Demonstration of a Volumetric Acceptance Program

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Once a mix design prepared in the laboratory meets the specifications for performance and has been approved, material-related problems can develop in many places in the plant operation during field production, from stockpiling, cold feed bins, baghouse fines, asphalt mixing, to the storage silo. Field verification, which is verifying that the field-produced hot mix asphalt (HMA) still meets the specifications for performance, is very important. Original field verification data from two Colorado data bases were examined. The volumetric (air voids) and strength (Hveem stability) properties measured during field verification was related to the rutting performance of the HMA pavements. Four trial projects were constructed using an acceptance specification based on volumetric and strength properties, not gradation. The results are reported here. Additionally, a checklist including eight items was developed to identify potential adjustments in an HMA to account for changes that occur in production through the plant.

INTRODUCTION

Improved field management of asphalt mixes is an area that needs to be emphasized. Once a mix design prepared in the laboratory meets the specifications for performance and has been approved, material-related problems can develop in many places in the plant operation during field production, from stockpiling, cold feed bins, baghouse fines, asphalt mixing, to the storage silo. In Demonstration Project 74: Field Management of Asphalt Mixes, D'Angelo (*1*) has shown that volumetric properties provide the necessary information to identify if changes have occurred and to assist in making effective adjustments to the hot mix asphalt (HMA).

This paper presents (a) the reasons why the Colorado Department of Transportation (CDOT) is pursuing a volumetric acceptance specification for HMA, (b) the results of the 1993 and 1994 implementation plan, and (c) a checklist of adjustments that have been identified to account for changes that occur in an HMA through the plant.

FIELD VERIFICATION AND KNOWN FIELD PERFORMANCE

Field verification, which is verifying that the plant-produced HMA still meets the specifications for performance, is very important. Field verification is defined as loose HMA produced in the plant, compacted in the laboratory, and tested for the mix design specifications. The pavements were originally constructed using the Colorado version of the California kneading compactor (AASHTO T 247).

1992 Data Base (*2*)

A total of 33 pavements that ranged from 5 to 30 years in age were evaluated by Aschenbrener (*2*). The pavements included some of the lowest and highest traffic levels and the lowest and highest temperature environments in Colorado. Additionally, pavements with both good and poor rutting performance in terms of plastic flow were included. Pavements with rutting depths greater than or equal to 8 mm (0.3 in.) were considered unacceptable. These criteria were selected because they are the basis for Colorado's pavement management system. Pavements with rut depths greater than 8 mm tend to hold water and create hydroplaning conditions. Pavements that rutted because of subgrade failure, stripping, or improper compaction were eliminated from this study.

The study included a review of project documentation to identify the original mix design and field verification properties. Additionally, cores for testing were obtained between the wheelpaths and in the wheelpaths. The complete results of the documentation review and testing program are reported elsewhere (*2*).

Air Voids in the Wheelpath

Air voids in the wheelpath were measured (AASHTO T 166 and T 209) and correlated to the pavement performance. All of the sites are listed in Figure 1 and are ranked in order from the lowest to the highest percentage of air void content. An air void content of 3.0 percent tended to delineate between the pavements with good and poor rutting performance. For all cases but two, the pavements that had no rutting also had greater than or equal to 3.0 percent air voids in the wheelpath, and pavements that rutted had less than 3.0 percent air voids in the wheelpath. There appears to be a strong, although not perfect, correlation between the rutting performance of the pavement and the air voids in the wheelpath.

Original Field Verification Data

The original field verification data (laboratory compacted samples of plant-produced material) was collected for 23 of the 33 pavements. All projects were designed and field verified using the Colorado version of the California kneading compaction procedure (AASHTO T 247). The data are summarized in Table 1.

Once again, an air void content of 3.0 percent tended to delineate between pavements with good and poor rutting performance. When field verification air voids were greater than 3.0 percent, there was a high probability that the pavement did not rut. When field verification air voids were less than 3.0 percent, there was a high probability that the pavement rutted. The pavements that had field verifi-

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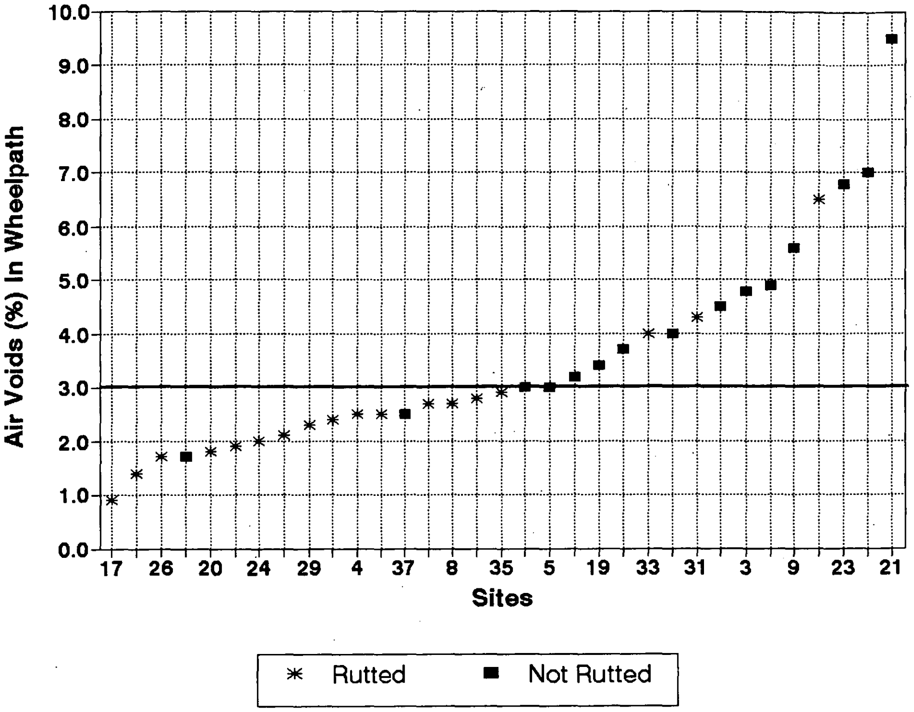

FIGURE 1 Ranked order of air voids in the wheelpath.

cation air voids less than 3.0 percent and did not rut, were either on low-volume highways or had Hveem stability values greater than 40. The pavements that had field verification air voids less than 3.0 percent and did rut, had Hveem stability values lower than 40.

Recompacted Cores

Cores from the 1992 study (*2*) were recompacted in the Texas gyratory compactor (ASTM D 4013) using the 1034 kPa (150 psi) and the 620 kPa (90 psi) end point stresses. The Texas gyratory was used because of a policy change to move toward gyratory compaction. The correlation of the air voids in the cores recompacted with the 620 kPa (90 psi) end point stress with performance is shown in Table 2.

When using the 1,034 kPa (150 psi) end point stress, the air voids from the recompacted cores were much lower than the air voids in the wheelpath of the pavement. When using the 620 kPa (90 psi) end point stress for traffic greater than 1 million design equivalent single axle loads (ESALs), there was excellent correlation between the air voids in the wheelpath and the air voids from the recompacted cores, as shown in Figure 2. The regression equation is:

$$y = 1.1x + 0.1$$

where

y = air voids (%) from recompacted cores and
x = air voids (%) in the wheelpath.

The coefficient of determination, r^2, is 0.78.

1986 Data Base (*3*)

The performance of 75 pavements ranging from 5 to 15 years in age in Colorado was reported by Tapp (*3*). There were 41 pavements that had the field verification data reported and were dense graded mixtures. These data are summarized in Table 3. Cores were not taken from any of the projects so air voids in the wheelpath or air voids from recompacted cores were not obtained.

Once again, an air void content of 3.0 percent tended to delineate between pavements with good and poor rutting performance. When the field verification air voids were greater than 3.0 percent, there was a high probability that the pavement did not rut. The one pavement that did rut had a high severity of alligator cracking indicative

TABLE 1 Summary of Field Verification Data from the 1992 Study

	Field Verification Air Voids (%)	
Rutting Performance	> 3%	< 3%
Acceptable	9	5
Unacceptable	0	9

TABLE 2 Summary of Recompacted Cores Using the 620 KPA (90 PSI) End Point Stress on the Texas Gyratory with Pavements from the 1992 Study

	Air Voids (%) from Recompacted Cores	
Rutting Performance	> 3%	< 3%
Acceptable	12	3
Unacceptable	1	17

of rutting from subgrade failure. When the field verification air voids were less than 3.0 percent, there was a high probability that the pavement rutted. When the air voids were below 3.0 percent and the Hveem stability (AASHTO T 246) values were greater than 35, there was generally no rutting. When the air voids were below 3.0 percent and the Hveem stability values were less than 35, there was rutting.

Summary

The air voids in the wheelpath of a pavement are related to the pavement's rutting performance. Additionally, the Hveem stability and air void properties from field verification are related to the air voids in the wheelpath and the pavement's rutting performance. Therefore, acceptance specifications for HMA based on Hveem stability and air void properties from field verification samples should be related to performance.

Based on studies by D'Angelo (*1*) and two studies in Colorado (*2,3*), it was thought that an acceptance specification based on air void and Hveem stability properties of field-produced material would be desirable. A specification and corresponding 5-year plan to implement the specification were developed.

SPECIFICATION AND IMPLEMENTATION PLAN

Currently, the CDOT field acceptance specification uses gradation, asphalt content, and density of the pavement behind the paver. When using this field acceptance specification, rutting was a sporadic but persistent problem. Based on an analysis of field verification data, the HMA produced during field production of the rutting pavements never met the actual mix design properties. Therefore, CDOT is considering changing its current gradation acceptance specification to a volumetric acceptance specification.

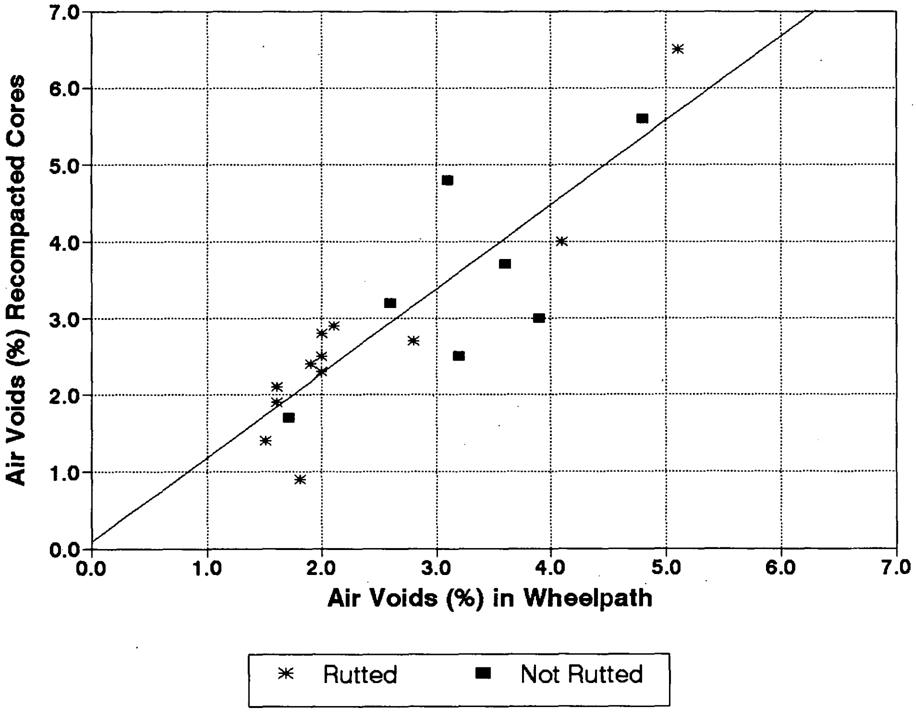

FIGURE 2 Air voids in the wheelpath versus air voids from recompacted cores in high traffic.

TABLE 3 Summary of Field Verification Data from the 1986 Study

	Field Verification Air Voids (%)	
Rutting Performance	> 3%	< 3%
Acceptable	21	11
Unacceptable	1	8

The Hveem stability and air void properties of the HMA measured during field verification appear to have a strong relationship with the future performance of the pavement. Therefore, the CDOT developed a 5-year plan to implement a volumetric acceptance specification to replace the gradation acceptance specification. The 5-year plan is summarized in Table 4. Since the development of the 5-year plan, it has been expanded to a 6-year plan.

The acceptance specification is used to calculate the pay factor for the HMA based on test results of the five elements shown in Table 5. These elements include field compaction, air voids, voids in the mineral aggregate (VMA), asphalt content, and Hveem stability. The VMA is calculated from the bulk specific gravity of the aggregate. The field compaction is based on the maximum specific gravity (AASHTO T 209) of the HMA.

The test results from each of the five elements are statistically analyzed and compared to their target values and specified tolerances. The allowable tolerances have been defined as ±2 standard deviations of acceptable variability from sampling, testing (within laboratory), and production. The standard deviations of acceptable variability are shown in Table 5. These standard deviations were developed based on the analysis of nearly 20 paving projects in Colorado. Four of the projects are presented in this report.

The quality level (QL) from each element of the HMA is calculated as the percentage of test results from each element that is within the tolerances. Tests within the established tolerances are considered within specification. The QL for the entire HMA is then calculated as the weighted average of QLs from each element. The weighting factors for each element are shown in Table 5. The QL is then used to calculate a pay factor that includes incentives and disincentives. If approximately 87 percent of the test results are within tolerances, a pay factor of 1.00 is used. A maximum pay factor of 1.05 can be achieved.

The tolerances are very important. By increasing or decreasing the tolerances, the percentage of tests within specification can increase or decrease, and the pay factor will be affected.

Therefore, field verification properties from numerous projects were analyzed to develop the standard deviations of normally acceptable variation. The standard deviation of normally acceptable variation will be monitored every year to analyze if it is still reasonable. The normally acceptable variation includes sampling, testing (within laboratory), and production variability.

TRIAL PROJECTS

During the 1993 construction season, three trial projects were constructed using the volumetric acceptance specification. Two of these projects used the volumetric acceptance specification for information and the gradation specification for payment. This allowed for a comparison of the two specifications. One of the projects used the volumetric acceptance specification for payment. These projects have been documented in more detail by Aschenbrener (*4*). During 1994, one project used the specification.

I-70, Silverthorne to Copper Mountain

The construction for this project was performed in the fall of 1992 and summer of 1993. The data analyzed from this project were placed in the fall of 1992.

Gradation Acceptance

The tests used for gradation acceptance are gradation, asphalt content, and field compaction. The gradation acceptance specification was used for payment on this project. All of the HMA placed by the contractor met or exceeded the CDOT specifications and the contractor received a 3.1 percent incentive.

TABLE 4 The Six-Year Plan for Implementation of the Volumetric Acceptance Program

Year	Task
1992	Obtain, learn and use the equipment
1993	Construct one or two pilot projects
1994	Construct one or two pilot projects
1995	Construct one project per Region Construct one project with the contractor performing QC
1996	Construct one project per Region with the contractor performing QC
1997	Full implementation of the specification will be available

TABLE 5 The Five Elements Used in the Volumetric Acceptance Specification

Element	Weight	Standard Deviation
Field Compaction (%)	40	1.0
Air Voids (%)	30	0.6
Voids in the Mineral Aggregate (%)	20	0.6
Asphalt Content (%)	5	0.15
Hveem Stability	5	3

Volumetric Acceptance

The tests used for volumetric acceptance are air voids, VMA, asphalt content, Hveem stability, and field compaction as shown in Table 5. A new mobile field trailer equipped to perform all of the volumetric testing was located at the plant. The testing was performed for information. The test results were statistically analyzed to calculate the QL, or percentage of tests within specification. If the payment for the project would have been based on the volumetric acceptance test results, the contractor would have received a 2.4 percent incentive. The standard deviations are shown in Table 6.

Discussion of Results

Both the gradation and volumetric acceptance specifications had similar incentives. It is possible that test results from both the gradation and volumetric acceptance specifications can provide similar pay factors.

The variability from sampling, testing (within laboratory), and production was equal to or less than the standard deviations listed in Table 5 for most of the elements. The standard deviations used to develop the tolerances appear reasonable.

After the first severe winter, the project showed signs of moisture damage. A great deal of testing was performed to improve the HMA scheduled to be placed during the summer of 1993 (*5*). Acceptance specifications only indicate how well the field-produced material matches the mix design specifications. Gradation and volumetric acceptance specifications cannot overcome deficient mix design specifications.

SH–88, Galena to Parker Road

The project included the placement of 24,000 tonnes (26,000 tons) of HMA. After analyzing the test results, the project was divided into two portions: the initial 15,000 tonnes (16,000 tons) and the final 9,000 tonnes (10,000 tons).

Gradation Acceptance

The gradation acceptance specification was used for payment on this project. All of the HMA placed by the contractor met or exceeded the CDOT specifications, and the contractor received a 1.9 percent incentive. During the initial 15,000 tonnes (16,000 tons), some problems were identified with the percentage passing the 4.75 mm (No. 4) sieve. During the final 9,000 tonnes (10,000 tons), the problem disappeared. According to the gradation acceptance specification, the material placed for the final part of the project was slightly better than the material placed at the beginning of the project.

Volumetric Acceptance

The volumetric properties of the HMA from this project were measured for information. The control chart for the air voids is shown in Figure 3. There appears to be two distinct materials that were produced for this project. The initial 15,000 tonnes (16,000 tons) is represented by Tests 1 through 14. The material is very uniform, within the tolerances, and similar to the mix design. The contractor would have received an incentive of 3.7 percent for the initial 15,000 tonnes (16,000 tons). The standard deviations are shown in Table 6.

TABLE 6 Sampling, Testing (Within-Laboratory), and Production Variability as Measured by the Standard Deviation

		Standard Deviations		
Project	n	Air Voids	VMA	Stability
I-70	40	0.64	0.37	4.5
SH-88	14	0.54	0.40	2.3
US-6	22	0.44	0.33	3.4
I-25	59	0.58	0.26	1.8
Specification		0.60	0.60	3.0

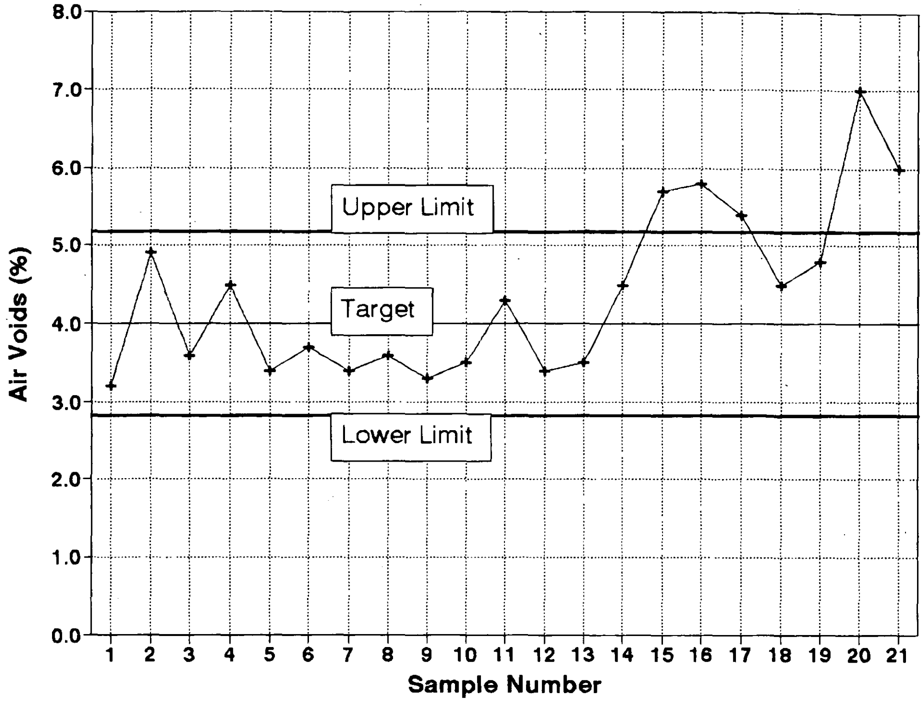

FIGURE 3 Control chart for air voids from SH–88.

The final 9,000 tonnes (10,000 tons) of HMA is represented by the last seven tests. This material does not resemble the initial 15,000 tonnes (16,000 tons) of HMA placed or the mix design. This material is consistently outside of the tolerances. The material would have required a 23.3 percent pay reduction based on the volumetric acceptance specification.

An investigation was performed to identify the cause of the change. Although it is unclear what happened, there are two causes that potentially could have contributed to the problem. First, the 19.0-mm (3/4-in.) rock used by the contractor was from a commercial aggregate source. The dust coating the coarse aggregates increased by over 2 percent for the final 9,000 tonnes (10,000 tons). Second, a change occurred with the baghouse. The contractor has had problems with the baghouse used at the plant. The baghouse required a major repair the day after the final 9,000 tonnes (10,000 tons) were placed. It is possible the baghouse problems could have also contributed to the HMA variability.

Discussion of Results

For the initial 15,000 tonnes (16,000 tons) of HMA produced, the gradation and volumetric acceptance specifications produced similar pay factors. For the volumetric properties, the variability from sampling, testing (within laboratory), and production was equal to or less than the standard deviations listed in Table 5 for each of the elements. The standard deviations used to develop the tolerances appear reasonable.

For the final 9,000 tonnes (10,000 tons) of HMA produced, the gradation specification indicated a higher quality level of material than the initial 15,000 tonnes (16,000 tons). The volumetric acceptance specification indicated an unacceptable quality level of material. Based on accelerated load testing using European equipment, it appears that the volumetric specification may more accurately represent the future performance of the pavement.

US–6, Wadsworth to Federal

The volumetric acceptance specification was used for payment on this project. The gradation acceptance testing was not performed.

Volumetric Acceptance

Three laboratories performed testing for this project. The CDOT Region laboratory performed the acceptance testing; the CDOT Central laboratory performed the assurance testing; and the contractor performed the control testing. The control chart for the air voids from the laboratory performing the acceptance testing is shown in Figure 4.

The first eight tests were performed over a 2- to 3-week period and involved "sporadic" paving. Although paving was sporadic, the test results from the three laboratories were very similar. When the mainline paving started, the test results from the three laboratories were no longer similar. The results for the testing of air voids and VMA are shown in Table 7. When the mainline paving began, the assurance and control testing laboratories continued to have statistically similar results. The acceptance testing laboratory had different results.

The precision of each laboratory's data can be defined as the standard deviation of each laboratory's results. All three of the laboratories had precise data. Their standard deviations were well within the acceptable standard deviation 0.6. The accuracy of each labora-

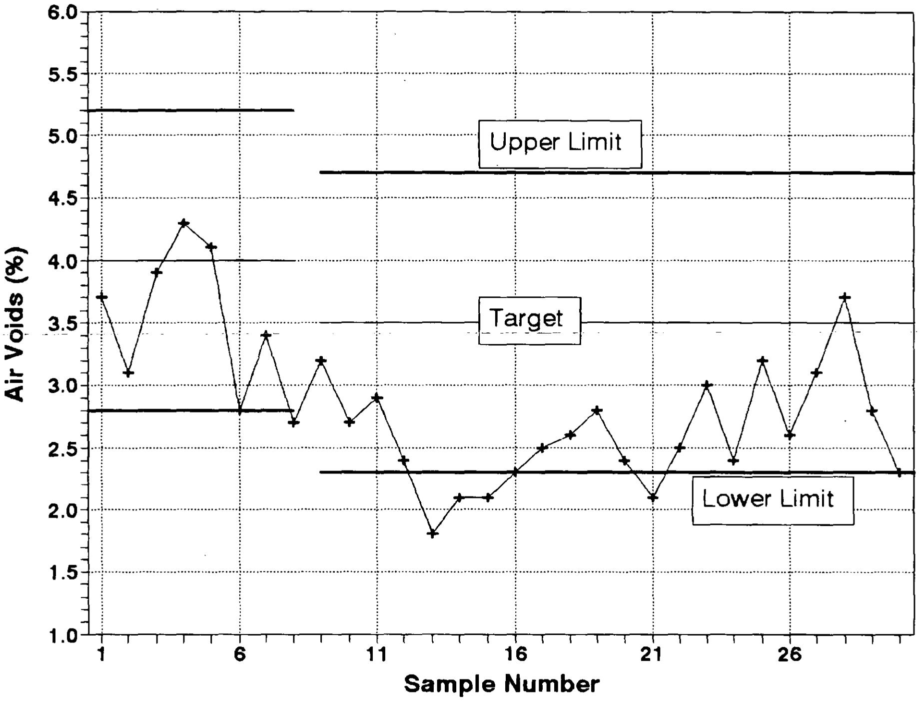

FIGURE 4 Control chart for air voids from US–66.

tory's data can be defined as the average of each laboratory's results. The assurance and control laboratories had similar averages, but the acceptance laboratory had an average air voids that were "shifted" 0.7 percent lower. The same trend was observed for the VMA data as shown in Table 7.

Although the acceptance testing laboratory had standard deviations similar to the other two laboratories, the average air voids and VMA were shifted slightly lower, approximately 0.7 percent. The assurance and control laboratories were assumed to have the "correct" test results because these laboratories have been testing for a very long time. The acceptance laboratory had just 1 year of experience. Therefore, the air voids target used by the acceptance testing laboratory was adjusted 0.5 percent lower to match the "correct" results. This can be observed by the shifted targets in Figure 4.

Using the acceptance testing laboratory's data with the targets shifted 0.5 percent lower, the resulting pay factor was a 2.9 percent incentive. The standard deviations are shown in Table 6.

Discussion of Results

The contractor made extraordinary efforts to validate the field-produced HMA prior to placing it on the project. The HMA produced from the plant was tested five different times before it was sent to the project. Advanced planning was critical to the success of the project.

Testing for the volumetric properties throughout the project was performed by three different laboratories. Results from one of the laboratories did not provide statistically similar results to the other two laboratories. The reproducibility of test results is a problem that must be corrected before future projects use the specification. An extensive laboratory procedure standardization, equipment calibration program, and tester certification program have begun.

For the volumetric properties measured in all three of the laboratories, the variability from sampling, testing (within laboratory), and production was equal to or less than the standard deviations listed in Table 5 for each of the elements. The standard deviations used to develop the tolerances appear reasonable.

TABLE 7 Comparison of Air Void and VMA Data from the Three Different Laboratories Used on the US-6 Project

		Air Voids (%)		VMA (%)	
Laboratory	n	Average	S.D.	Average	S.D.
Acceptance	19	2.55	0.39	12.87	0.33
Assurance	11	3.30	0.44	13.50	0.41
Control	54	3.42	0.51	13.44	0.51

n - number of tests
VMA - Voids in the Mineral Aggregate
S.D. - Standard Deviation

I-25 at Colorado City

The volumetric acceptance specification was used for payment on this project. Testing for the volumetric properties throughout the project was performed by three different laboratories. Results from the laboratories were very similar. The problem with reproducibility of test results encountered on US-6 was corrected. An extensive laboratory procedure standardization, equipment calibration program, and tester certification program were performed in the fall and winter of 1993 and were attributed with the successful reproducibility.

Checklist for Field Adjustments

Volumetric properties were monitored by CDOT Region laboratories on projects throughout the state. During several instances, problems were identified by using the volumetric properties that the gradation acceptance testing did not identify. By using test results from the Region laboratories, a checklist including eight items was developed that identifies adjustments that were made to account for changes that occurred in the HMA as it went through the plant.

Aggregate Specific Gravity

On a project in Denver for over 1 week, the field compaction was achieved using a roller pattern established during the compaction test section. Something changed, and for the next day of paving, field compaction could not be achieved with any roller pattern. Aggregate gradation and asphalt contents indicated the HMA had incurred no change. The field verification of air voids had increased approximately 2 percent. Additional asphalt cement was added to the HMA based on the volumetric test results. The contractor returned to the original roller pattern and was able to achieve compaction.

Two weeks later, the problem was identified. The specific gravity of the aggregates delivered to the contractor lowered. Because aggregate is added into the plant by weight, the increased volume was not identified. The increased volume resulted in a "drier" HMA. Because the gradation test is by weight, it did not identify the volumetric problem. However, the field verification volumetric properties identified the drier HMA because of the increase in the percentage of air voids.

Natural Sands

On a project near Wray, the field verification air void properties lowered by approximately 2 percent. No changes in gradation or asphalt content were detected. The contractor had inadvertently increased the quantity of rounded natural sands and decreased the quantity of angular crushed sands. Because the natural and crushed sands had similar gradations, gradation testing indicated no difference. However, the field verification volumetric properties identified the change.

Absorptive Aggregates

On a project near Wolf Creek Pass, a highly absorptive aggregate was used. The aggregate absorbed 3.5 percent water. The nuclear asphalt content gauge indicated the contractor was producing HMA at the specified asphalt content. Although moisture corrections were performed as part of the nuclear asphalt content gauge procedure, not all of the moisture was removed from the highly absorptive aggregate. The gauge reading was incorrectly identifying that the HMA had the optimum asphalt content. Because the HMA actually had a lower asphalt content, there were problems achieving compaction on the project.

The field verification air voids indicated that HMA had air voids of 2.7 percent higher than the mix design. Additional asphalt cement was added to the HMA to fill the air voids. Compaction problems were reduced. However, some compaction problems remained because of the HMA's tenderness that was likely caused by the water absorbed into the aggregate.

Baghouse Fines

Extraction testing on a project near Silverthorne indicated an increase of 2.0 percent material passing the 0.075 mm (No. 200) sieve. Gradation testing on the cold feed belt identified a 1.3 percent increase from the stockpile, and the remaining 0.7 percent increase was attributed to the aggregate degradation and the baghouse. By using gradation acceptance, a ±2 percent tolerance is allowed on the 0.075 mm (No. 200) sieve, and the contractor received an incentive. Field verification using volumetric properties indicated air voids of 1.8 percent to 2.2 percent, a potential rutting problem.

The contractor adjusted the HMA gradation by increasing the quantity of 19.0-mm (3/4-in.) rock and washed sand and decreasing quantity of the crushed sand. This resulted in a lowered quantity of material passing the 0.075 mm (No. 200) sieve. Additionally, the asphalt content was lowered 0.2 percent. By making slight adjustments in gradation and asphalt content, the volumetric properties returned to their target ranges.

Recycled Asphalt Pavement

On a project near Springfield, the air voids of the field produced mix were 2 percent lower than the mix design and the Hveem stability was very low. The HMA contained 30 percent recycled asphalt pavement (RAP). In most instances, quality control testing is not performed when constructing a RAP stockpile. When using high percentages of a material that is variable, changes to the field verification properties should not be unexpected. The RAP on this project had high levels of 75 μm material and was fine graded, and the aggregate was not hard.

During production, adjustments were made to the HMA that included using lower percentages of RAP. When 10 percent to 15 percent RAP was used instead of 30 percent, the air voids and stability from field verification samples met the acceptable mix design specifications.

Representative Sampling

On a project near the New Mexico State Line, a sample of aggregate was submitted to the Central laboratory for a mix design. The water absorption of the aggregate was measured (using AASHTO T 84 and 85) to be 2.7 percent, and the optimum asphalt content was 6.5 percent. After the project started, the field verification air voids were approximately 2 percent. A new aggregate sample was submitted to the Central laboratory. The new aggregate sample had a water absorption of 1.9 percent and an optimum asphalt content of 5.8 percent. Apparently, the original aggregates submitted for the mix design were not representative of the entire stockpile. In the past, the entire project could have been constructed based on the initial aggregate sample.

The problem of obtaining representative aggregates from the stockpiles was not unique to this project. This happened several times throughout the summer.

Plant Produced Mix Design

On a project through Monument, the field verification air voids fell to 1.5 percent. The contractor adjusted the gradation and asphalt content of the HMA based on experience and used its batch plant to produce one truck load of HMA. This material was field verified to have an air void content of 5.0 percent. A second fine-tuning adjustment was made to increase the asphalt content to 0.4 percent. The field verification air voids were then at 4.0 percent, and the VMA was acceptable. Although the problem was not specifically identified, the plant-produced material was used to quickly and effectively adjust the HMA.

Adjust Asphalt Content

On a project near the U.S. Air Force Academy, the air voids of several field verification tests averaged 2.8 percent. The asphalt content of the HMA was adjusted from 5.2 percent to 4.8 percent. This reduction in asphalt cement of 0.4 percent allowed the field verification air voids to increase to 3.5 percent to 4.0 percent. It is very important to note that the VMA still exceeded the minimum specified value at the lower asphalt content.

CONCLUSIONS

- The volumetric and strength properties measured during field verification relate to the rutting performance of an HMA pavement.
- The volumetric acceptance of HMA is a new idea in Colorado and should be implemented over an extended period of time for the industry to become familiar with the specification. Additionally, the specification will likely need adjustments.
- The use of a volumetric acceptance specification measures only the field-produced material's resemblance to the mix design specifications. As observed on the I–70 project, the volumetric acceptance testing without other material quality tests assured the poor quality mix design was produced for the project.
- The pay factors when using volumetric acceptance can be very similar to the pay factors when using gradation acceptance. However, as observed on the SH–88 project, the pay factors from the two different specifications do not always agree. It is believed the volumetric acceptance test results will relate more closely to the long-term performance of the pavement than the gradation acceptance test results.
- Test results from a variety of laboratories do not always agree, as observed on US–6. It is necessary to have a laboratory procedure standardization, equipment calibration, and tester certification program. When great care was taken to address these items, test results from different laboratories were very close in agreement, as observed on the I–25 project.
- The standard deviations of test results used to develop the specification tolerances appear reasonable. The standard deviations that include the acceptable variability from sampling, testing (within laboratory), and production were achieved by the contractors in these experimental projects. The standard deviations should be monitored for future adjustments.
- A checklist including eight items has been developed to identify the potential changes that occur in an HMA through the plant. These items include aggregate specific gravity, aggregate angularity, aggregate absorption, percentage of aggregate passing the 75 μm (No. 200) sieve, RAP variability, representative aggregate samples, and adjustment of the asphalt content. Using plant-produced HMA can allow the quick and effective adjustment of HMA. When volumetric acceptance test results are unacceptable, the items on this checklist should be investigated. The checklist should be expanded with additional experience.

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DISCUSSION

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This paper is an outstanding demonstration of a volumetric acceptance Program, clearly demonstrating the limitations, as well as the positive aspects, of using a narrow range of air voids for bituminous mix design and acceptance criteria.

Of major significance is the inclusion of a measure of strength (Hveem stability), which, in each instance, gave a valid indication of rutting potential when the voids criteria would have rejected an acceptable mix in the below 3% air voids range. Referring to Fig. 1, 2 out of 17 mixes (approx. 12%) showed no rutting even though they were in the below 3% air voids range. The Hveem stability, however, correctly indicated that these mixes were acceptable.

Referring (again to Fig. 1) to the mixes with plus 3% air voids, 3 out of 14 (approx. 21%) showed rutting even though they were in the above 3% air voids range. Evidently the Hveem stability did not indicate unacceptability in terms of the measured strength for these mixes.

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