AF2903 Road Construction and Maintenance

Pavement Quality Control/Quality Assurance (QC/QA)

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Quality Control (QC)

Testing performed to determine the level of quality of the product being produced; this level of quality consists of two key components:

- **Target value.** This is the goal set for a certain material characteristic. As a minimum it should conform to standards and be achievable.

- **Variability.** This describes how much a process varies from item-to-item (or location-to-location).

QC is normally performed by the Contractor.

“Process Control” is latest buzzword.
Quality Control

A quality control program consists of:

• Actions and considerations necessary to assess production and construction processes.

• Setting the end product target value and controlling variability.

In order for a quality control program to be effective it should:

• Base actions and decisions on measurable results.

• Be statistically valid.
Quality Assurance (QA)

Testing performed to make a decision on acceptance of a project and hence to ensure that the product being evaluated is indeed what the owner specified; it is normally performed by the Owner.

Independent Assurance

Verification by a third party (not directly responsible for quality control or acceptance) of the product and/or the reliability of test results obtained from quality control and acceptance testing.
Acceptance Plan

The key is to appropriately apply acceptance sampling (small number of random samples to draw conclusions about a large amount of material) and its associated statistics to the pavement construction industry to create a viable overall plan. Correct application involves proper implementation of the following acceptance sampling components:

- Acceptance sampling type
- Quality characteristics
- Specification limits
- Statistical model
- Quality level goals
- Risk
- Pay factors
Acceptance Sampling

There are two basic types of acceptance sampling:

• **Attribute sampling**

Each sample is inspected for the presence of one or several attributes (Quality characteristics); such attributes are compared to a standard then recorded as either passing or failing.

• **Variable sampling**

Measured quality characteristics are used as continuous variables (measurement values are retained). It takes fewer variable samples to get the same information than attribute sampling. Because of this, most statistical acceptance plans use variable sampling. Usually variable sample plans assume a normal distribution of the measured property.
Specification Limits

Specification limits must be based on sound engineering judgment (target value) and sound statistical analysis (acceptable range). This range is used to account for the various sources of variability inherent in producing and testing HMA; specifically, there are four types of variability to consider (Hughes, 1996):

- Material variability
- Sampling variability
- Testing variability
- Manufacturing and construction variability
Measurement of Variability

Statistical Tools:

• Standard Deviation ($\sigma$)
• Variance ($\sigma^2$)
• Coefficient of Variance (CV)
Normal Distribution

\[ y \approx \frac{1}{\sqrt{2\pi}} e^{-\frac{(x-\mu)^2}{2\sigma}} \]

\( \mu \) = Mean
\( \sigma \) = Standard Deviation
\( \pi \approx 3.14159 \)
\( e \approx 2.71828 \)

\( \bar{X} = 5.1 \)

Asphalt Binder Content

4.6  4.7  4.8  4.9  5.0  5.1  5.2  5.3  5.4  5.5  5.6

No. of Samples
Standard Deviation

\[ \sigma = \sqrt{\frac{\sum (x - \mu)^2}{n - 1}} \]

68% of values are within 1 standard deviation of the mean.

95% are within 2 standard deviations.

99.7% are within 3 standard deviations.
## Standard Deviation (σ)

<table>
<thead>
<tr>
<th>Sublot</th>
<th>Asphalt Binder Content</th>
<th>Difference from Mean ((x - \bar{x}))</th>
<th>Square of Differences</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>4.7</td>
<td>-0.4</td>
<td>0.16</td>
</tr>
<tr>
<td>2</td>
<td>5.2</td>
<td>0.1</td>
<td>0.01</td>
</tr>
<tr>
<td>3</td>
<td>5.1</td>
<td>0.0</td>
<td>0.00</td>
</tr>
<tr>
<td>4</td>
<td>5.4</td>
<td>+0.3</td>
<td>0.09</td>
</tr>
<tr>
<td>Sum</td>
<td>20.4</td>
<td></td>
<td>0.26</td>
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</tbody>
</table>

Mean = \(\bar{x} = \frac{20.4}{4} = 5.1\)

\[\sigma = \sqrt{\frac{0.26}{3}} = 0.29\]
Variance and Coefficient of Variation

Variance = $(0.29)^2 = 0.08$

$$CV = \left[ \frac{\text{Standard Deviation}}{\text{Mean}} \right] \times 100$$

$$CV = \left[ \frac{0.29}{5.1} \right] \times 100$$

$$CV = 5.7\%$$
Specifications and Variability

No. of Samples

In-Place Density

Minimum Specification Limit

\( \bar{X} = 93.5 \)
\( \sigma = 0.75 \)

\( \bar{X} = 96.0 \)
\( \sigma = 2.0 \)
Variability

**Material variability** is the true random variation of the material; it is a function of material characteristics alone.

**Sampling variability** is the variation in sample characteristics from sample-to-sample that is attributable to variations in sampling technique.

**Testing variability** is the lack of repeatability of test results. Operators, equipment condition, calibration, and test procedure all contribute to testing variability.

**Manufacturing and construction variability** is the variation in material caused by manufacturing and construction process. These variations can be localized (density or thickness of pavement) or global and easily detected (asphalt content or aggregate gradation).
MATERIAL VARIABILITY

Asphalt Binder:

Different Grades (Same Source)
Different Sources (Same Grade)

Uniformity

Aggregates:

Uniformity of Pit or Quarry
Stockpiling
Moisture Content
MATERIAL VARIABILITY

Quarry Uniformity, Crushing and Sizing
MATERIAL VARIABILITY

Stockpiling
SAMPLING VARIABILITY

- Sample Location
- Sample Method
- Sample Size
- Sample Split
Asphalt Binder Sampling Location

- Refinery
  - Truck Transport
  - Contractors Storage Tank
  - Feed Line to Mixing Location

Sample
Sample
Sample
Sample
SAMPLING VARIABILITY

Aggregate Sampling Location

Pit or Quarry
- Belt
- Chute
- Stockpile

Contractors HMA Plant
- Stockpile
- Cold Feeds
- Cold Feed Collector Belt
SAMPLING VARIABILITY

Aggregate Sampling Size
SAMPLING VARIABILITY

Aggregate Sampling Method
SAMPLING VARIABILITY

HMA Sampling Location

- Plant Conveyor/Chute
- Truck at Plant
- Hopper in Paver
- Loose Mat (Behind Paver)
SAMPLING VARIABILITY

HMA Sampling Location
SAMPLING VARIABILITY

HMA Sampling Location
SAMPLING VARIABILITY

HMA Sampling split
TESTING VARIABILITY

- Precision and Bias
- Details of Test Method
- Options within a Test Method
TESTING VARIABILITY

Precision and Bias

<table>
<thead>
<tr>
<th>Preciseion</th>
<th>Bias</th>
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<tbody>
<tr>
<td>poor</td>
<td>low</td>
</tr>
<tr>
<td>good</td>
<td>high</td>
</tr>
<tr>
<td>good</td>
<td>low</td>
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</table>
## TESTING VARIABILITY

### Asphalt Binder Content Test

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Test Method</th>
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<tbody>
<tr>
<td></td>
<td>Solvent</td>
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<tr>
<td>Precision</td>
<td>Moderate</td>
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<tr>
<td>Bias</td>
<td>Low</td>
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TESTING VARIABILITY

Automatic Gradation Devices

<table>
<thead>
<tr>
<th>Sieve Size</th>
<th>Cum. % Passing</th>
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<tbody>
<tr>
<td>#4</td>
<td>100</td>
</tr>
<tr>
<td>#8</td>
<td>75</td>
</tr>
<tr>
<td>#16</td>
<td>57</td>
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<td>#30</td>
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</tr>
<tr>
<td>#100</td>
<td>15</td>
</tr>
<tr>
<td>#200</td>
<td>10</td>
</tr>
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MANUFACTURING/CONSTRUCTION VARIABILITY

HMA Production

Plant Calibration

Coldfeeds

Belt Scales and Wind Velocity

Baghouse Fines Return System

Conveyors/Chutes

Moisture Content

Storage

Uniformity
MANUFACTURING/CONSTRUCTION VARIABILITY

Coldfeed System
MANUFACTURING/CONSTRUCTION VARIABILITY

Belt Scales and Wind Velocity
Baghouse Return System
MANUFACTURING/CONSTRUCTION VARIABILITY

Storage
HMA Placement and Compaction

Trucking (Loading/Tarping)
Truck/Paver Interface
Paver Mechanics
Rolling Mechanics
Environment
Uniformity
MANUFACTURING/CONSTRUCTION VARIABILITY

Tack Coat
MANUFACTURING/CONSTRUCTION VARIABILITY

Binder Delivery
MANUFACTURING/CONSTRUCTION VARIABILITY

Trucking
MANUFACTURING/CONSTRUCTION VARIABILITY

Placement/Paver Mechanics
MANUFACTURING/CONSTRUCTION VARIABILITY

Compaction Mechanics
LABORATORY MIXTURE DESIGN
- Asphalt Binder
- Aggregate
- Gyratory Compacted Weight-Volume

JMF 1

FIELD TRIAL SECTIONS
- Asphalt Binder Content
- Aggregate Gradation
- Gyratory Compacted Weight-Volume
- In-Place Air Voids

JMF 2

HMA PRODUCTION
- Asphalt Binder Content
- Gradation (All Sizes)
- Lab Compacted + Air Voids
- Dust to Asphalt Ratio

QUALITY ASSURANCE
- SHA Standard Specification

Figure 2. HMA QC/QA guide specification tests.
HMA Field Performance

Greatly affected by Material and Construction Variability

- Rutting
- Fatigue Cracking
- Thermal Cracking
- Durability

Long-term HMA field prediction?
Questions??