Construction Quality Index

Construction Conference 2010
About the Research

- FDOT contracts PR608014 and PR1575813
- Research organizations
  - University of Florida
- Research reports available online
  - http://www.dot.state.fl.us/research-center/Completed_StateMaterials.shtm
What is a Construction Quality Index?

- CQI is a rational measure of the overall quality of a constructed facility
  - Determine the quality of the individual components
  - Link together to obtain a composite index
- CQI as developed is not based on fundamental material properties directly related to long term pavement performance
- The subject CQI is, rather, a measure of specification compliance
Why do we need a CQI?

- Increased need for “quality-driven” workmanship
- There is a need for quantifying quality and implementing appropriate measurement techniques and approaches
Research Objectives

- Develop a practical and effective pavement CQI that is...
  - Implementable without modification to the Department’s current test and measurement system
  - Addresses material, structural, smoothness, and other construction requirements as defined in current specifications
  - Applicable for new and rehabilitated pavements
Technical Approach

Task 1: Literature Review

Task 2: Model Formulation

Task 3: Model Development

Task 4: Model Evaluation

Task 5: Documentation
Model Formulation

◆ Goals

✓ Based on FDOT specifications
✓ Practical, transparent and easily understood
✓ Address quality factors for major types of construction
✓ Feature simple, readily-implementable relationships and logic
✓ Modular
Acceptance Quality Characteristic

- Inherent pavement construction characteristic:
  - Thought to affect future pavement performance
  - Under the control of the contractor
  - Measurable at or near the time of construction
Model Formulation

CQI of individual AQC:
\[(cqi)_{AQC} = PWL_{(AQC)}\]

CQI of individual layer:
\[CQI_{layer} = \sum_{AQC} w_{AQC} \cdot (cqi)_{AQC}\]

CQI of pavement:
\[CQI_{pavement} = \sum_{layers} W_{layer} \cdot CQI_{layer}\]

http://www.dot.state.fl.us/research-center/Completed_StateMaterials.shtml
**Expert Panel Meetings**

- Expert panel of stakeholders developed CQI weighting factors
- **Contracts**
- **DOT**
- **FHWA**
- **Academia**

- Three meetings held during Summer ’06

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**FDOT Construction Quality Index**

**Expert Panel Rating Sheet**

**Rigid Pavement**

<table>
<thead>
<tr>
<th>Rigid Pavement System Components</th>
<th>Concerning</th>
<th>Rigid Pavement Quality Factors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Embankment</td>
<td>Concerning</td>
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<td>Embankment</td>
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<td>Embankment</td>
<td>Embankment</td>
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<tr>
<td>Embankment</td>
<td>Stabilized Subgrade</td>
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<tr>
<td>Embankment</td>
<td>PCC</td>
<td></td>
</tr>
<tr>
<td>Embankment</td>
<td>Treated Permeable Base</td>
<td></td>
</tr>
<tr>
<td>Embankment</td>
<td>Other</td>
<td></td>
</tr>
</tbody>
</table>

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**Rigid Pavement Quality Factors**

- **Density**
  - LBR
  - Thickness
- **LBR**
  - Thickness
- **Stabilized Subgrade**
  - Gradation
  - Water-Cement Ratio
  - Air Content
  - Compressive Strength
- **PCC**
  - Asphalt Content Gradation
  - Air Content
  - Compressive Strength

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**Concerning**

- **Affiliation**
  - Florida Department of Transportation
  - Construction Industry
  - Consultant
  - Academia
  - Other

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**Name:**

**Location:**

**Date:**
Components of Flexible Pavement System

- Embankment
- Subgrade
- Base Course
- Superpave
- Friction Course

\[ CQI_{FP} = W_E (cqi)_E + W_{SG} (cqi)_{SG} + W_{BC} (cqi)_{BC} + W_{SP} (cqi)_{SP} + W_{FC} (cqi)_{FC} \]
Superpave AQCs

<table>
<thead>
<tr>
<th>Quality Characteristic</th>
<th>Specification Limits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Passing No. 8 [2.36 mm] sieve (percent)</td>
<td>Target ± 3.1</td>
</tr>
<tr>
<td>Passing No. 200 [75 μm] sieve (percent)</td>
<td>Target ± 1.0</td>
</tr>
<tr>
<td>Asphalt Content (percent)</td>
<td>Target ± 0.40</td>
</tr>
<tr>
<td>Air Voids – Coarse Mixes (percent)</td>
<td>4.00 ± 1.40</td>
</tr>
<tr>
<td>Air Voids – Fine Mixes (percent)</td>
<td>4.00 ± 1.20</td>
</tr>
<tr>
<td>Density – Coarse Mixes (percent of $G_{mm}$):</td>
<td>94.50 ± 1.30</td>
</tr>
<tr>
<td>Density – Fine Mixes (percent of $G_{mm}$):</td>
<td>$93.00 ± 2.00, -1.20 (1)$</td>
</tr>
</tbody>
</table>

Note (1): If the Engineer (or Contract Documents) limits compaction to the static mode only, the specification limits are as follows: $92.00 ± 3.00, -1.20$. No additional compensation, cost or time, shall be made.

$$cqi_{SP} = w_{P(#8)} PWL_{P(#8)} + w_{P(#200)} PWL_{P(#200)} + w_{Pb} PWL_{Pb}$$

$$+ w_{Va} PWL_{Va} + w_{P(G_{mm})} PWL_{P(G_{mm})}$$
Layer Weights – Flexible

\[ CQI_{pavement} = \sum_{\text{layers}} W_{\text{layer}} \cdot CQI_{\text{layer}} \]
AQC Weights – Friction Course

\[ CQI_{layer} = \sum_{AQC} w_{AQC} \cdot (cqi)_{AQC} \]

FC 5

FC 9.5 and FC 12.5
AQC Weights – Structural Layer

\[ CQI_{layer} = \sum_{AQC} w_{AQC} \cdot (cqi)_{AQC} \]

- **Passing #200, 0.089**
- **Passing #8, 0.089**
- **Density, 0.316**
- **Air Voids, 0.269**
- **Asphalt Content, 0.237**
AQC Weights – Supporting Layers

\[ CQI_{layer} = \sum_{AQC} w_{AQC} \cdot (cqi)_{AQC} \]

Base Course
- Thickness, 0.333
- Density, 0.667

Subgrade
- Thickness, 0.327
- Density, 0.413
- LBR, 0.260

Embankment
- Density, 1.000
Components of a Rigid Pavement System

- Embankment
- Subgrade
- Base Course
- PCC Slab

\[ CQI_{RP} = W_E (cqi)_E + W_{SG} (cqi)_{SG} + W_{BC} (cqi)_{BC} + W_{PCC} (cqi)_{PCC} \]
Layer Weights – Rigid Pavement System

\[ CQI_{\text{pavement}} = \sum_{\text{layers}} W_{\text{layer}} \cdot CQI_{\text{layer}} \]

- Embankment, 0.075
- Stabilized Subgrade, 0.099
- Base Course, 0.212
- PCC, 0.614
AQC Weights – PCC Slab

\[ CQI_{\text{layer}} = \sum_{AQC} w_{AQC} \cdot (cqi)_{AQC} \]

- **Profile Index, 0.328**
- **Air Content, 0.039**
- **Slump, 0.058**
- **Water-cement Ratio, 0.133**
- **Compressive Strength, 0.176**
- **Thickness, 0.266**
AQC Weights – Permeable Base

\[ CQI_{layer} = \sum_{AQC} w_{AQC} \cdot (cqi)_{AQC} \]

ATPB

CTPB

Binder Content, 0.333
Gradation, 0.667

Water-cement ratio, 0.413
Gradation, 0.327
Cement Factor, 0.260
AQC Weights – Supporting Layers

\[ CQI_{layer} = \sum_{AQC} w_{AQC} \cdot (cqi)_{AQC} \]

- **Subgrade**
  - Thickness, 0.327
  - Density, 0.413
  - LBR, 0.260

- **Embankment**
  - Density, 1.000
Model Evaluation

- Representative real world projects
  - Flexible/rigid
  - Rehabilitation/new

- Recent
  - Current methods and specifications
  - Data available in LIMS

- Project managers requested to provide a level of satisfaction or rating based on specification compliance
Model Evaluation for Flexible Pavements

- 37 projects identified with sufficient data
  - 20 ‘good’ and 17 ‘poor’
  - 8 new construction projects
  - 29 resurfacing projects
CQI Rating for Flexible Projects

- **Good Projects**
- **Poor Projects**

<table>
<thead>
<tr>
<th>CQI (Asphalt Layers only)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.00</td>
</tr>
<tr>
<td>0.10</td>
</tr>
<tr>
<td>0.20</td>
</tr>
<tr>
<td>0.30</td>
</tr>
<tr>
<td>0.40</td>
</tr>
<tr>
<td>0.50</td>
</tr>
<tr>
<td>0.60</td>
</tr>
<tr>
<td>0.70</td>
</tr>
<tr>
<td>0.80</td>
</tr>
<tr>
<td>0.90</td>
</tr>
<tr>
<td>1.00</td>
</tr>
</tbody>
</table>

**Projects:** 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50

- **CQI Rating:**
  - Good Projects: 0.50, 0.60, 0.70, 0.80, 0.90
  - Poor Projects: 0.90, 0.80, 0.70, 0.60, 0.50
CQI Rating for Flexible Projects

- A CQI of approximately 0.80 appears to discriminate between good and poor flexible projects

- Average CQI for ride number
  - Good: 0.94
  - Poor: 0.51

- Average CQI for density
  - Good
    - Friction course: 0.88
    - Structural layer: 0.85
  - Poor
    - Friction course: 0.58
    - Structural layer: 0.64
Model Evaluation for Rigid Pavements

- 14 projects provided
  - Only 7 projects had sufficient data for statistical analysis
  - All 7 projects rated as good by district engineers
  - Because of lack of a larger representative sample, a definitive comprehensive assessment was not appropriate
Model Evaluation for Rigid Pavements

No poor projects evaluated
### CQI Breakdown:

<table>
<thead>
<tr>
<th>Layer / Test Name</th>
<th>CQI</th>
<th>Weight</th>
<th>CQI x Weight</th>
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</thead>
<tbody>
<tr>
<td>PCS 4464A</td>
<td>0.7151</td>
<td>0.2760</td>
<td>0.1971</td>
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<tr>
<td>Passing 3/8&quot;</td>
<td>0.9815</td>
<td>1.0000</td>
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<tr>
<td>Passing #4</td>
<td>0.6665</td>
<td>0.1070</td>
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<tr>
<td>Passing #6</td>
<td>0.6771</td>
<td>0.0960</td>
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<tr>
<td>Asphalt Content</td>
<td>0.9629</td>
<td>0.3920</td>
<td></td>
</tr>
<tr>
<td>Ride Number</td>
<td>0.2659</td>
<td>0.3130</td>
<td></td>
</tr>
<tr>
<td>East</td>
<td>0.3207</td>
<td>0.5000</td>
<td></td>
</tr>
<tr>
<td>West</td>
<td>0.2139</td>
<td>0.5000</td>
<td></td>
</tr>
<tr>
<td>SuperPave 3305E</td>
<td>0.8818</td>
<td>0.8172</td>
<td></td>
</tr>
<tr>
<td>Passing #200</td>
<td>1.0000</td>
<td>0.0990</td>
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</tr>
<tr>
<td>Passing #8</td>
<td>0.5981</td>
<td>0.0850</td>
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</tr>
<tr>
<td>Air Voids</td>
<td>0.9796</td>
<td>0.2690</td>
<td></td>
</tr>
<tr>
<td>Asphalt Content</td>
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<tr>
<td>Density</td>
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<tr>
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<td>Passing #200</td>
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<td>0.0890</td>
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<tr>
<td>Passing #8</td>
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<tr>
<td>Air Voids</td>
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<tr>
<td>Density</td>
<td>0.6449</td>
<td>0.3160</td>
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</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td></td>
<td>0.8404</td>
</tr>
</tbody>
</table>
Pavement Performance

- CQI is not based on fundamental properties inherent to pavement performance
- CQI is a measure of specification compliance
Contractor CQI

**Historical noncompliance rates from 2005 to 2007**
Summary and Conclusions

- CQI threshold of 0.80 appears to discriminate between good and poor flexible rehabilitation projects

- Rigid projects were limited and did not consider whole construction spectrum
  - All good projects had a CQI > 0.80
  - Need to expand evaluation to include a larger pool projects

- What’s next?
  - Continue to evaluate CQI
  - Develop implementation plan