## 2014 Eastern Region Annual Airports Conference
### Workshop for Asphalt Pavement for Airports
#### Statistical Analysis

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Consultant

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### Overview

**P 401 Test Results**

- Statistical Analysis; PWL Estimate
- Verify Production Process: Payment

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### Theory

1. **Assumptions**
2. **Normal Distribution**
3. **Tools: Average and Standard Deviation**
4. **Percent Within Limits (PWL) Concept**

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### Assumptions

1. Limited # of test results  
   - Statistical Analysis  
   - Quality characteristics of large amount of material
2. Test result variability
   - Components:
     - materials
     - sampling-ERLPM
     - testing-ERLPM
3. Same Process
4. Random sampling-Lot, Sublot
5. Normal Distribution

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### Specific Procedures

1. **Sublots, Lots, Partial Lots**
2. **Calculations**
3. **Retesting**
4. **Outliers**

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### Analysis

- % Taller than 5'-6”
- % between 5'-6” and 6'-6”
- Average Height

**Population**

<table>
<thead>
<tr>
<th>Frequency</th>
<th>Limit # of samples</th>
<th>Statistical Analysis</th>
<th>Estimate average and % within limits</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>10</td>
<td></td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>30</td>
<td></td>
<td></td>
</tr>
<tr>
<td>30</td>
<td>40</td>
<td></td>
<td></td>
</tr>
<tr>
<td>50</td>
<td>60</td>
<td></td>
<td></td>
</tr>
<tr>
<td>70</td>
<td>80</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Figure 1

PWL Calculation Procedures

Table 5: Marshall Acceptance Limits
Given

\[ \begin{align*}
x_1 &= 2 \\
x_2 &= 4 \\
x_3 &= 6 \\
x_4 &= 8
\end{align*} \]

\[ X = \frac{2 + 4 + 6 + 8}{4} = 5 \]

\[ S_n = \sqrt{\frac{d_1^2 + d_2^2 + d_3^2 + d_4^2}{n-1}} \]

Roundout Rules

ERLPM-page 48

Example-last digit to be kept nearest 10

<table>
<thead>
<tr>
<th>Roundout</th>
<th>Rule</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.61</td>
<td>Even Digit—same</td>
</tr>
<tr>
<td>4.62</td>
<td>Odd Digit—increase by 1</td>
</tr>
<tr>
<td>4.64</td>
<td>If it was 4.6500 it would become 4.7</td>
</tr>
<tr>
<td>4.6500</td>
<td></td>
</tr>
<tr>
<td>4.66</td>
<td></td>
</tr>
<tr>
<td>4.67</td>
<td></td>
</tr>
<tr>
<td>4.68</td>
<td></td>
</tr>
<tr>
<td>4.69</td>
<td></td>
</tr>
</tbody>
</table>

MAT Density—One side density acceptance

Manual Appendix E, page 4

Sublot

<table>
<thead>
<tr>
<th>No</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>100</td>
</tr>
<tr>
<td>2</td>
<td>99</td>
</tr>
<tr>
<td>3</td>
<td>96</td>
</tr>
</tbody>
</table>

\[ x = 98 \]

\[ S_n = 1.8 \]

\[ Q_u = 101.3 - 98.0 = 1.3 \] (101.3 found in spec Table 5)

Determine PWL using ERLPM table 4. In column \( n=4 \) look up the \( P_L \) value which corresponds to \( Q_u = 1.3 \)

Read \( P_L = 100 \)

Mat Density—Two sided acceptance for density

\[ x = 98.0 \]

\[ S_n = 1.8 \]

\[ Q_L = \frac{98-x}{S_n} \] (ERLPM page 50)

\[ Q_L = \frac{98-98.0}{1.8} = 0.000 \]

PWL calculation for two sided specification

\[ PWL = PL + PU - 100 \]

(ERLPM page 50 par 8.5.2)

\[ PWL = 82 + 100 - 100 = 82 \]
Target Density 98.0 Achieved  
$Sn=1.8$ versus 1.3  
Acceptable QC Value  
as per P-401 spec. Table 5

Effect of Quality Control

Air Voids

Air Voids

Air Voids

Air Voids
### Payment – One side for density

**TABLE 6. PRICE ADJUSTMENT SCHEDULE**

<table>
<thead>
<tr>
<th>Percentage of Material Within Specification Limits (PWL)</th>
<th>Lot Pay Factor (Percent of Contract Unit Price)</th>
</tr>
</thead>
<tbody>
<tr>
<td>96 – 100</td>
<td>106</td>
</tr>
<tr>
<td>90 – 95</td>
<td>PWL + 10</td>
</tr>
<tr>
<td>75 – 89</td>
<td>0.5 PWL + 55</td>
</tr>
<tr>
<td>Below 75</td>
<td>Reject</td>
</tr>
</tbody>
</table>

Payment

Spec-par 401-8.1a
MAT Density PWL=82
Air Voids PWL= 58 — Lower value

Lot Pay Factor
Air Voids- 1.4 x 58-12= 69.2%
Mat Density- 0.5 x 82+55= 96%
Use lower of 2 values- 69.2%

### Joint Density

Appendix P, page 5

<table>
<thead>
<tr>
<th>93.3</th>
<th>95.0</th>
<th>97.0</th>
<th>96.0</th>
</tr>
</thead>
<tbody>
<tr>
<td>X= 95.3</td>
<td>1.58</td>
<td>1.58</td>
<td></td>
</tr>
</tbody>
</table>

Ql = (95.3 - 93.3) / 1.58 = 1.2658

P = 93

Spec. par. 401-5.2(b)(3) if < 71% there is a 5% penalty

### Partial Lots

Section P-401-5.1c

### Sample Problem

Flow-Appendix D, page 5
Partial lot situation

8.0, 8.2, 8.5, 8.2, 8.9, 9.1
X= 8.5
Sn = 1.58

Ql = 5.2

X= 8.5 ± 1.58 = 10.08

P = 88

PWL = 88+100= 188.90

Corrective Action 401-5.2(b)(2)
Outliers

Spec 401-5.2d
401-5.3c
MAT Density and Air Voids

Test for Outliers

<table>
<thead>
<tr>
<th>MAT Density</th>
<th>QL = 96.2 - 96.3 = 0.085</th>
</tr>
</thead>
<tbody>
<tr>
<td>94.0</td>
<td>1.71</td>
</tr>
<tr>
<td>96.0</td>
<td></td>
</tr>
<tr>
<td>97.0</td>
<td>PL = 50%</td>
</tr>
<tr>
<td>98.0</td>
<td></td>
</tr>
<tr>
<td>x = 96.2</td>
<td></td>
</tr>
<tr>
<td>Sn = 1.71</td>
<td></td>
</tr>
</tbody>
</table>

ASTM E 178, par. 4

\[ T_p = \frac{(x - \bar{x})}{S_n} \]

\[ T_p = \frac{96.2 - 94}{1.71} = 1.286 \]

Since 1.286 < 1.463, the 94.0 test value is not considered an outlier and is retained!

Sample Problem-Outliers

- Table 1-ASTM E 178
- N=4
- Upper 5% significance level 1.463
- Since 1.286 < 1.463 the 94.0 test value is not considered an outlier and is retained!
Resampling

MAT Density ONLY
(Appendix E pg 4)
Prior MAT Density: 96, 97, 99, 100
PWL 82

4 new cores 96, 96, 97, 98
AVG all 88, 97.4
Sα 1.51

Qα = 1.51
27.4 96.3 = .7337
Sn = 1.51
Table 4, N=8
PWL = 77

Questions?

Thanks!