

# TechBrief

The Asphalt Pavement Technology Program is an integrated national effort to improve the long-term performance and cost effectiveness of asphalt pavements. Managed by the Federal Highway Administration through partnerships with state highway agencies, industry and academia, the program's primary goals are to reduce congestion, improve safety, and foster technology innovation. The program was established to develop and implement suggestions, methods, procedures and other tools for use in asphalt pavement materials selection, mixture design, testing, construction and quality control.

Office of Preconstruction,  
Construction, and  
Pavements

FHWA-HIF-20-033

Date: April 2020



U.S. Department of Transportation  
**Federal Highway Administration**

## Asphalt Materials Quality Assurance Practices

*This Technical Brief provides an overview of asphalt materials quality assurance with a focus on acceptance risks and potential strategies for minimizing them.*

*The contents of this document do not have the force and effect of law and are not meant to bind the public in any way. This document is intended only to provide clarity to the public regarding existing requirements under the law or agency policies. This document references American Association of State Highway and Transportation Officials (AASHTO) standards which are private, voluntary standards that are not required under Federal law.*

### Introduction

Many State Highway Agencies (SHAs) have asphalt material design standards, policies, test methods, practices and specifications associated with quality assurance (QA). QA is defined as “All those planned and systematic actions necessary to provide confidence that a product or facility will perform satisfactorily in service” (1). QA involves continued evaluation of planning, design, development of plans and specifications, advertising and awarding of contracts, construction, maintenance, and the interactions of these activities. There are six core elements of a QA program. They are contractor quality control (QC), agency acceptance, independent assurance (IA), dispute resolution, laboratory accreditation, and personnel certification. Agency specifications outline the proper application of QA, but not everyone always interprets the specifications the same nor uses them the same way. This is particularly important with the trend of reduced SHA staffing and increased contractor responsibility for asphalt mixture design and QC activities (2). Therefore, agency acceptance responsibility is critically important in a QA program. The public's money is spent on asphalt materials and SHAs ultimately have responsibility to verify that the public is getting what it pays for.

Performing QA results in assigning separate responsibilities to the SHA and the contractor. These responsibilities typically include design, SHA acceptance activities and contractor QC. In assigning these responsibilities it is possible to inadvertently create increased risk related to acceptance. Examples include those related to sampling, testing, inspecting and/or reporting as well as many more. These risks can occur if the contractor is assigned responsibility for activities that otherwise would be performed by the SHA. Risk can also occur if activities are performed by the contractor that benefit from SHA controls (monitoring) to assure that risks related to acceptance is minimized, but inadequate controls are in place.

In the context of QA, risks are defined as “the probability of suffering harm or loss” (3). Simply put, they occur when product is accepted when it should not be (buyer’s risk) or alternatively, when product is rejected when it should not be (seller’s risk). These concepts which seem simple, are not so simple in practice and the determination of them depends on the type of acceptance plan the SHA uses. As defined in AASHTO R-10, *Standard Recommended Practice for Definition of Terms Related to Quality and Statistics*, an acceptance plan is defined as an “...agreed upon process for evaluating the acceptability of a lot of material. It includes: lot size and sample size (i.e., number of samples), quality measure, acceptance limit(s), evaluation of risks, and pay adjustment provisions” (1). AASHTO standards are private, voluntary standards that are not required under Federal law. A thorough description of all aspects of QA is covered in Reference 4, “Optimal Procedures for Quality Assurance Specifications.”

When risks are not managed properly, the impact can result in pavement distress, which in turn can lead to unplanned costly repair. Management of risks is also important to contractors to help assure they are bidding and operating on a level playing field with competition. Furthermore, deviation from standard practices tends to increase the risk to one or both parties because of the uncertainty of the result.

## **Purpose**

The purpose of this TechBrief is to provide information that could help SHAs strengthen their QA programs and to communicate the importance of reviewing specifications for risks related to acceptance. It can be used to identify common items for risks related to acceptance and as a tool for communicating the importance of addressing them in specifications, policies, and standards. The TechBrief includes a series of common examples of risk along with strategies a SHA could use to mitigate them.

## **Statistical Risks**

Risks associated with asphalt materials acceptance plans can include buyer and seller risk as well as payment risk. Buyer’s risk ( $\beta$ ) is also called “agency risk” or “risk of a Type II or beta ( $\beta$ ) error.” It is the risk to the agency of accepting rejectable quality level (RQL) material or workmanship. The simplest determination of risks is related to “accept/reject” acceptance plans. For this type of acceptance plan it is the probability that the plan leads to accepting RQL material or workmanship with respect to a single acceptance quality characteristic (AQC) when it should be rejected. For acceptance plans using adjusted pay schedules it is the probability that this type of plan leads to erroneously accepting RQL material or workmanship at 100 percent pay or greater with respect to a single acceptable quality characteristic (AQC). Seller’s risk ( $\alpha$ ) is also called “contractor’s risk,” or “risk of a Type I or alpha ( $\alpha$ ) error.” This is the risk to the contractor of having AQL material or workmanship rejected. For an accept/reject acceptance plan, it is the probability that an acceptance plan leads to erroneously rejecting AQL material or workmanship with respect to a single AQC when it should have been accepted. For acceptance plans using adjusted pay schedules, it is the probability that this type of plan leads to erroneously accepting AQL material or workmanship at less than 100 percent pay with respect to a single AQC.

Expanding on these risk factors has evolved as acceptance plans now commonly include pay adjustment schedules that relate alpha sub pf ( $\alpha_{pf}$ ) and beta sub pf ( $\beta_{pf}$ ) to payment based on the quality being measured (3). For these risks to be balanced, the acceptance plan would allow for both payment incentive and disincentive. The SHA should determine the risks associated with the acceptance plan to assure the agency’s oversight responsibilities are being met and buyer and seller risk are balanced. Further discussion of agency and contractor responsibilities can be found in “Use of Contractor Test Results in the Acceptance Decision, Recommended Quality Measure, and the Identification of Contractor/Department Risks,” FHWA TA 6120.3 (5).

## Engineering Risks

Engineering risks associated with asphalt materials QA programs can be grouped into three categories:

- Mixture Design – Will laboratory-mixed materials remain consistent when they are plant produced?
- Mixture Design Verification – Changes are inevitable between laboratory mixture design and asphalt plant production. An initial check between laboratory and plant produced materials is done to verify what/if any changes have taken place. The question becomes “Have the materials remained essentially the same to produce the same mixture properties?” A further question becomes “When changes are found what is going to be done to correct the situation?”
- Acceptance – When acceptance tests are run on plant mixed materials, are the same laboratories and test equipment used as were used in earlier laboratory or verification testing?

The answers to these questions associated with asphalt materials, mixture design, construction, QC and acceptance have a high potential for risk that are impacted by:

- Measurement and use of aggregate specific gravities.
- Aggregate absorption.
- Ignition furnace and use of correction factors.
- Making adjustments to mixtures from the mix design to plant production.
- Use of reclaimed asphalt materials (RAM) (i.e., reclaimed asphalt pavement (RAP) and/or reclaimed asphalt shingles (RAS)).
- Use of different tests in construction than are used in design (moisture damage example).

Each of these tests, adjustments, or change of materials adds a level of complexity that can have a significant effect on engineering and acceptance risks.

## Examples of Potential Risks

Some examples of potential QA risks related to mixture design, verification and acceptance are listed in Table 1. An explanation of the risks and potential risk mitigation strategies for each one follows.

Table 1. Examples of Potential Engineering Risks.

Activity	Potential QA Risk Item
Mixture Design	Ignition Furnace Asphalt Correction Factor
Mixture Design	Aggregate Specific Gravity
Mixture Design	RAM Specific Gravity
Verification	Mixture Adjustments
Acceptance	Aggregate Specific Gravity
Acceptance	Relationship of Properties
Acceptance	Recycled Materials

### Ignition Furnace Asphalt Correction Factor in Mixture Design

Most SHA specifications include the quantitative evaluation of asphalt content as an AQC determined per AASHTO T308, *Standard Method of Test for Determining the Asphalt Binder Content of Hot Mix Asphalt (HMA) by the Ignition Method* (6). AASHTO standards are private, voluntary standards that are not required under Federal law. Loose mixture tested is typically exposed to temperatures in excess of 1000°F in the ignition furnace with a forced draft exhaust system. The combination of material, temperature and equipment conditions normally results in a loss of aggregate during the test. When

asphalt content is calculated based on the initial mixture sample mass and final aggregate mass after burning, a correction is needed to account for the aggregate lost during the test. A unique asphalt content correction factor (CF) is determined for each mixture/ignition furnace combination by performing the test on two precisely prepared samples of known asphalt content. The average difference in the known asphalt content and measured asphalt contents is the CF. It's important to note that a unique CF for each mixture tested is need for each ignition oven used. In other words, a correction factor determined using one ignition furnace cannot be used for another ignition furnace.

The ignition method is straightforward, but incorrect application of the procedure can lead to increased acceptance risk. One example is having one lab determine a CF and then sharing the same CF for use in both SHA and contractor ignition ovens. Another example is allowing a lab, other than a SHA laboratory to prepare CF samples for the SHA's ignition furnace. It is not uncommon for the mixture design laboratory to prepare CF samples for both the SHA and QC labs as part of the mixture design process out of convenience. However, if the mixture design lab in not a SHA lab, then the SHA should prepare its own CF samples. This assures that they are accurately prepared to the target asphalt binder content with or without the correct amount of RAM.

Recently completed NCHRP Research Report 847, Variability of Ignition Furnace Correction Factors quantifies variability that typically occurs with the ignition method in terms of precision and bias, and highlights some important specific aggregate characteristics (7). An interlaboratory study to assess the precision of ignition method CFs using four mixes revealed that the average within-laboratory standard deviation for the CF was 0.113, with a range of 0.074 to 0.178. The average between-laboratory standard deviation for the CF was 0.227, with a range of 0.111 to 0.403. These results show that substantial errors in reported asphalt content could occur for different mixes if the same CF is used with different ignition furnaces. Other findings were that mixtures with higher CFs tend to be more variable and that some aggregates, such as dolomitic material, can experience significant breakdown in an ignition furnace.

### **Risk Mitigation Strategies**

To minimize risk associated with reported asphalt binder values a SHA could:

1. Only allow the SHA to prepare its own CF test samples.
2. Per AASHTO T 308 (a private, voluntary standard), for each mixture and each ignition furnace, conduct unique CF determinations.
3. Not allow sharing of CFs between multiple ignition furnaces, even if they are the same brand in the same laboratory.

### **Aggregate Specific Gravity in Mixture Design**

Aggregate specific gravity is the ratio of an aggregate's density to the density of water. The density of an object is the ratio of its mass to the volume it occupies as illustrated for aggregate in Figure 1. There are several specific gravities important to asphalt mixture design and volumetric properties that include:

- $G_{sa}$  = apparent specific gravity of aggregate has the smallest volume and is the largest number.
- $G_{sb}$  = bulk specific gravity dry of aggregate has the largest volume and is the smallest number.
- $G_{se}$  = effective specific gravity of aggregate has a volume between  $G_{sa}$  and  $G_{sb}$  and, is thus, between the two values.
- $G_{mb}$  = bulk specific gravity of mixture is calculate using the bulk volume of compacted mixture.
- $G_{mm}$  = maximum specific gravity of mixture is calculated using the voidless volume of the mixture.

$G_{sa} > G_{se} > G_{sb}$  It is important to note that  $G_{sa}$  has to be greater than  $G_{se}$ , and  $G_{se}$  has to be greater than  $G_{sb}$ . If this does not occur, then a calculation or measurement mistake has occurred.

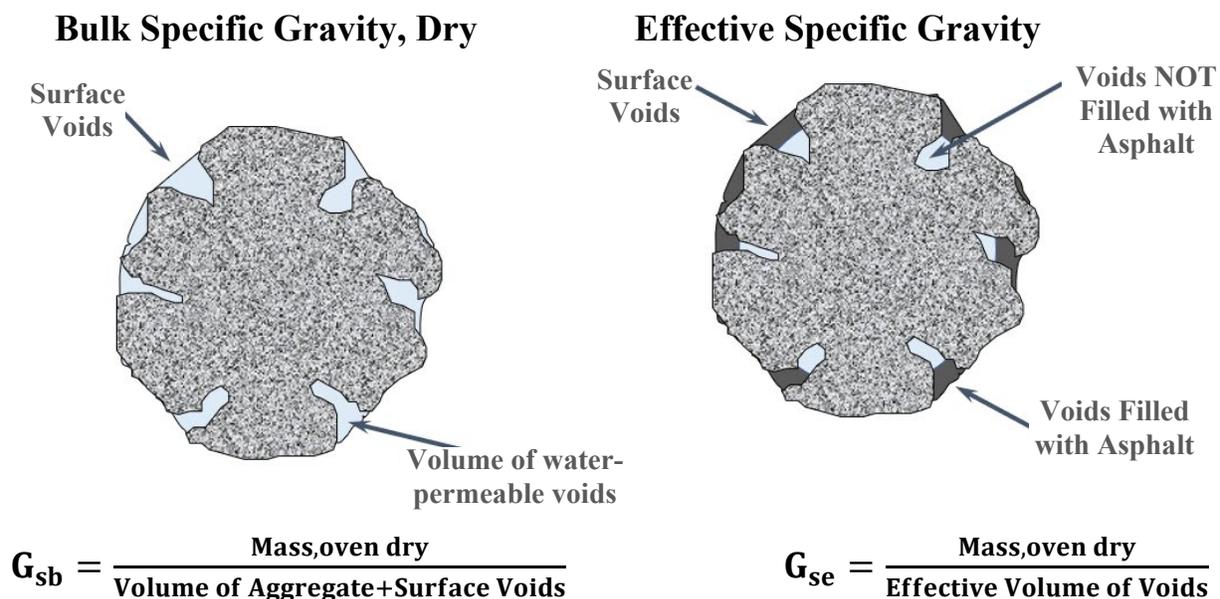


Image: University of Nevada Reno

Figure 1. Different aggregate specific gravities.

The AASHTO M323, *Standard Specification for Superpave Volumetric Mix Design*, has minimum voids in mineral aggregate (VMA) criteria (8). AASHTO standards are private, voluntary standards that are not required under Federal law. This VMA criteria can be a challenge to meet with some aggregates, and as VMA increases the asphalt binder content in a mixture increases, thus increasing mixture cost. VMA is calculated using aggregate specific gravity and other properties. So, it's important that the right aggregate specific gravity, which is the bulk specific gravity dry ( $G_{sb}$ ), be used. It is also important that the  $G_{sb}$  of an aggregate source be measured frequently enough by the SHA to assure the value used for mix design and field acceptance is representative. Using the wrong specific gravity results in incorrect VMA. If the wrong specific gravity is used and is higher, then the VMA calculated is artificially higher than the actual value, resulting in lower than necessary asphalt binder in the mixture, and thus increases the performance risk for the SHA.

Table 2 illustrates how one-one hundredth increments in artificially high  $G_{sb}$ , from using  $G_{se}$  of RAM for  $G_{sb}$  of RAM, results in over reported VMA. It also shows how much lower the corresponding asphalt content of the mixture is. A couple of easy checks that can routinely be done to help prevent this are to make sure  $G_{sa} > G_{se} > G_{sb}$  and to check that the absorbed asphalt binder value is reasonable. Asphalt absorption can't be negative and should be about one-half of the water absorption.

Table 2. Artificially high  $G_{sb}$  impact on reported VMA and reduction in asphalt binder.

Artificially High $G_{sb}$	Increase in Reported VMA (%)	Reduction in Asphalt Binder (%)
+0.01	0.3	0.15
+0.02	0.6	0.30
+0.03	1.3	0.60

Some SHAs measure  $G_{sb}$  and allow a tolerance around the observed when reviewing mixture designs submitted by contractors. Tolerances of 0.02 to 0.04 have been used. Figure 2 shows a comparison of SHA and contractor reported  $G_{sb}$  values over a ten-year period in one State. If the results were normally distributed due to random variability there would be about 50 percent of the observations above and below the line of equality. The figure shows only 22 percent below and 76 percent above the line, indicating a bias in contractor data higher than SHA data.

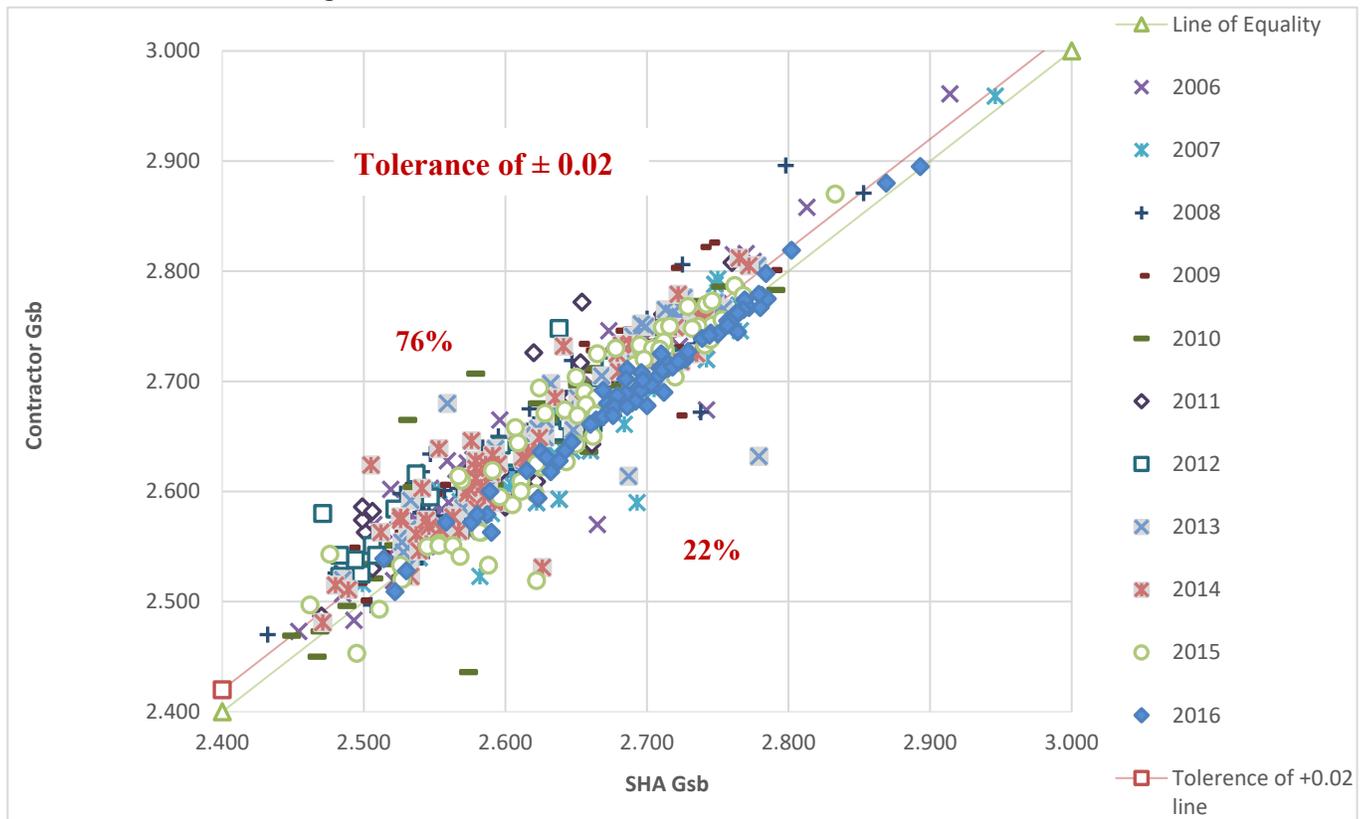


Figure 2. Comparison of SHA and contractor reported  $G_{sb}$  values.

### Risk Mitigation Strategies

To minimize acceptance risk associated with aggregate specific gravity, a SHA could:

1. Routinely measure source aggregate specific gravity and compare it to the values reported in contractor performed mixture designs. Some SHAs do this:
  - a. For each individual mixture design with highly variable aggregates.
  - b. By bench for quarry sources annually resulting in a “book” value used by both the SHA and contractor.
  - c. On specific frequencies (e.g. 6 months or annual) depending on source variability resulting in a “book” value use by both the SHA and contractor.
  - d. Verify the mix design  $G_{sb}$  during a project startup evaluation.
2. Include reporting of aggregate  $G_{sa}$ ,  $G_{se}$ ,  $G_{sb}$ , and percent water absorption, as well as asphalt absorption in mixture design submittals, then checking that  $G_{sa} > G_{se} > G_{sb}$  and the reported absorbed asphalt binder values are reasonable.
3. Avoid using tolerances for comparing SHA and contractor  $G_{sb}$  values in the mixture design process.
4. Routinely analyze differences in SHA and contractor  $G_{sb}$  values and share the observations with the contracting community.

## Recycled Asphalt Materials (RAM) Specific Gravity in Mixture Design

Recycled asphalt materials (RAM) include RAP and RAS. With the present emphasis on the increase in percent of RAM in asphalt mixtures acceptance, risks may be increased in several areas due to:

- Consistency of RAM stockpiles.
- Consistency of RAM percentage being introduced in the mixture during plant production.
- Proper measure and use of RAM specific gravity.

Producing RAM stockpiles with consistent gradation and asphalt binder content is important to assure plant produced mixture has volumetric and performance properties generated in the mixture design. This becomes more critical as RAM percentage increases. When a product is inconsistent, a higher percentage of it has a larger effect on the consistency of the final product. Additionally, the specific gravity of RAM aggregates is used to calculate VMA. Some SHAs allow the use of  $G_{se}$ , rather than  $G_{sb}$  for RAM aggregates, because it can be obtained much easier in the laboratory than  $G_{sb}$ . To accurately obtain RAM aggregate  $G_{sb}$  the asphalt binder is removed from the RAM aggregates by chemical extraction or ignition furnace methods. Because  $G_{se}$  is larger than  $G_{sb}$ , using  $G_{se}$  when calculating VMA results in higher reported than actual VMA and lower than needed asphalt binder content. This is illustrated for RAP in Figure 3. The difference in actual and reported VMA becomes significant at about 10 percent RAP and is material dependent.

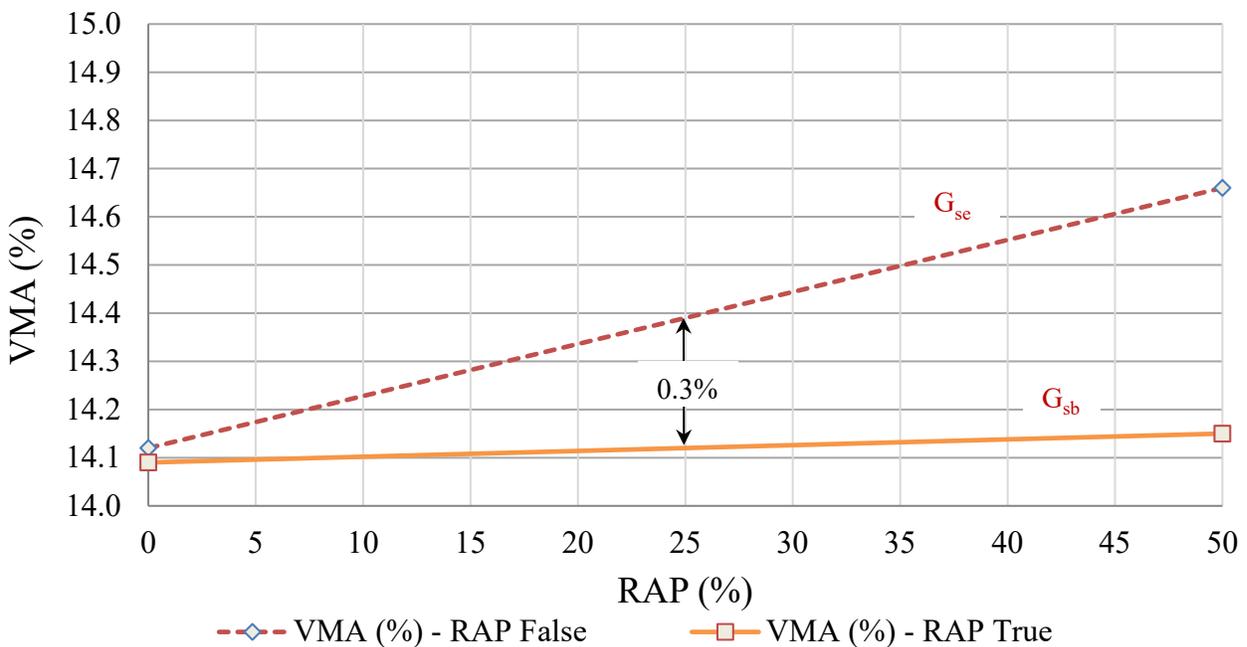


Figure 3. Comparison of reported VMA when using both  $G_{sb}$  and  $G_{se}$  for the same mixture.

An example of the impact of using  $G_{se}$  rather than  $G_{sb}$  for RAM and its impact on VMA follows. It is for a case where a mixture contains 20 percent RAP. The RAP  $G_{se}$  is 2.732,  $G_{sb}$  is 2.609, and water absorption is 1.0 percent. For this example, using  $G_{se}$  is similar to the  $G_{sb}$  being 0.024 higher in the composite mix. This results in the VMA being incorrectly reported as 0.6 percent higher and results in a lower asphalt content of 0.3 percent, creating a drier than desirable mix. The proper specific gravity to use in this case to minimize risk is  $G_{sb}$ .

## **Risk Mitigation Strategies**

To minimize mixture design risk associated with RAM specific gravity an SHA could:

1. Not allow the use of  $G_{se}$  for RAM materials in place of  $G_{sb}$ .
2. Only allow the use of RAM  $G_{sb}$  for all materials in mixture design.

## **Mixture Adjustments from Mixture Design to Construction for Verification**

Differences commonly exist between laboratory mixture design and plant produced mixtures. This is why SHA specifications have provisions for start-up evaluations (sometimes called test strips or other names), so adjustments can be made to address these differences. A common question is, “How much change occurs in volumetric properties and performance values from mixture design, to plant production or to construction?” This question is the focus of NCHRP Report 818 *Comparing the Volumetric and Mechanical Properties of Laboratory and Field Specimens of Asphalt Concrete* (9).

The magnitude and cause of differences in commonly measured asphalt mixture properties among different specimen types was studied. Volumetric and mechanistic properties of three specimen types [design (LL), production (PL), and construction (PF)] were measured and analyzed for mixtures from several states throughout the country. Variations in the mixture production process were identified and varied throughout the mixtures. The impact of baghouse fines return, delay in specimen fabrication, aggregate absorption, aggregate hardness, and stockpile moisture content were evaluated. For each mixture, volumetric and mechanistic properties were evaluated for the three specimen types. Volumetric properties included: air voids (AV), VMA, voids filled with asphalt (VFA),  $G_{sb}$ , maximum theoretical specific gravity ( $G_{mm}$ ), asphalt binder content (AC), and gradation. Mechanistic properties evaluated were: loaded wheel tracking rut depth, axial dynamic modulus, and indirect tension dynamic modulus. The magnitudes of the differences in volumetric and mechanistic properties were quantified. These differences were used to identify tolerance values and conversion factors among properties for the three specimen types.

Conclusions in NCHRP Report 818 related to this TechBrief include:

- Air voids: Stockpile moisture had a significant effect on the difference between design and production specimens. This may be attributed to aggregates not having sufficient time to dry during production or proper quantification of stockpile moisture content.
- Asphalt binder content: The return of baghouse fines was significant in the difference between design and production as well as construction specimens. Additionally, aggregate absorption was significant on the measure difference between design and production specimens.
- Aggregate gradation: The return of the baghouse fines was significant in the difference between the aggregate passing the #200 sieve of design and production as well as construction specimens. This may warrant the use of baghouse fines during the design of mixtures in regions where baghouse return is necessary. In addition, aggregate hardness was significant in the differences between the percent passing the #200 sieve of design and production, as well as construction specimens.

NCHRP Report 818 also identified single operator confidence limits and maximum acceptable ranges were developed based on the average difference between specimen type comparisons as shown in Table 3. Since these tolerance values encompass mixtures from around the country, regional or individual SHA values may be appropriate. In addition to single operator tolerance values, a maximum range of acceptable differences for each parameter was also suggested as shown in the last column of Table 3.

Table 3. Single Operator Confidence Limit and Maximum Acceptable Ranges (Ref. 9).

Comparison	Property	Single Operator Confidence Limit	Maximum Acceptable Range
Design (LL) - Production (PL)	AV, %	0.8	± 1.3
Design (LL) - Production (PL)	VMA, %	1.2	± 2.0
Design (LL) - Production (PL)	VFA, %	5.4	± 9.1
Design (LL) - Production (PL)	AC, %	0.2	± 0.30
Design (LL) - Construction (PF)	AC, %	0.020	± 0.30
Production (PL) – Construction (PF)	AC, %	0.014	± 0.30
Design (LL) - Production (PL)	G <sub>mm</sub>	0.5	± 0.034
Design (LL) - Construction (PF)	G <sub>mm</sub>	0.2	± 0.022
Production (PL) – Construction (PF)	G <sub>mm</sub>	0.013	± 0.030
Design (LL) - Production (PL)	G <sub>sb</sub>	0.019	± 0.024
Design (LL) - Construction (PF)	G <sub>sb</sub>	0.7	± 0.032
Production (PL) – Construction (PF)	G <sub>sb</sub>	0.2	± 0.029
Design (LL) - Production (PL)	Passing #200, %	0.018	± 0.80
Design (LL) - Construction (PF)	Passing #200, %	0.017	± 1.2
Production (PL) – Construction (PF)	Passing #200, %	0.5	± 0.80

The highest risk item associated with making adjustments to mixtures in production is reducing AC at the asphalt plant when the laboratory compacted mixture's AV and VMA drop from mixture design to plant production. This is driven by breakdown of aggregate in the production process and returning of baghouse fines to the mixture (9). Reducing AC leads to a drier, less durable mixture. Rather than reducing AC, aggregate gradation changes should be made to increase the laboratory compacted mixture AV and VMA, while leaving the AC at the mixture design target value. Rules of thumb relative to the impacts of AC and gradation changes are:

- A ± 0.1 percent change in AC results in an approximate 0.25 percent change in AV. This is an inverse relationship in which as AC is increased AV decreases.
- Small changes in AC do not result in VMA changes.
- A ± 1.0 percent change in the amount of material passing the #200 sieve results in a 0.3 to 1.0 percent change in VMA. This is an inverse relationship in which as percent passing the #200 sieve is increased VMA decreases.
- For coarse graded mixtures reducing the amount of material passing #8 sieve increases VMA.
- For fine graded mixtures increasing the amount of material passing #8 sieve increases VMA.

Additional examples of how aggregate property changes can impact VMA for different types of gradations are presented in Table 4.

Table 4. Changes in VMA due to Aggregate Property Changes (Ref. 14).

Aggregates Property Change	Fine Gradation Change in VMA	Straight Gradation Change in VMA	Coarse Gradation Change in VMA
Percent passing #200 sieve from 8 to 3 percent	+1.6	+0.5	+0.3
Percent passing #200 sieve from fine to coarse	-0.5	+0.1	-0.1
Crushed aggregate from 80 to 100 percent	+0.3	+1.1	+1.0

## Risk Mitigation Strategies

To minimize risk associated with mixture adjustments from mixture design to plant production, an SHA could:

1. Include standard specification provisions that direct how differences in mixture design and plant produced mixtures are to be addressed.
2. Only allow gradation changes before considering allowing AC changes.
3. Include VMA and dust to asphalt ratio (D/A) acceptance criteria on plant produced mixture that are equal to the minimum VMA and maximum D/A in AASHTO M323 (8). AASHTO standards are private, voluntary standards that are not required under Federal law.
4. Not use tolerances such as those shown in Table 3 in specifications if they lead to bias as illustrated in Figure 2.

## Aggregate Specific Gravity and Relationship of Properties in Acceptance

Monitoring and analyzing aggregate specific gravity and absorption properties in production and as part of the acceptance process is one technique for reducing QA risks. Monitoring relationships among the properties can also lead to early recognition of raw material or mixture changes. With such changes identified design and/or production modifications can be made to reduce risk. Key properties to monitor are aggregate specific gravities ( $G_{sb}$ ,  $G_{se}$ ,  $G_{sa}$ ) and percent absorption (%Abs), as well as percent asphalt absorption ( $P_{ba}$ ). Recall that  $G_{sa} > G_{se} > G_{sb}$ . It is physically impossible for this not to be the case for a given mixture. Asphalt absorption is typically about 50 percent of water absorption, so  $G_{se}$  should be about halfway between  $G_{sb}$  and  $G_{sa}$ . Table 5 illustrates the meaning of any of the three aggregate specific gravities being equal to each other, which are all again not physically possible.

Table 5. Meaning of Equal Aggregate Specific Gravities and Relation to Asphalt Absorption.

<b>Aggregate Specific Gravities</b>	<b>Meaning</b>	<b>Asphalt Absorption (percent of Water Absorption)</b>
$G_{sa} = G_{sb}$	No absorption of water or asphalt	-
$G_{se} = G_{sb}$	No asphalt absorption	0
$G_{se} = G_{sa}$	Asphalt absorption equals water absorption	100

For a given mixture, the relationship between the three aggregate specific gravities should not change. A simple way to monitor this is to plot a control chart of  $G_{se}$  during production compared to  $G_{sb}$  and  $G_{sa}$  determined during the mix design process as illustrated in Figure 4.  $G_{se}$  is easily obtained at a high frequency during production since it is calculated from AC and theoretical maximum specific gravity ( $G_{mm}$ ). A change in  $G_{se}$  beyond the test method variability indicates that a change in aggregate specific gravity or absorption has occurred and needs to be addressed. Small changes in  $G_{se}$  may occur due to large changes in mixture production temperature or silo/haul times. When a change occurs, as illustrated in Figure 4 at sample number 10, it is important to determine its cause and to determine and use updated specific gravities for volumetric property determinations.

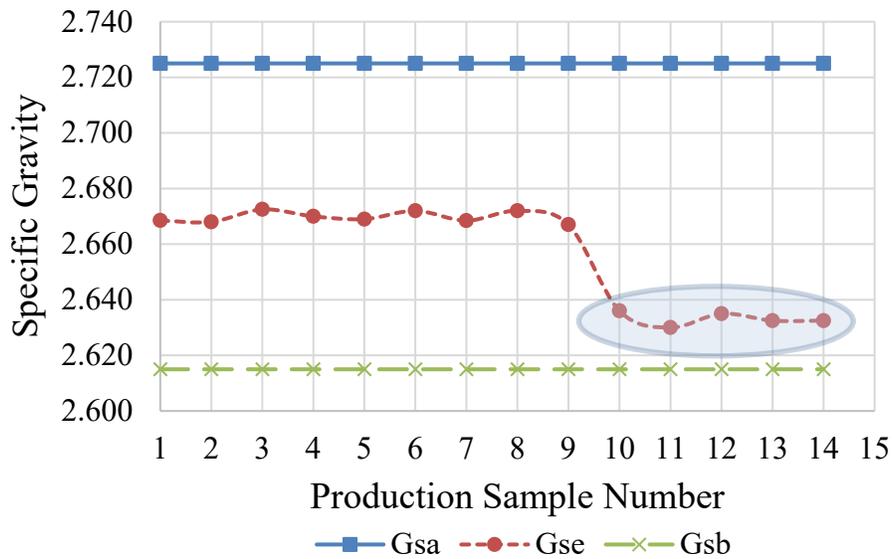


Figure 4. Aggregate Specific Gravities Control Chart.

Table 6 is a summary of specific gravities along with water and asphalt absorption. The last column of the table is the ratio of asphalt binder absorption  $P_{ba}$  to water absorption (%Abs). This is another parameter that can be easily monitored during production that can flag a potential change in aggregate specific gravities.

Table 6. Absorption Monitoring.

Production Sample Number	$G_{se}$	Running Average of 3 $G_{se}$	Mix Design $G_{sa}$	Mix Design $G_{sb}$	Water Absorption (%Abs)	Asphalt Absorption, $P_{ba}$ (%)	$P_{ba} / \%Abs$
1	2.669		2.725	2.615	1.45	0.80	55
2	2.668		2.725	2.615	1.45	0.58	40
3	2.673	2.670	2.725	2.615	1.45	0.87	60
4	2.670	2.670	2.725	2.615	1.45	0.52	36
5	2.669	2.671	2.725	2.615	1.45	0.98	68
6	2.672	2.670	2.725	2.615	1.45	0.64	44
7	2.668	2.670	2.725	2.615	1.45	0.86	59
8	2.672	2.671	2.725	2.615	1.45	0.81	56
9	2.667	2.669	2.725	2.615	1.45	0.58	40
10	2.636	2.658	2.725	2.615	1.45	0.86	59

In-place density plays a significant role in long-term pavement performance (10).  $G_{mm}$  is the basis for most SHA in-place compaction specifications and in-place compaction is typically heavily weighted in specifications with incentives and disincentives.  $G_{mm}$  can be used to determine percent in-place air voids and percent in-place density. During the mixture design process, a relationship between  $G_{mm}$  and asphalt binder content (AC) is established. As AC increases,  $G_{mm}$  decreases as illustrated in Figure 5. Monitoring  $G_{mm}$  during production for this directional trend is helpful to identify potential issues with  $G_{mm}$  determinations. If this trend is not observed, then the determination of  $G_{mm}$  values should be investigated to determine the reason for deviation since it is the basis for such an important acceptance and payment item.

## Risk Mitigation Strategies

To minimize acceptance risks associated specific gravities and absorption an SHA could:

1. Regularly monitor aggregate and mixture specific gravities and absorption during production to assure:
  - a.  $G_{sa} > G_{se} > G_{sb}$ .
  - b.  $G_{mm}$  decreases as AC increases.
  - c.  $P_{ba}$  is about 50 percent of water absorption.
2. Have graphical reporting of items 1.a through 1.c with charts similar to Figure 4 and Figure 5. Have related specification provisions indicating what is to be done when changes in specific gravities and/or absorption are observed.
3. Verify the mix design  $G_{sb}$  during a project startup evaluation.

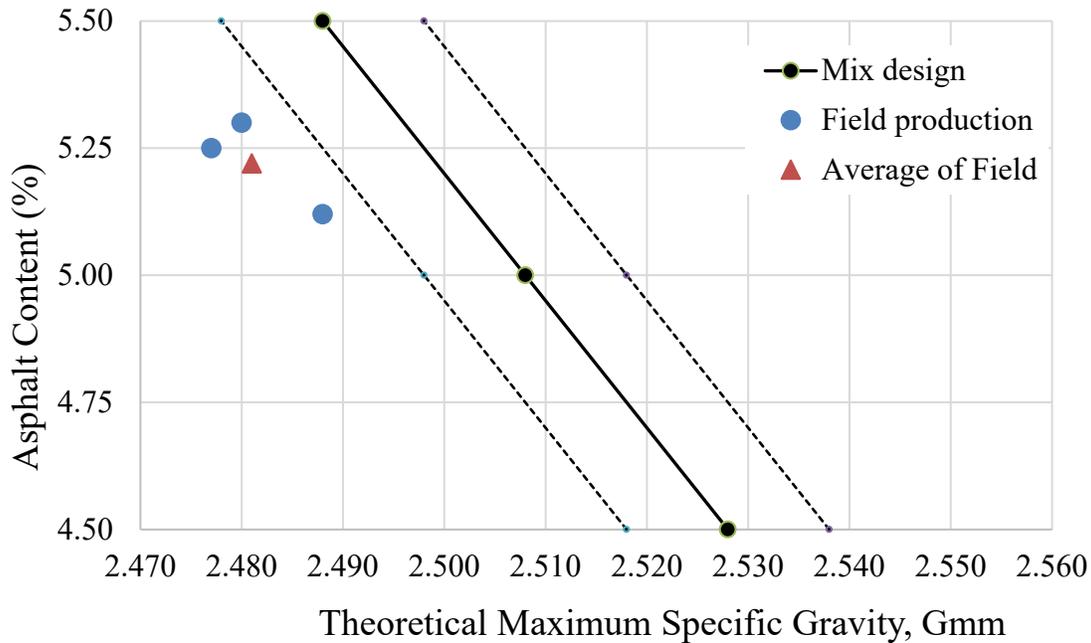


Figure 5. Relationship Between  $G_{mm}$  and Asphalt Content.

## Recycled Asphalt Materials (RAM) in Acceptance

A primary purpose of a SHA QA program is to assure the quality and quantity of what is specified is provided. This is particularly important with RAM since it contains asphalt binder which is the most expensive component in asphalt mixture. The question is often asked, “*How do you know you are getting the specified quantity of RAS or RAP?*” This can be a particularly challenging question with RAS since it is so light and small quantities (2 to 5 percent) are commonly used relative to common asphalt plant feed and weighing systems. It is critical that plant calibrations be performed to the precision level necessary and verified on a regular basis. This is important for measurement purposes and helps ensure that the plant equipment in place is functioning properly. There are also many plant operational practices beyond the scope of this TechBrief that are important to follow which can be found in References 11, 12 and 13. Other techniques that have been used include:

- Having RAM production and stockpile QC program elements.
- Reconciling plant control data logger reports with loadout tickets and/or plant stockpile inventory and asphalt binder inventory changes.
- Surveying dedicated stockpiles.
- Having on-site inspectors.

## **Risk Mitigation Strategies**

To minimize acceptance risk associated with using RAM, a SHA could:

1. Include plant calibrations and verification on a regularly frequency in specifications.
2. Include RAM production and stockpile QC program elements in specifications.
3. Have a specification item for reconciling plant control data logger reports with loadout tickets and/or plant stockpile inventory and asphalt binder inventory at the individual project level.
4. Survey dedicated RAM stockpiles.
5. Have on-site inspectors monitoring for implementation of the practices outlined in References 14, 15 and 16.

## **Example Solution to Rectify Potential Cost of Premature Pavement Distress**

As stated previously, the purpose of this TechBrief is to provide information that could help SHAs strengthen their QA programs and to communicate the importance of reviewing specifications for risks related to acceptance. A primary reason for this function is to make the specifications reasonable and cost effective for SHAs. When risks are not managed properly the impact can result in costly repairs due to premature pavement distress.

The Maine Department of Transportation (Maine DOT) experienced significant raveling in overlays on a number of asphalt pavements throughout the State. In one construction season, it was estimated that Maine DOT lost 20 percent of its pavements' service life. This loss of service life was estimated to be \$15 million in one year (14). The Maine DOT final report documents an extensive evaluation of the raveling problem, identifies potential causes, and recommends improvements that could be implemented to prevent it in the future.

The Maine DOT report identified seven causes potentially related to the poor pavement performance. Of these, six unique causes were identified to relate to the pavements of known performance:

- Higher quantity of material passing the #200 sieve in production without a production Dust/Effective Binder Content (D/A) criteria.
- Lack of an aggregate durability test.
- Insufficient thickness/Nominal Maximum Aggregate Size (t/NMAS) criteria contributed to a more permeable pavement than desired.
- Not verifying  $G_{sb}$  led to inaccurate volumetric properties.
- Higher than desirable permeability from multiple causes.
- The lack of moisture susceptibility testing.

The Maine DOT report recommended the following items for improvements to test methods, specifications, and/or practices to minimize the risk of premature raveling failures in the future by minimizing the effects of the above causes. These recommendations were forward looking with a focus on making changes to improve future pavement performance. They included:

1. Improve the weighting of pay factors for control of the percent passing the #200 sieve, either the change in percent passing the #200 from mix design to construction and/or field-produced D/A.
2. Improve the acceptance and validation process for the  $G_{sb}$ .
3. Implement moisture susceptibility testing such as the Hamburg wheel-track testing using the stripping inflection point.
4. Implement an aggregate durability test for fine and coarse aggregates such as the Micro-Deval.
5. Establish guidelines for the use of thin overlays that includes the t/NMAS, as well as the type of gradation (coarse versus fine).

The effort also concluded that these recommended changes could be accomplished in a cost-effective manner.

## **Strategies for Reducing Risks**

There are several strategies available to a SHA for reducing potential risks. There is not a one size fits all strategy; one risk may be best addressed with a SHA policy change, while another may be best addressed with a specification change coupled with a test method change and related training.

First, a SHA may review its policies; design, construction and materials standards and specifications, test methods and overall QA program on a regular basis with goals of maximizing efficiency and minimizing risk in the process. One approach could be to follow applicable AASHTO protocols including Standard Recommended Practices, Recommended Guidelines, and Standard Test Methods. These voluntary protocols have been developed by, among other procedures, round-robin testing between several States to refine the procedures to produce the most consistent and accurate results. Deviating from these standards without a strong technical basis, may very likely produce less consistent results and lead to higher material quality risks, although these standards are not required under Federal law. Listed below are some standards directly applicable to risks:

- AASHTO Standard Recommended Practice R-9 *Acceptance Sampling Plans for Highway Construction*.
- AASHTO Standard Recommended Practice R-10 *Definitions of Terms Related to Quality and Statistics Used in Highway Construction*.
- AASHTO Standard Recommended Practice R-42 *Developing a Quality Acceptance Plan for Hot Mix Asphalt (HMA)*.

These are private, voluntary standards that are not required under Federal law.

## **Summary**

Engineering and statistical risks do exist and the potential cost associated with them can be significant. Such risks often exist because specifications lack detail. The lack of detail or definition can lead to different interpretations of specification intent. Specifications should be written with clarity and in an unambiguous manner to minimize the need for “interpretations.” One example would be specifically stating if re-testing is allowed or not and if so, what is associated with how to determine when it is acceptable, how it is performed, reported, used in the acceptance process, etc. Another example would be stating that 15 percent RAM is allowed in asphalt mixture with defining the type (RAP, RAS, or RAP and RAS), the basis (weight versus binder replacement), etc.

Potential risks have changed with the transition from method specifications to implementation of QA specifications that transfer responsibility for items such as QC and mixture design to the contractor, as well as incorporate payment incentives and disincentives. Regularly reviewing policies, design standards, test methods, practices and specifications associated with QA for potential acceptance risk is an important SHA responsibility. Doing so and making changes to manage identified risks is equally important. Implementing changes when risks are identified, communicating and providing training on them for agency and contractor stakeholders, and closely examining the impact of these changes is also important. These changes may lead to different combinations of mix design criteria, material source controls, lot or sample size determinations, production testing, and responsibilities for QC and acceptance activities.

## References

1. *Standard Recommended Practice for Definition of Terms Related to Quality and Statistics*, American Association of State Highway and Transportation Officials, AASHTO R-10, Washington, D.C., 2016.
2. Hancher, D.E, Y. Wang, and K.C. Mahboub, *Contractor Performed Quality Control on KyTC Projects*, Kentucky Transportation Center, Report No. KTC-02-26/SPR-01-222-1F, Lexington, KY, 2002.
3. *Glossary of Highway Quality Assurance Terms*, Transportation Research Circular E-C235, Transportation Research Board, Washington, D.C., 2018.
4. Burati, J I., R. M. Weed, C. S. Hughes, H.S. Hill, *Optimal Procedures for Quality Assurance Specifications*, FHWA-RD-02-095, Washington, D.C., June 2003.
5. *Use of Contractor Test Results in the Acceptance Decision, Recommended Quality Measure, and the Identification of Contractor/Department Risks*, FHWA TA 6120.3, Washington D.C., August, 2004.
6. “*Standard Method of Test for Determining the Asphalt Binder Content of Hot Mix Asphalt (HMA) by the Ignition Method*,” AASHTO T 308-18, Washington, D.C., 2018.
7. Rodezno, C., R. Brown, G. Julian, and B. Prowell, *Variability of Ignition Furnace Correction Factors*, NCHRP Research Report 847, Transportation Research Board, Washington, D.C., 2017.
8. *Standard Specification for Superpave Volumetric Mix Design*, AASHTO M 323-17, American Association of State Highway and Transportation Officials, Washington, D.C., 2017.
9. Mohammad, L.N., M.A. Elseifi, S.B. Cooper, III, C.S. Hughes, J.W. Button, and E.L. Dukatz, Jr., “*Comparing the Volumetric and Mechanical Properties of Laboratory and Field Specimens of Asphalt Concrete*,” NCHRP Research Report 818, National Academies of Sciences, Engineering, and Medicine, Washington, D.C., 2016.
10. Aschenbrener, T., F. Leiva, and N. Tran, *FHWA Demonstration Project for Enhanced Durability of Asphalt Pavements through Increased In-place Pavement Density, Phase 2*, FHWA, Report Number FHWA-HIF-19-052, Washington, D.C., 2019.
11. *Best Practices for RAP and RAS Management*, NAPA QIP-129E, National Asphalt Pavement Association, Lanham, MD, 2015.
12. *Use of RAP & RAS in High Binder Replacement Asphalt Mixtures: A Synthesis*, NAPA SR-213E, National Asphalt Pavement Association, Lanham, MD., 2016.
13. *TechBrief: State of the Knowledge for Use of Asphalt Mixtures with Reclaimed Binder Content*, FHWA, Report Number FHWA-HIF-18-059, Washington, D.C., 2018.
14. Aschenbrener, T. and D. Nener-Plante, *Premature Distress Investigation for the Maine DOT*, Maine Department of Transportation, Report Number ME 17-05, Augusta, ME, 2017.
15. Decker, D., *Specifying and Measuring Asphalt Density to Ensure Pavement Performance*, NCHRP Research Report 856, National Academies of Sciences, Engineering, and Medicine, Washington, D.C., 2016.
16. Aschenbrener, T. and C. MacKean, *Factors that Affect the Voids in the Mineral Aggregate in Hot Mix Asphalt*, Colorado Department of Transportation, Report Number 92-13, Denver, CO, 1992.

## Asphalt Materials Quality Assurance Practices

**Contact** — For more information, contact Federal Highway Administration (FHWA):

Office of Preconstruction, Construction, and Pavements

Tim Aschenbrener — [timothy.aschenbrener@dot.gov](mailto:timothy.aschenbrener@dot.gov)

Office of Technical Services — Resource Center

Dennis Dvorak — [dennis.dvorak@dot.gov](mailto:dennis.dvorak@dot.gov)

**Researcher** — This TechBrief was developed by Chuck Hughes (Consultant), Adam Hand (University of Nevada Reno) and Tim Aschenbrener (FHWA), as part of FHWA's Development and Deployment of Innovative Asphalt Pavement Technologies cooperative agreement. The TechBrief is based on research cited within the document.

**Distribution** — This Technical Brief is being distributed according to a standard distribution. Direct distribution is being made to the Division Offices and Resource Center.

**Availability** — This Tech Brief may be found at <http://www.fhwa.dot.gov/pavement/>.

**Key Words** — quality assurance, asphalt, mixture design, acceptance

**Notice** — This Technical Brief is disseminated under the sponsorship of the U.S. Department of Transportation in the interest of information exchange. The U.S. Government assumes no liability for the use of the information contained in this document. The U.S. Government does not endorse products or manufacturers. Trademarks or manufacturers' names appear in this report only because they are considered essential to the objective of the document. They are included for informational purposes only and are not intended to reflect a preference, approval, or endorsement of any one product or entity.

**Quality Assurance Statement** — The Federal Highway Administration (FHWA) provides high-quality information to serve Government, industry, and the public in a manner that promotes public understanding. Standards and policies are used to ensure and maximize the quality, objectivity, utility, and integrity of its information. FHWA periodically reviews quality issues and adjusts its programs and processes to ensure continuous quality improvement.