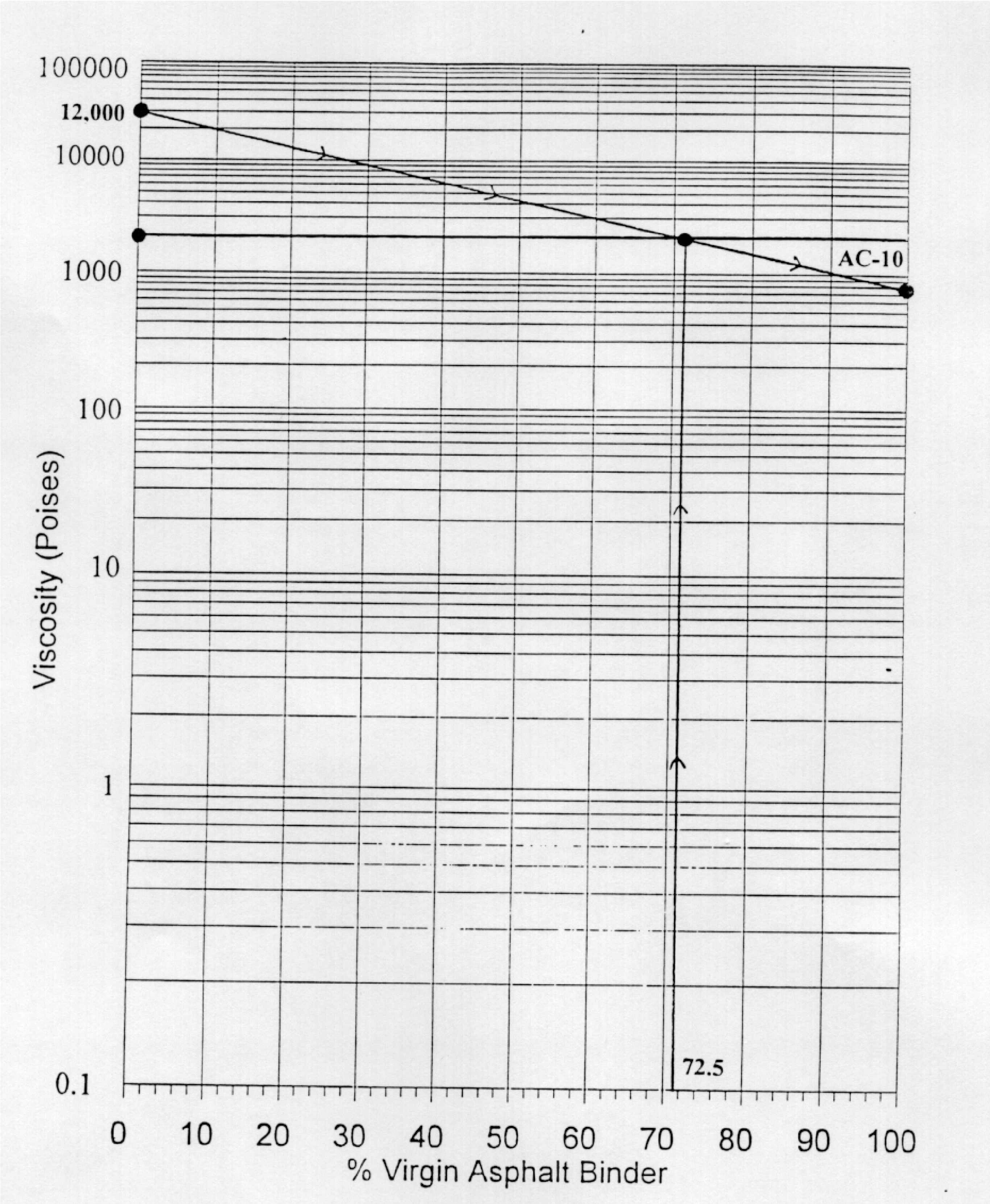

Figure 8-1. Blending chart for selection of virgin asphalt cement grade.

Table 8-2. Recycled mix production test data.

	Percent Passing		Asphalt Content (%)	Air Voids (%)
	2.36 mm (No. 8)	0.075 mm (No. 200)		
Design	27.0	4.9	4.0	5.5
Average (N = 31)	26.5	5.6	4.0	4.5
Standard Deviation	1.3	0.6	0.17	0.5
95% Confidence Limits	± 2.6	± 1.2	± 0.34	± 1.0

Distress surveys conducted after 10 years of recycling indicated no difference between the recycled and control sections in terms of rutting and cracking.

QUALITY CONTROL/QUALITY ASSURANCE (QC/QA)

Good QC/QA practices are essential to obtain a satisfactory HMA. QC normally refers to those tests necessary to control the HMA production and to determine the quality of the HMA being produced. These QC tests are usually performed by the contractor. QA refers to those tests necessary to make a decision on acceptance of a HMA and hence to ensure that the product being evaluated is indeed what the owner specified. These QA tests are normally performed by the owner. QC/QA of recycled HMA is not significantly different than those of conventional HMA except that some additional tests need to be performed when producing recycled HMA. For example, the asphalt binder need to be recovered from the recycled mix and tested for consistency (penetration, viscosity or $G^*/\sin\delta$). The following QC/QA procedures apply to both conventional and recycled HMA mixes except those specifically mentioned for recycled mixes.

Testing of the asphalt mixture during production is essential to ensure that a satisfactory product is obtained. The tests that should be performed during manufacture and placement of HMA may include aggregate gradation, asphalt content, temperature, mixture properties of laboratory samples, theoretical maximum density, and in-place density.(2)

Aggregate Gradation

For QC/QA testing, aggregate samples are typically taken from the stockpile, cold feeder belt, hot bins (if applicable), and extracted asphalt mixture. The gradation of the aggregate from the asphalt mixture is of most importance since this is the end product; however, the aggregate gradation must be controlled at the other points to ensure that the gradation of the final product is satisfactory. Since the RAP may have a significant amount of material passing 0.075 mm (No. 200) (generally referred to as the P200 fraction) sieve, the P200 in the total gradation must be monitored closely.

The aggregate and RAP stockpiles should be sampled and tested during the mix design process and approved for use. Once production begins, it is only necessary to sample new aggregate material that is added to the aggregate stockpile since the overall stockpile gradation has already been determined. The new material added to the stockpile must have the same gradation as the original stockpile, within reasonable tolerances, otherwise the gradation of the final mixture is affected. Causes in gradation variations at the stockpile include changes at source, segregation during hauling or stockpiling, and sampling and testing errors. No new RAP should be added to the RAP stockpile which was used for developing the mix design.

The second typical location for taking aggregate samples is the cold feeder belt. This belt contains the combined aggregate being fed into the HMA facility. Variability of gradation that results at this point is caused by variations in stockpile gradations, segregation of aggregate, improper loading of cold feed bins, improper setting of individual cold feed bins, and sampling and testing errors.

The third location for sampling aggregate is in the HMA batch plant hot bins (drum mix plants do not have aggregate hot bins). Causes for variability here include improper gradation fed from cold feeder, erratic feed from dust collector system, changing production rate (screening efficiency changes with production rate), blinding screens, holes in screens or bin walls, and sampling and testing errors. The hot bins, if operated correctly, will partially correct for gradation fluctuations coming into the plant.(2)

The fourth location for determining gradation is from the produced HMA. The sample is normally taken from loaded trucks but can be taken behind the asphalt paver. This test, which is performed on the finished product, must be controlled because it is the one on which acceptance of the mixture is normally based. Variability of gradation at this point (for a batch plant) could involve incorrect hot bin gradations, incorrect percentage of material from each hot bin, change in RAP composition, segregation of aggregate traveling through the plant or in the storage silo, and sampling and testing errors. For a drum mix plant, the causes of variability at this point include improper cold feed gradation, erratic feed from the dust collector, change in RAP composition, segregation of aggregate traveling through the plant or in the storage silo, and sampling and testing errors.

Evaluation of the gradation at several locations allows the engineer to troubleshoot the gradation problem and quickly identify the location where it is occurring. For instance, if the stockpile gradation is satisfactory but the cold feed gradation changes, then the problem areas are likely to be segregation of mixture, improper loading of cold feed bins, or sampling and testing errors. These items can be quickly checked and modifications made to correct the problem.(2)

Asphalt Content

Another mixture property that must be evaluated is asphalt content. The asphalt content of HMA is very important to ensure satisfactory performance. A HMA mixture with low asphalt content is not durable, and one with high asphalt content is not stable. The actual asphalt content directly affects mixture properties, such as asphalt film thickness, voids, stability (Hveem or Marshall), and Marshall flow. Therefore, it is important to monitor asphalt content, but it is really these mixture properties that need to be controlled.

The asphalt content of a mixture is measured by extraction test (AASHTO T 164) or with a nuclear gauge (ASTM D 4125). The extraction test involves adding a solvent to the asphalt mixture to dissolve the asphalt cement. The asphalt cement and solvent are then passed through a piece of filter paper, but the aggregate is now allowed to pass. This is not a highly accurate test but it is widely used for measuring asphalt content. One advantage of the extraction test when compared to nuclear asphalt content gauge is that it allows determination of the aggregate gradation of the mixture. A disadvantage of the extraction test is that the solvent used is hazardous and is difficult to dispose.(2)

The National Center for Asphalt Technology (NCAT) has developed a test method to determine the asphalt content of HMA mixtures by ignition. The test method is based on research started in 1990 at NCAT.(3) In the NCAT ignition method, a sample of HMA mixture is subjected to an elevated temperature of 538ºC (1000ºF) in a furnace to ignite and burn the asphalt cement from the aggregate. NCAT’s work has resulted in a test procedure and equipment that automatically measures the asphalt content in 30-40 minutes. The grading of the aggregate can then be determined using standard sieve analysis. Based on round robin studies conducted by NCAT in which 12 laboratories participated, the accuracy and precision of the NCAT ignition test was found to be better than those of the solvent extraction method. Therefore, this test method (AASHTO TP 53-95) is increasingly replacing solvent extraction methods, which are being eliminated due to growing health and environmental concerns associated with the use of chlorinated solvents.

Improper asphalt content can be caused by several factors in a batch plant. These causes include inaccurate aggregate scales, inaccurate asphalt cement scales, leaking valve in asphalt cement pot, segregation, and sampling and testing errors. Causes of incorrect asphalt content in a drum mix plant include inaccurate aggregate belt scales, improperly calibrated asphalt cement meter, incorrect moisture content correction for aggregates, segregation, and sampling and testing error.(2)

Field Management of Volumetric Properties

The Federal Highway Administration (FHWA) Demonstration Project No. 74 has clearly shown that significant differences exist between the volumetric properties of the laboratory designed and plant produced HMA mixtures. The volumetric properties include voids in the mineral aggregate (VMA) and voids in the total mix (VTM). The FHWA project concluded that a field mix verification of the material produced at the HMA facility should be included as a second phase in the mix design process. This also applies to recycled HMA mixtures. Mix verification is defined as the validation of a mix design within the first several hundred tons of HMA production. Field management of HMA provides a viable tool to identify the differences between plant produced and laboratory designed HMA mixes and effectively reconcile these differences.(4) The National Center for Asphalt Technology (NCAT) conducted a statistical analysis of field data from 24 FHWA demonstration projects to develop practical guidelines for the HMA contractors to reconcile the differences, thereby assisting them to consistently produce high quality HMA mixes.(5) Recycled HMA mixtures were used on some projects. The field data was analyzed first to identify and, if possible, quantify the independent variables (such as asphalt content and the percentages of material passing 0.075 mm (No. 200) and other sieves) significantly affecting the dependent variables such as VMA and VTM. The following conclusions were drawn from the

NCAT study:

1. Significant differences exist between the volumetric properties of the laboratory designed and plant produced hot mix asphalt.
2. VMA is most affected by the amount of material passing 0.075 mm (No. 200) sieve and the relative proportions of coarse and fine aggregates.
3. VMA can be increased by reducing the amount of material passing 0.075 mm (No. 200) sieve or natural sand in the HMA mixes. VMA can also be increased by moving the aggregate gradation away from the maximum density line (MDL) especially for HMA mixes with no natural sand.
4. VTM is most affected by asphalt content, material passing 0.075 mm (No. 200) sieve, and the relative proportions of coarse and fine aggregates.
5. VTM can be increased by reducing asphalt content and material passing 0.075 mm (No. 200) sieve.

Flow charts were developed as general guidelines for reconciling the VMA and VTM difference between the laboratory designed and plant produced HMA mixes. These flow charts are given in figures 8-2 and 8-3.

Construction

The temperature of the mixture during production should be closely monitored. The temperature must be just high enough to provide good coating on the aggregate and to allow for satisfactory compaction. The temperature of the recycled mix need to be monitored more closely when the recycling is done in a batch plant rather than a drum plant.

The TMD (Theoretical Maximum Density) should be measured on a daily basis, since this is needed to calculate voids in the mixture and is used in some cases to specify density. A change in TMD indicates a change in asphalt content, aggregate gradation, specific gravity and absorption of the aggregate, RAP composition, or sampling and testing errors.

Compacting the asphalt mixture to a satisfactory in-place density is required for satisfactory performance. Two methods that are used for checking in-place density are nuclear gauges and cores. The nuclear gauge is generally preferred for QC testing while cores are desirable for QA testing. When the nuclear gauge is used for QA testing, some cores must be taken routinely for verifying the accuracy of the nuclear gauge. Low density can be caused by inaccurate reference density, improper gradation or asphalt content, a mixture temperature which is too low, a layer thickness which is too thin (cools quickly and bridges under rollers) or too thick, improper rolling techniques, inadequate rollers sampling and testing errors.

Testing and Quality Control Charts

Testing Frequency. It is impossible to establish one desired testing frequency for all projects. Factors that may affect testing frequency include the size of project, importance of project, and variability of materials. However, the suggested number of tests in Table 8-3 is provided as a rough guide to the actual minimum number that should be conducted on a project. Obviously, the specifying agency's guidelines should be followed, if available.

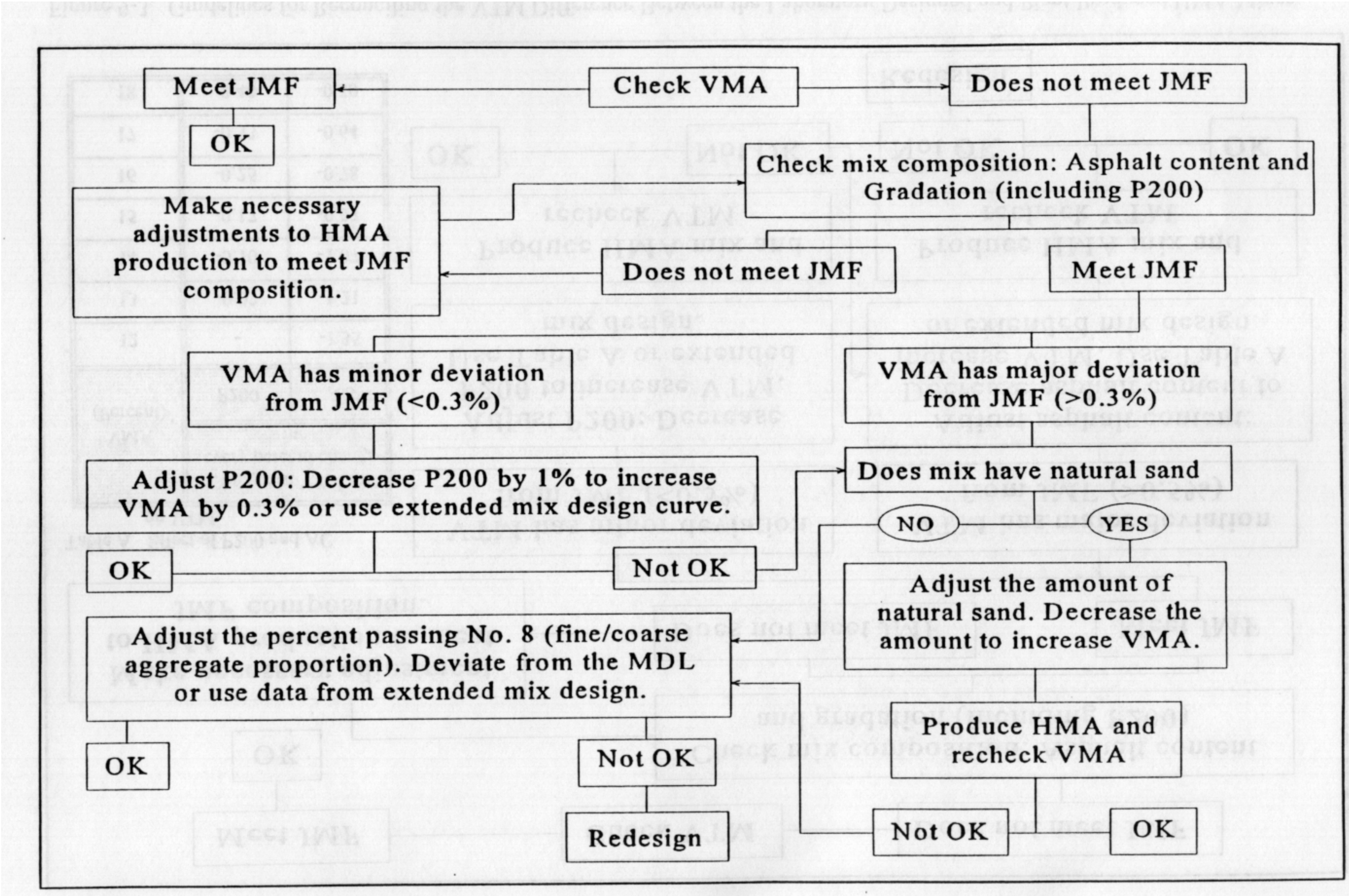

Figure 8-2. Guidelines for reconciling the VMA difference between the laboratory designed and plant produced HMA mixes.

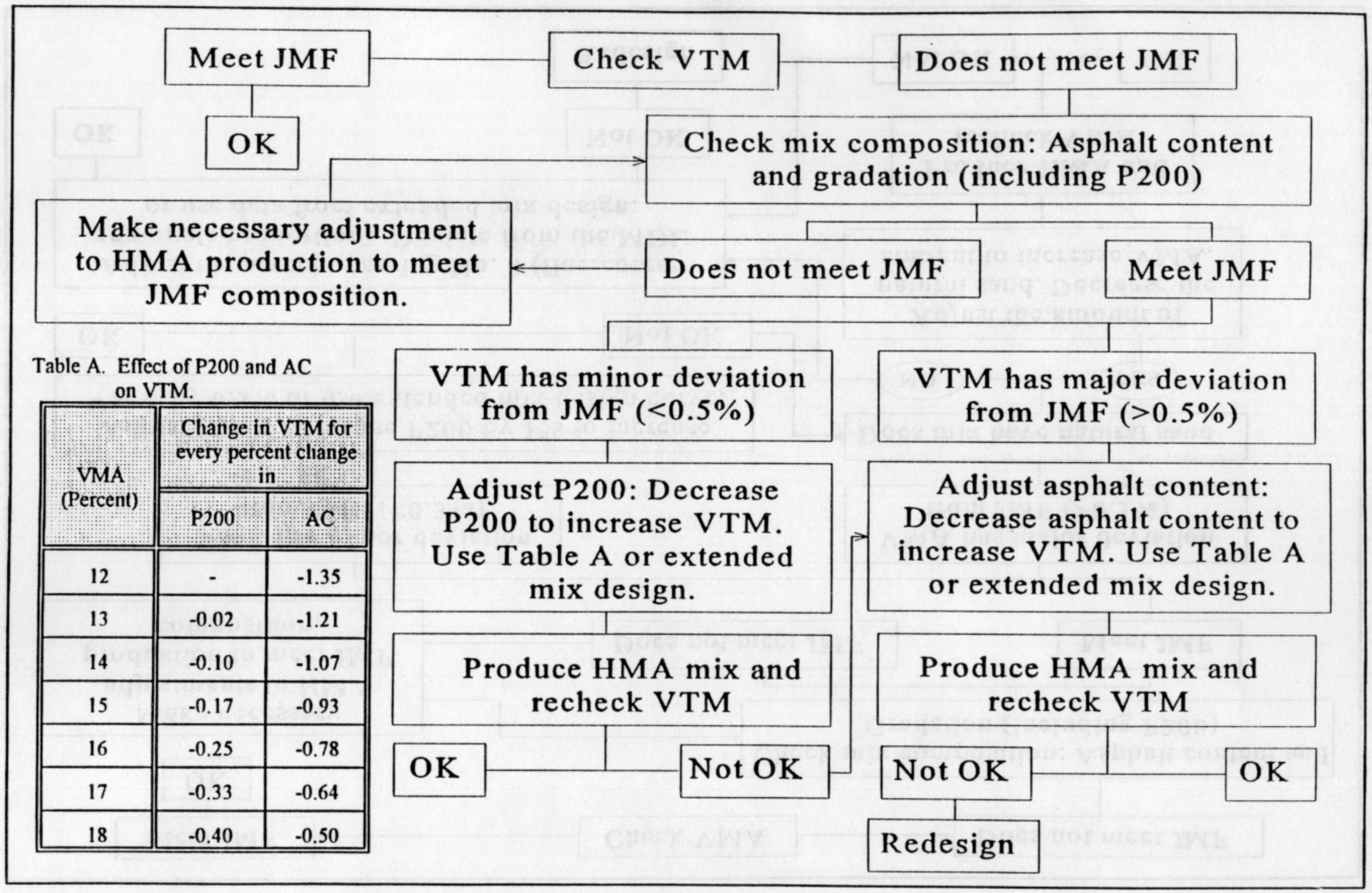

Table A. Effect of P200 and AC on VTM.

VMA (Percent)	Change in VTM for every percent change in P200	AC
12	-	-1.35
13	-0.02	-1.21
14	-0.10	-1.07
15	-0.17	-0.93
16	-0.25	-0.78
17	-0.33	-0.64
18	-0.40	-0.50

Figure 8-3. Guidelines for reconciling the VTM difference between the laboratory designed and plant produced HMA mixes.

Technician Qualifications. Sampling and testing errors can be a high percentage of the overall variations in test results. For this reason it is essential that testing technicians be highly qualified to ensure that sampling and testing errors (for some tests this is over 50 percent of variability) are minimized. Many states have begun to require certification of technicians (state and contractor) that work on state or federally funded projects. More emphasis needs to be placed on this technician certification program to ensure that all projects have qualified personnel performing QC and QA tests.

Quality Control Charts. Analysis and evaluation of test results must be performed during the progress of work for adequate control of the project. The best way to monitor the quality of work during construction is with control charts. Control charts are simple methods of graphically displaying the QC data as it is developed. Control charts are helpful in detecting trends which may lead to HMA production out of specified tolerance limits.

QC/QA procedures are also applicable to recycled HMA mixtures used in the Superpave system.

Table 8-3. Suggested number of tests per project.

Test	Frequency
Stockpile gradation	1 per day
Cold feed gradation	1 per day
Hot bin gradation (if applicable)	1 per day
Extracted asphalt content and gradation	2 per day
Laboratory compacted samples voids, stability, flow	2 sets per day
Theoretical maximum density	2 per day
Temperature	Regularly throughout day
In-place density	6-10 per day
RAP composition (asphalt content and gradation)	1 per week (more if RAP is very variable)
Consistency of asphalt binder recovered from recycled mix	1 per 1000 tons of HMA (more at the beginning of the project)

SUMMARY

The use of hot mix asphalt recycling is no longer considered an experimental process. A selected case history of hot mix asphalt recycling shows that the recycled mix met all DOT specification requirements for 100 percent virgin mix. The test data on the recycled mix was found to be quite consistent and equal to or better than that of a 100 percent virgin mix. However, it must be noted that good quality control and quality assurance (QC/QA) practices are essential to obtain satisfactory results with recycled mix. Testing required for proper QC/QA control include testing of asphalt mixture during production, gradation testing of aggregates from stockpile, feeder belt, bins and extracted aggregates from asphalt mixtures. The asphalt content of the recycled mix and the RAP material should be determined. After design, during field production, the mix should be verified for proper VMA and VTM. If any significant difference is found between designed and produced mixes, the VTM or the VMA can be adjusted by changing the percent passing 0.075 mm sieve. During placement of the mix, proper temperature required for coating and compaction of the mix must be obtained. For satisfactory compaction, the density of the in-place mix should be checked in terms of the theoretical maximum density, which should be determined before compaction. Finally, quality control charts should be maintained so as to identify any trend which may lead to HMA production out of specified tolerance limits.

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