TECHNICAL ADVISORY
T 6120.3
Use of Contractor Test Results in the Acceptance Decision ...

2007 Louisiana Transportation Engineering Conference
Baton Rouge, LA
February 12, 2007
TECHNICAL ADVISORY
T 6120.3

www.fhwa.dot.gov/pavement/ta.htm
Why?

- Outline for effective QA stewardship and implementation
- Clarification of existing regulation on independent samples, split samples and the validation of test results
- Unified Agency goals
  Statistically valid specifications, Percent within Limits (PWL), Risk Analysis
Background

Title 23 Code of Federal Regulations
Part 637
(23 CFR 637)

June 29, 1995

http://www.access.gpo.gov/nara/cfr/waisidx_03/23cfr637_03.html
33 States using Contractor Test Results in the Acceptance Decision
17 States Reviewed as part of QA Stewardship Reviews
23CFR637B Sec. 637.207 QA Program

Contractor sampling and test results can be used as part of the acceptance decision provided:

(a)(1)(ii)(B) … they are validated by verification sampling and testing … verification testing shall be performed on samples taken independently of the contractor samples
\[ \sigma^2_{\text{material}} + \sigma^2_{\text{process}} + \sigma^2_{\text{sampling}} + \sigma^2_{\text{testing}} \]
(d) The verification sampling and testing are to be performed by qualified testing personnel employed by the State or its designated agent, excluding the contractor and vendor.
Independent Samples

When is it possible to allow some limited contractor involvement in taking independent verification samples for the State?

- Labor Regulations
- Hazardous Conditions
- Liability Issues
Independent Samples

When is it possible to allow some limited contractor involvement in taking independent verification samples for the State?

- Labor Regulations
- Hazardous Conditions
- Liability Issues

EXCEPTION
NOT THE RULE
The State can use the services of the contractor’s personnel to assist in obtaining independent verification samples when the following requirements are adhered to:
Independent Samples

- The verification sample location or time is randomly selected by the State and is only given to the contractor immediately prior to sampling.
- The contractor’s personnel are used only to provide labor to assist in physically obtaining the verification sample of the material.
- The State is present to witness the taking of the verification sample.
Independent Samples

- Both the State witness and contractor labor are qualified sampling personnel.
- The State witness controls the sampling process by choosing the location or timing and directing the taking of the verification sample.
- The State witness immediately takes possession of the verification sample.
Split Samples

Can be used in the acceptance decision if the test results are independently validated.
Split Samples – Independent Validation

Contractor's Tests = Contractor Tests

State Tests = State Tests

Testing by Contractor

Testing by State

Not Used for Validation

Validation

Contractor's Test Results are Validated by State Verification Tests
Split Samples – Independent Validation

Contractor's Test Results are Validated by State Verification Tests

Testing by Contractor

Testing by State

Verification Testing by State

Not Used for Validation

Contractor's Test

Results are Validated by State Verification Tests
TECHNICAL ADVISORY

= Contractor Tests

= State Tests

Split Samples
TECHNICAL ADVISORY

Acceptance of Validated Test Results

(a) + Split

(b) + Split

(c)

(d) +

= Contractor Tests

= State Tests
Independent Sample Validation

F-test

\[ H_0: \text{variances are equal, } s^2_{\text{contractor}} = s^2_{\text{state}} \]

\( t \)-test (independent)

\[ H_0: \text{means are equal, } \overline{X}_{\text{contractor}} = \overline{X}_{\text{state}} \]
### Power of the $F$-test

<table>
<thead>
<tr>
<th>Ratio of Standard Deviations</th>
<th>Number of Contractor Tests</th>
<th>Number of Agency Tests</th>
<th>Probability of Detecting a Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>3</td>
<td>3</td>
<td>0.10</td>
</tr>
<tr>
<td>5</td>
<td>5</td>
<td>5</td>
<td>0.21</td>
</tr>
<tr>
<td>20</td>
<td>5</td>
<td>5</td>
<td>0.49</td>
</tr>
<tr>
<td>40</td>
<td>10</td>
<td>10</td>
<td>0.77</td>
</tr>
<tr>
<td>50</td>
<td>15</td>
<td>15</td>
<td>0.90</td>
</tr>
</tbody>
</table>
**TECHNICAL ADVISORY**

## Power of the (independent) $t$-test

<table>
<thead>
<tr>
<th>Difference in Means</th>
<th>Number of Contractor Tests</th>
<th>Number of Agency Tests</th>
<th>Probability of Detecting a Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>5</td>
<td>1</td>
<td>0.34</td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>1</td>
<td>0.42</td>
</tr>
<tr>
<td></td>
<td>7</td>
<td>1</td>
<td>0.46</td>
</tr>
<tr>
<td></td>
<td>8</td>
<td>1</td>
<td>0.53</td>
</tr>
<tr>
<td></td>
<td>9</td>
<td>1</td>
<td>0.54</td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>1</td>
<td>0.58</td>
</tr>
</tbody>
</table>
## Power of the (paired) $t$-test

<table>
<thead>
<tr>
<th>Difference in Means</th>
<th>Number of Contractor Tests</th>
<th>Number of Agency Tests</th>
<th>Probability of Detecting a Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>2</td>
<td>2</td>
<td>0.17</td>
</tr>
<tr>
<td>3</td>
<td>3</td>
<td>3</td>
<td>0.47</td>
</tr>
<tr>
<td>4</td>
<td>4</td>
<td>4</td>
<td>0.73</td>
</tr>
<tr>
<td>...</td>
<td>...</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>7</td>
<td>7</td>
<td>7</td>
<td>0.98</td>
</tr>
<tr>
<td>10</td>
<td>10</td>
<td>10</td>
<td>1.00</td>
</tr>
</tbody>
</table>
33 States using Contractor Test Results in the Acceptance Decision
All States using Contractor Test Results in the Acceptance Decision?
No States using Contractor Test Results in the Acceptance Decision?
Quality Measures

Recommended
- Percent within Limits (PWL)
- Percent Defective (PD)

Not Recommended
- Average Deviation
- Absolute Average Deviation
- Conformal Index
- Moving Average
TECHNICAL ADVISORY

Percent within Limits (PWL)

\[ \bar{X} - \text{mean} \]
\[ s - \text{standard deviation} \]
TECHNICAL ADVISORY

Percent within Limits (PWL)
Percent Defective (PD)

\[ \overline{X} \text{- mean} \]
\[ s \text{- standard deviation} \]
TECHNICAL ADVISORY

✓ Percent within Limits (PWL)

Percent Defective (PD)

\[ \text{PWL} = 100 - \text{PD} \]
\[ \text{PD} = 100 - \text{PWL} \]
Benefits of Percent within Limits

- More discerning than other quality measures
- Efficiently captures the mean and standard deviation into one measure of quality
- Encourages Uniformity
  - Controls both the average level and variability of the product in a statistically efficient way
- Predictor of performance
- Economic benefit for payment purposes
Incentive to provide a more uniform product.
Incentive to provide a more uniform product.

- **μ = 6.0**
- **σ = 0.1**
- **μ = 6.0**
- **σ = 0.3**
Incentive to provide a more uniform product.
Incentive to provide a more uniform product.

As sample standard deviation decreases, mean can approach spec. limit and remain acceptable.

\[ \mu = 6.0 \]
\[ \sigma = 0.3 \]

\[ \mu = 5.63 \]
\[ \sigma = 0.1 \]
TECHNICAL ADVISORY

Benefit to the State

95PWL

90PWL
Risks

- Considered in properly developed QA plans
- Dependent on selected AQL and RQL
- Lowered with larger sample quantities
- Developed using computer simulation
  - Programs: NONCENTT, Demo89, PWL-Pay, SPEC Risk (mid 2007)
  - Operating Characteristic (OC) Curves
  - Expected Pay (EP) Curves
TECHNICAL ADVISORY

OC Curves

(accept/reject)

![OC Curves Diagram](image)

- **Seller’s (Contractor) Risk, $\alpha$**
- **Buyer’s (Department) Risk, $\beta$**

```
Level of Quality
```

```
Prob. of Acceptance, %
```

```
RQL
```

```
AQL
```

```
100
```

```
80
```

```
60
```

```
40
```

```
20
```

```
0
```

OC Curves

Probability (%) of Receiving PF

Level of Quality

PF = Pay Factor

α₀
α₀
α₁₀₀
β₀
β₀
β₁₀₀

PF > 0.00
PF ≥ 0.70
PF ≥ 0.90
PF ≥ 0.95
PF ≥ 1.00
PF ≥ 1.05
PF = 1.10

(pay adjustments)
EP Curve

AQL = 100% Pay

Maximum Payment Factor = 102%
TECHNICAL ADVISORY

Risks

Producer Risk

Agency Risk

Level of Quality

Prob. of Acceptance, %

Expected Payment, %

Seller’s (Contractor) Risk, α

AQL

RQL

PF = 0.00

PF = 0.70

PF = 0.90

PF = 0.95

PF = 1.00

PF = 1.05

PF = 1.10

U.S. Department of Transportation
Federal Highway Administration
Resources

- FHWA-RD-02-095  “Optimal Procedures for Quality Assurance Specifications”

(Burati, Weed, Hughes, Hill)
Resources

- NHI Course 134042: Materials Control and Acceptance - Quality Assurance
- FHWA Basic PWL Workshop
- SPECRISK software (mid 2007)
- NHI Course 134059: Quality Assurance Specification Development and Validation Course (end 2008)
- 2003-2005 Summary Report
Matthew Corrigan, P.E.
Mobile Asphalt Laboratory Program Manager
Warm Mix Asphalt Program Manager

Office of Pavement Technology
HIPT-10, Room 3118
400 Seventh Street S.W.
Washington, DC 20590

matthew.corrigan@fhwa.dot.gov
www.fhwa.dot.gov/pavement