Using Contractor-Performed Tests in Quality Assurance

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Project Objective

To develop procedures to assist state transportation agencies in effectively using contractor-performed tests in the quality assurance (QA) process
Components of Quality Assurance

QUALITY ASSURANCE IN CONSTRUCTION

PROCESS CONTROL (QUALITY CONTROL)  ACCEPTANCE  INDEPENDENT ASSURANCE
Components of Quality Assurance

- Contractor-performed test results are used for:
  - Quality/process control
  - Acceptance

- 23CFR637B requires a validation/verification process when contractor-performed tests are used for acceptance

- Validation/Verification issues are critical to accomplishing the project objective
Guiding Principles

• Results of contractor-performed tests can be effectively used in the QA process, particularly for acceptance, if they are the same as results of state DOT-performed tests

• Equality/inequality can be determined by statistical comparisons

• Look for methodology that produces comparable contractor and state DOT-performed test results
Research Approach
1: State of the Practice

• There is **extreme** diversity in how results of contractor-performed tests are used in the QA process.

• When contractor sampling and testing are required, test results will more often that not be used in the acceptance process.
Research Approach
1: State of the Practice (continued)

• The use of results of contractor-performed tests in the QA process is most widespread for:
  1. Hot-mix asphalt concrete
  2. Portland cement concrete (both paving and structural)
  3. Base courses and soils
• Key Issues for using C-P tests for Acceptance:
  - Verification/validation procedures
  - Referee (dispute resolution) procedures
  - Acceptance decision methodology
Research Approach

2: Availability of Comparable Data

• Comparable contractor and state DOT-performed test results

• Archived by state DOT

• State DOTs willing to provide data

• Sufficient diversity in QA methodology to evaluate effects on comparisons
Research Approach
2: Availability of Comparable Data (continued)

• Hot Mix Asphalt Concrete
  - 9 states identified
  - Use at least 7

• Portland Cement Concrete
  - 3 states identified

• Base
  - 2 states identified
Research Approach

3: Evaluate Procedures for Using Contractor-Performed Tests

- Hot Mixed Asphalt Concrete
- LOT Size
  - Day
  - 1500-4000 tons
  - Entire project mix design
- Contractor to State DOT Test Ratio
  - 2 to 1
  - 10 to 1
- Verification Method
  - 1 to 1 Comparison
  - t test of means
  - F and t tests for variance and means
Research Approach
3: Evaluate Procedures for Using Contractor-Performed Tests (continued)

- Type Samples Compared
  - Split
  - Independent

- Acceptance Data
  - State DOT
  - Contractor
  - Combined

- Acceptance Method
  - Accept/Reject
  - Pay Factor
    - Deviation from Target
    - Absolute Deviation from Target
    - Percent Within Limits
Research Approach
3: Evaluate Procedures for Using Contractor-Performed Tests (continued)

• Method of Pay Factor Application
  Lowest for several properties
  Composite for several properties
  Independently for several properties

• Disincentive/Incentive
Research Approach
4: Collect Data and Conduct Analysis

• Construction season of data

• Analyze total database and by project

• Statistically compare contractor and state DOT-performed test results

• Means, variability and other functions thereof (e.g. MSD)
# ALDOT Superpave Data

Parker and Hossain (2002)

<table>
<thead>
<tr>
<th></th>
<th>$\bar{T}_{\text{DOT}}$</th>
<th>$\bar{T}_{\text{CONT}}$</th>
<th>Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Asphalt Content, %</td>
<td>-0.045</td>
<td>-0.036</td>
<td>NSD</td>
</tr>
<tr>
<td>Voids, %</td>
<td>-0.357</td>
<td>-0.281</td>
<td>SD</td>
</tr>
<tr>
<td>Mat Density, % TMD</td>
<td>-1.245</td>
<td>-0.997</td>
<td>SD</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>$S_{\text{DOT}}$</th>
<th>$S_{\text{CONT}}$</th>
<th>Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Asphalt Content, %</td>
<td>0.272</td>
<td>0.230</td>
<td>SD</td>
</tr>
<tr>
<td>Voids, %</td>
<td>1.025</td>
<td>0.863</td>
<td>SD</td>
</tr>
<tr>
<td>Mat Density, % TMD</td>
<td>1.470</td>
<td>1.175</td>
<td>SD</td>
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$\alpha = 0.05$

$\Delta = x - x_T$
### Kentucky Transportation Cabinet
**Mahboub, Hancher and Yang (2004)**

<table>
<thead>
<tr>
<th>Difference</th>
<th>$\bar{x}$</th>
<th>$s$</th>
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</thead>
<tbody>
<tr>
<td>HMA - Voids</td>
<td>NSD</td>
<td>SD</td>
</tr>
<tr>
<td>HMA - Asphalt Content</td>
<td>NSD</td>
<td>SD</td>
</tr>
<tr>
<td>HMA - VMA</td>
<td>NSD</td>
<td>NSD</td>
</tr>
<tr>
<td>PCCP - Air</td>
<td>NSD</td>
<td>SD</td>
</tr>
<tr>
<td>PCCP - Slump</td>
<td>NSD</td>
<td>SD</td>
</tr>
<tr>
<td>PCCP - Strength</td>
<td>NSD</td>
<td>SD</td>
</tr>
<tr>
<td>PCCS - Air</td>
<td>NSD</td>
<td>NSD</td>
</tr>
<tr>
<td>PCCS - Slump</td>
<td>NSD</td>
<td>NSD</td>
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<tr>
<td>PCCS - Strength</td>
<td>NSD</td>
<td>NSD</td>
</tr>
</tbody>
</table>

$\alpha = 0.05$
## Hot Mixed Asphalt Concrete

### Independent Samples - 2003

### Table 1: Concentration (DOT vs. Cont)

<table>
<thead>
<tr>
<th></th>
<th>DOT</th>
<th>CONT</th>
<th>Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>% Passing 3/8&quot;</td>
<td>0.246 (2099)</td>
<td>0.231 (11587)</td>
<td>NSD</td>
</tr>
<tr>
<td>% Passing #8</td>
<td>0.253 (2488)</td>
<td>0.196 (14051)</td>
<td>NSD</td>
</tr>
<tr>
<td>% Passing #200</td>
<td>0.359 (2488)</td>
<td>0.400 (14036)</td>
<td>NSD</td>
</tr>
<tr>
<td>Asphalt Content, %</td>
<td>0.004 (2487)</td>
<td>0.005 (14061)</td>
<td>NSD</td>
</tr>
</tbody>
</table>

### Table 2: Variance (DOT vs. CONT)

<table>
<thead>
<tr>
<th></th>
<th>DOT</th>
<th>CONT</th>
<th>Difference</th>
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<tbody>
<tr>
<td>% Passing 3/8&quot;</td>
<td>6.605</td>
<td>6.044</td>
<td>SD</td>
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<tr>
<td>% Passing #8</td>
<td>9.488</td>
<td>5.534</td>
<td>SD</td>
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<tr>
<td>% Passing #200</td>
<td>1.212</td>
<td>0.769</td>
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<tr>
<td>Asphalt Content, %</td>
<td>0.064</td>
<td>0.040</td>
<td>SD</td>
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$$\alpha = 0.01$$
# Hot Mixed Asphalt Concrete Split Samples - 2003

<table>
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<tr>
<th></th>
<th>(n)</th>
<th>(\bar{\Delta}_{\text{DOT}})</th>
<th>(\bar{\Delta}_{\text{CONT}})</th>
<th>Difference</th>
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</thead>
<tbody>
<tr>
<td>% Passing (3/8'')</td>
<td>953</td>
<td>0.516</td>
<td>0.329</td>
<td>SD</td>
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<tr>
<td>% Passing #8</td>
<td>1142</td>
<td>0.449</td>
<td>0.244</td>
<td>SD</td>
</tr>
<tr>
<td>% Passing #200</td>
<td>1141</td>
<td>0.334</td>
<td>0.447</td>
<td>SD</td>
</tr>
<tr>
<td>Asphalt Content, %</td>
<td>1135</td>
<td>0.005</td>
<td>0.002</td>
<td>NSD</td>
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</table>

<table>
<thead>
<tr>
<th></th>
<th>(S^2_{\text{DOT}})</th>
<th>(S^2_{\text{CONT}})</th>
<th>Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>% Passing (3/8'')</td>
<td>8.479</td>
<td>5.545</td>
<td>SD</td>
</tr>
<tr>
<td>% Passing #8</td>
<td>8.673</td>
<td>6.561</td>
<td>SD</td>
</tr>
<tr>
<td>% Passing #200</td>
<td>1.137</td>
<td>0.791</td>
<td>SD</td>
</tr>
<tr>
<td>Asphalt Content, %</td>
<td>0.088</td>
<td>0.045</td>
<td>SD</td>
</tr>
</tbody>
</table>

\(\alpha = 0.01\)

1 to 1 comparisons

Paired \(t\) test for means
Independent Samples

Project DOT QA Mean (%)

Project Contractor Mean QCT (%)

[Graph showing a scatter plot with data points and axis labels]

- Project DOT QA Mean (%)
- Project Contractor Mean QCT (%)
Independent Samples

![Graph showing correlation between Project Contractor QC Variance (%) and Project DOT QA Variances (%)]
Split Samples

Project Contractor QC Variance (%) vs. Project DOT Comparison Variance (%)

The scatter plot shows the relationship between Project Contractor QC Variance (%) and Project DOT Comparison Variance (%). The dashed line represents a linear trend.
### Hot Mixed Asphalt Concrete
Independent Samples - 2003

<table>
<thead>
<tr>
<th></th>
<th>$\Delta_{DOT}$</th>
<th>$\Delta_{CONT}$</th>
<th>Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Voids, %</td>
<td>0.322 (393)</td>
<td>0.262 (1494)</td>
<td>NSD</td>
</tr>
<tr>
<td>Mat Density, % TMD</td>
<td>1.454 (2281)</td>
<td>1.645 (4554)</td>
<td>SD</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>$S^2_{DOT}$</th>
<th>$S^2_{CONT}$</th>
<th>Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Voids, %</td>
<td>0.643</td>
<td>0.318</td>
<td>SD</td>
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<tr>
<td>Mat Density, % TMD</td>
<td>3.016</td>
<td>1.674</td>
<td>SD</td>
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</table>

$\Delta = X - X_T$ for voids

$\Delta = X - LSL$ for mat density
Preliminary Conclusions from Comparisons

• Means may or may not be SD

• Means of DOT differences from targets likely larger

• Variabilities likely SD

• Variabilities of DOT test results likely larger