

# *Construction Quality Index*



*Construction Conference 2010*



# ***About the Research***

- ◆ FDOT contracts PR608014 and PR1575813
- ◆ Research organizations
  - ✓ Applied Research Associates, Inc.
  - ✓ University of Florida
- ◆ Research reports available online
  - ✓ [http://www.dot.state.fl.us/research-center/Completed\\_StateMaterials.shtm](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*

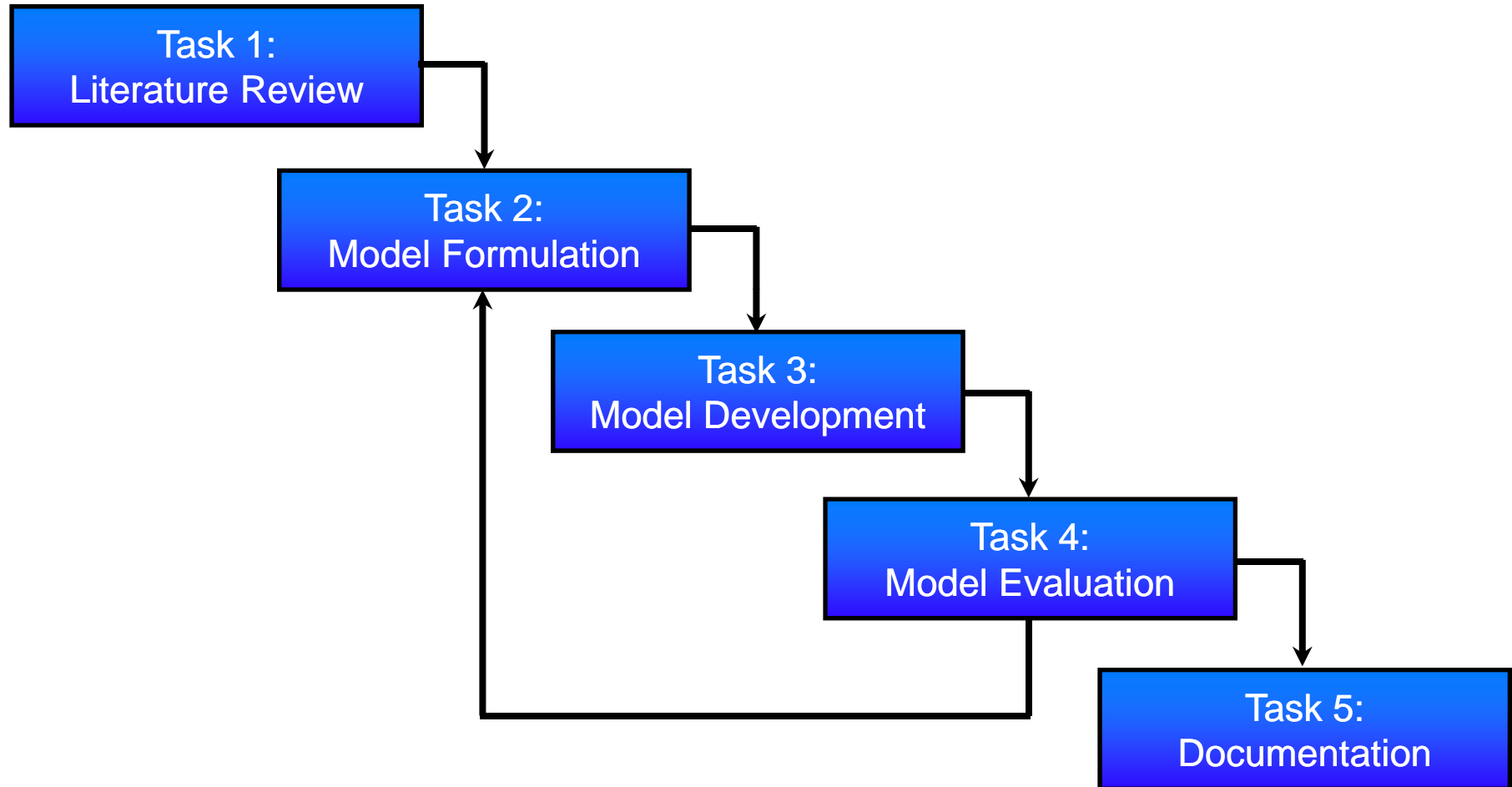


# Research Objectives

- ◆ 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*



# ***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



Layer 1



Layer 2



·  
·  
·



Layer n

CQI of individual AQC:

$$(cqi)_{AQC} = PWL_{(AQC)}$$

CQI of individual layer:

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

CQI of pavement:


$$CQI_{pavement} = \sum_{layers} W_{layer} \cdot CQI_{layer}$$



# Expert Panel Meetings

- ◆ Expert panel of stakeholders developed CQI weighting factors
  - ✓ Contractors
  - ✓ DOT
  - ✓ FHWA
  - ✓ Academia
  
- ◆ Three meetings held during Summer '06

Sheet 1 of 1



**FDOT CONSTRUCTION QUALITY INDEX  
EXPERT PANEL RATING SHEET  
RIGID PAVEMENT**

Name: \_\_\_\_\_  
 Location: \_\_\_\_\_  
 Date: \_\_\_\_\_

Affiliation:  Florida Department of Transportation  
 Construction Industry  
 Consultant  
 Academia  
 Other

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Concerning: **Rigid Pavement System Components**  
 Which factor has the greater influence on quality?

Factor	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Factor
Embankment																		Stabilized Subgrade
Embankment																		Treated Permeable Base
Embankment																		PCC
Stabilized Subgrade																		Treated Permeable Base
Stabilized Subgrade																		PCC
Treated Permeable Base																		PCC

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Concerning: **Stabilized Subgrade**  
 Which factor has the greater influence on quality?

Factor	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Factor
Density																		LBR
Density																		Thickness
LBR																		Thickness

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Concerning: **Cement Treated Permeable Base**  
 Which factor has the greater influence on quality?

Factor	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Factor
Gradation																		Water-Cement Ratio
Gradation																		Cement Factor
Water-Cement Ratio																		Cement Factor

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Concerning: **Asphalt Treated Permeable Base**  
 Which factor has the greater influence on quality?

Factor	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Factor
Asphalt Binder Content																		Gradation

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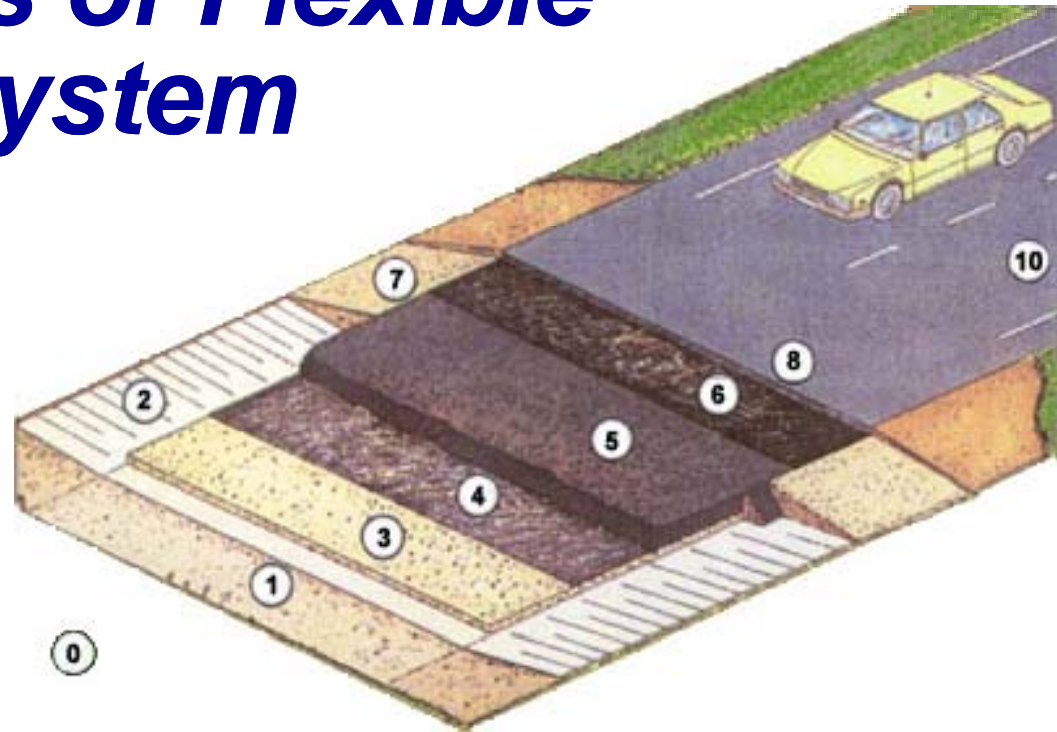
Concerning: **PCC**  
 Which factor has the greater influence on quality?

Factor	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Factor
Air Content																		Compressive Strength
Air Content																		Profile Index
Air Content																		Slump
Air Content																		Thickness
Compressive Strength																		Water-Cement Ratio
Compressive Strength																		Profile Index
Compressive Strength																		Slump
Compressive Strength																		Thickness
Profile Index																		Water-Cement Ratio
Profile Index																		Slump
Profile Index																		Thickness
Slump																		Water-Cement Ratio
Slump																		Water-Cement Ratio
Thickness																		Water-Cement Ratio



# 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 AQC's

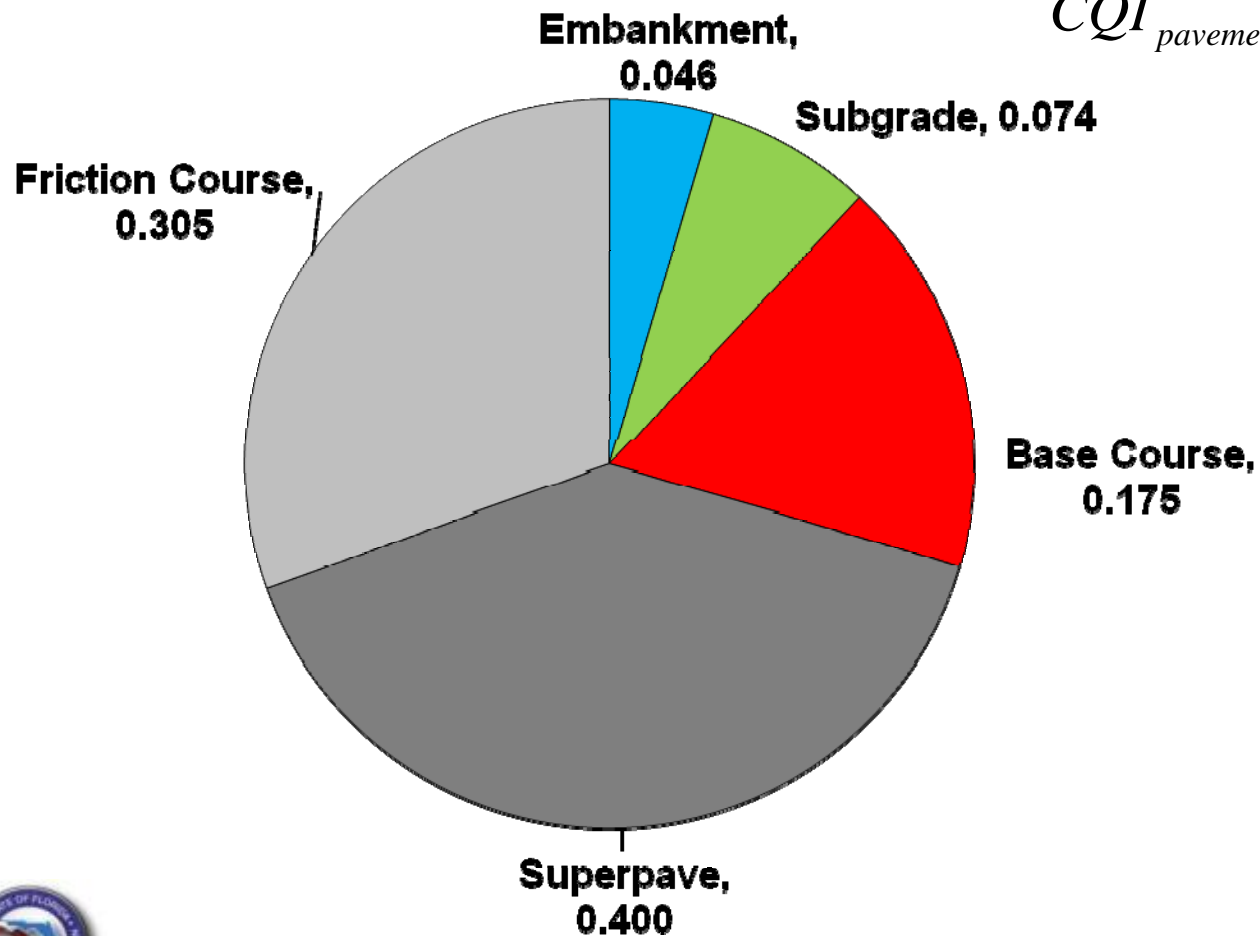
Table 334-7 Specification Limits	
Quality Characteristic	Specification Limits
Passing No. 8 [2.36 mm] sieve ( percent)	Target ± 3.1
Passing No. 200 [75 µm] sieve ( percent)	Target ± 1.0
Asphalt Content ( percent)	Target ± 0.40
Air Voids – Coarse Mixes ( percent)	4.00 ± 1.40
Air Voids – Fine Mixes ( percent)	4.00 ± 1.20
Density – Coarse Mixes ( percent of $G_{mm}$ ):	94.50 ± 1.30
Density – Fine Mixes ( percent of $G_{mm}$ ):	93.00 + 2.00, - 1.20 (1)
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.	

$$cqi_{SP} = w_{P(\#8)}PWL_{P(\#8)} + w_{P(\#200)}PWL_{P(\#200)} + w_{P_b}PWL_{P_b} \\ + w_{V_a}PWL_{V_a} + w_{P(G_{mm})}PWL_{P(G_{mm})}$$



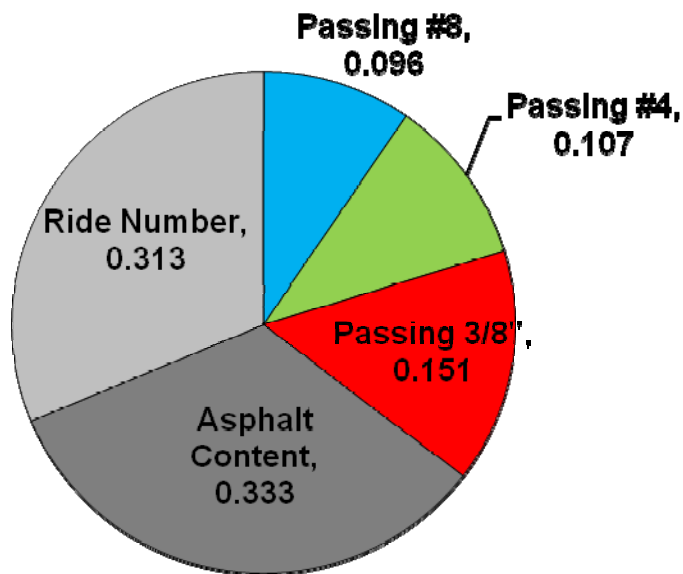
# Layer Weights – Flexible

$$CQI_{pavement} = \sum_{layers} W_{layer} \cdot CQI_{layer}$$

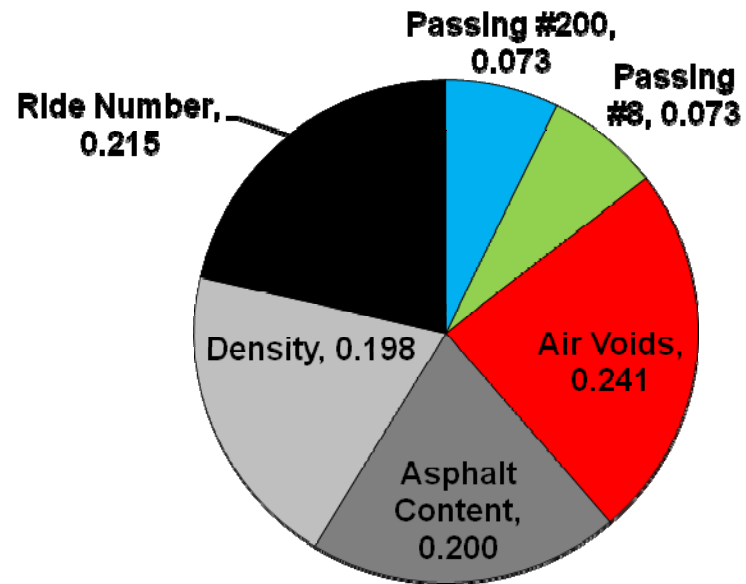


# AQC Weights – Friction Course

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



FC 5

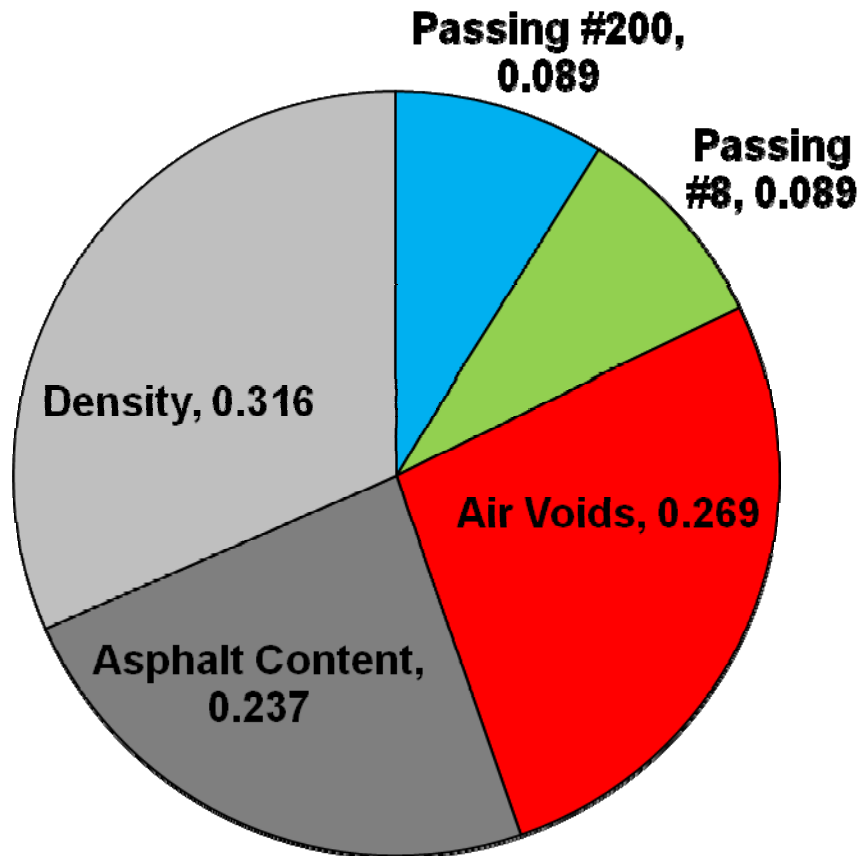


FC 9.5 and FC 12.5

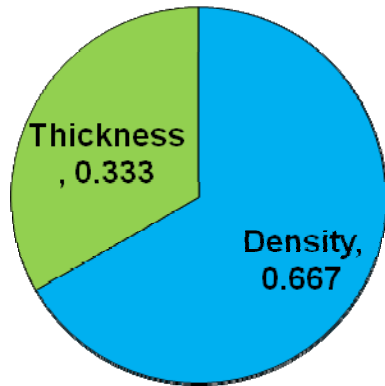


# AQC Weights – Structural Layer

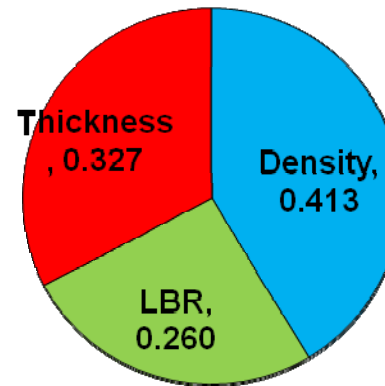
$$CQI_{layer} = \sum_{AQC} w_{AQC} \cdot (cqi)_{AQC}$$



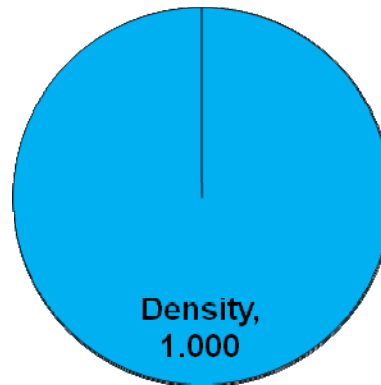
# AQC Weights – Supporting Layers



Base Course



Subgrade



Embankment

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



# Components of a Rigid Pavement System

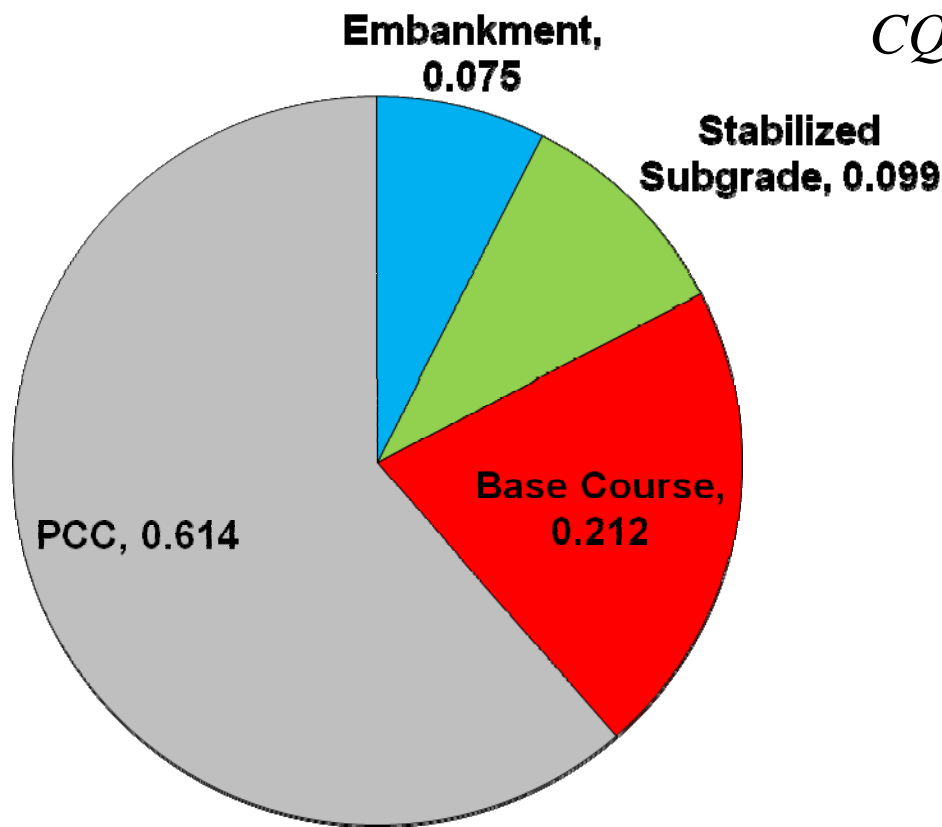
- ◆ Embankment
- ◆ Subgrade
- ◆ Base Course
- ◆ PCC Slab



$$CQI_{RP} = W_E (cqi)_E + W_{SG} (cqi)_{SG} + W_{BC} (cqi)_{BC} + W_{PCC} (cqi)_{PCC}$$



# Layer Weights – Rigid Pavement System

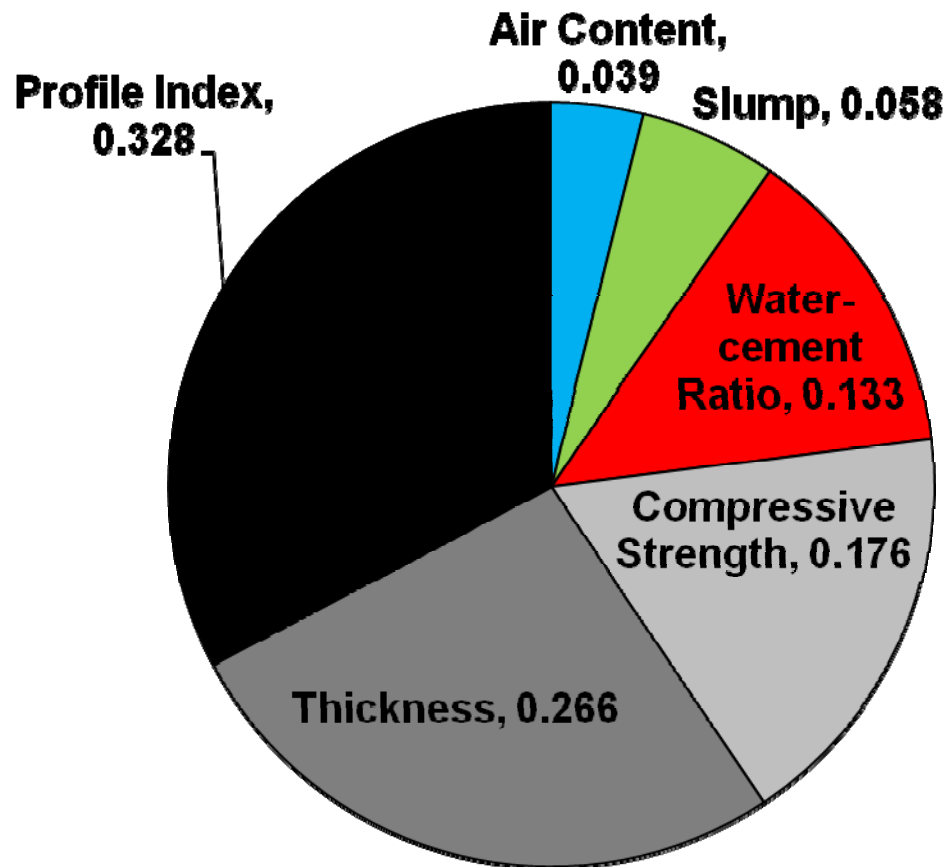


$$CQI_{pavement} = \sum_{layers} W_{layer} \cdot CQI_{layer}$$



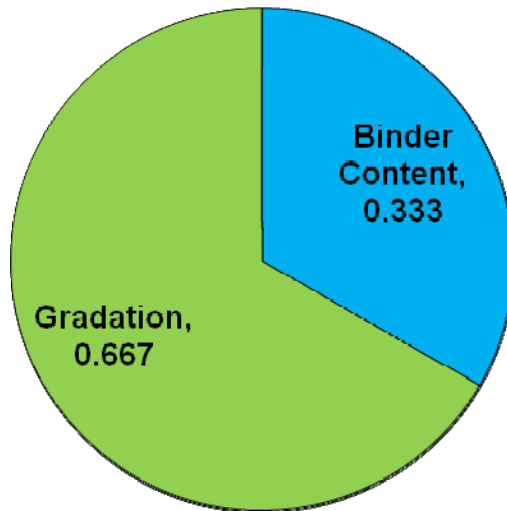
# AQC Weights – PCC Slab

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

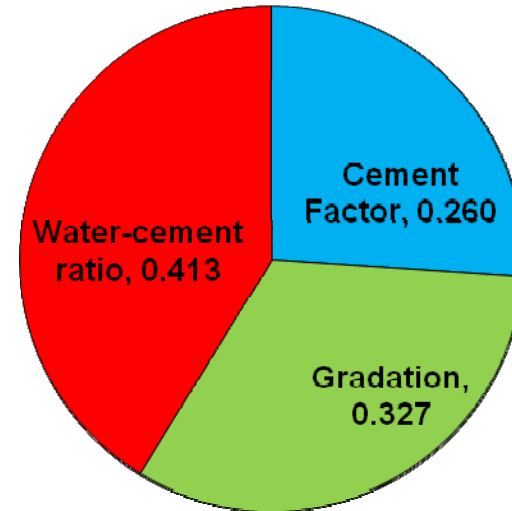


# AQC Weights – Permeable Base

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



ATPB

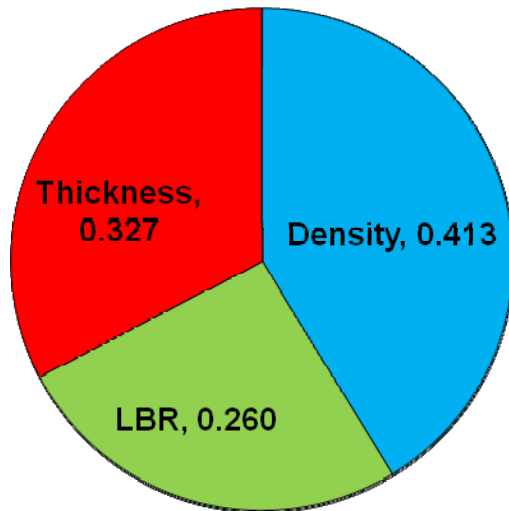


CTPB

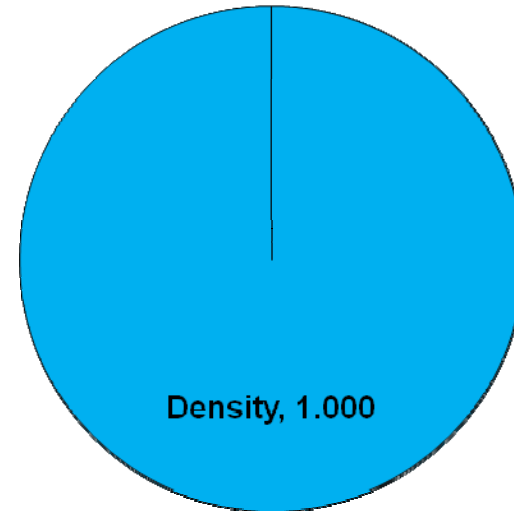


# AQC Weights – Supporting Layers

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



Subgrade



Embankment



# ***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

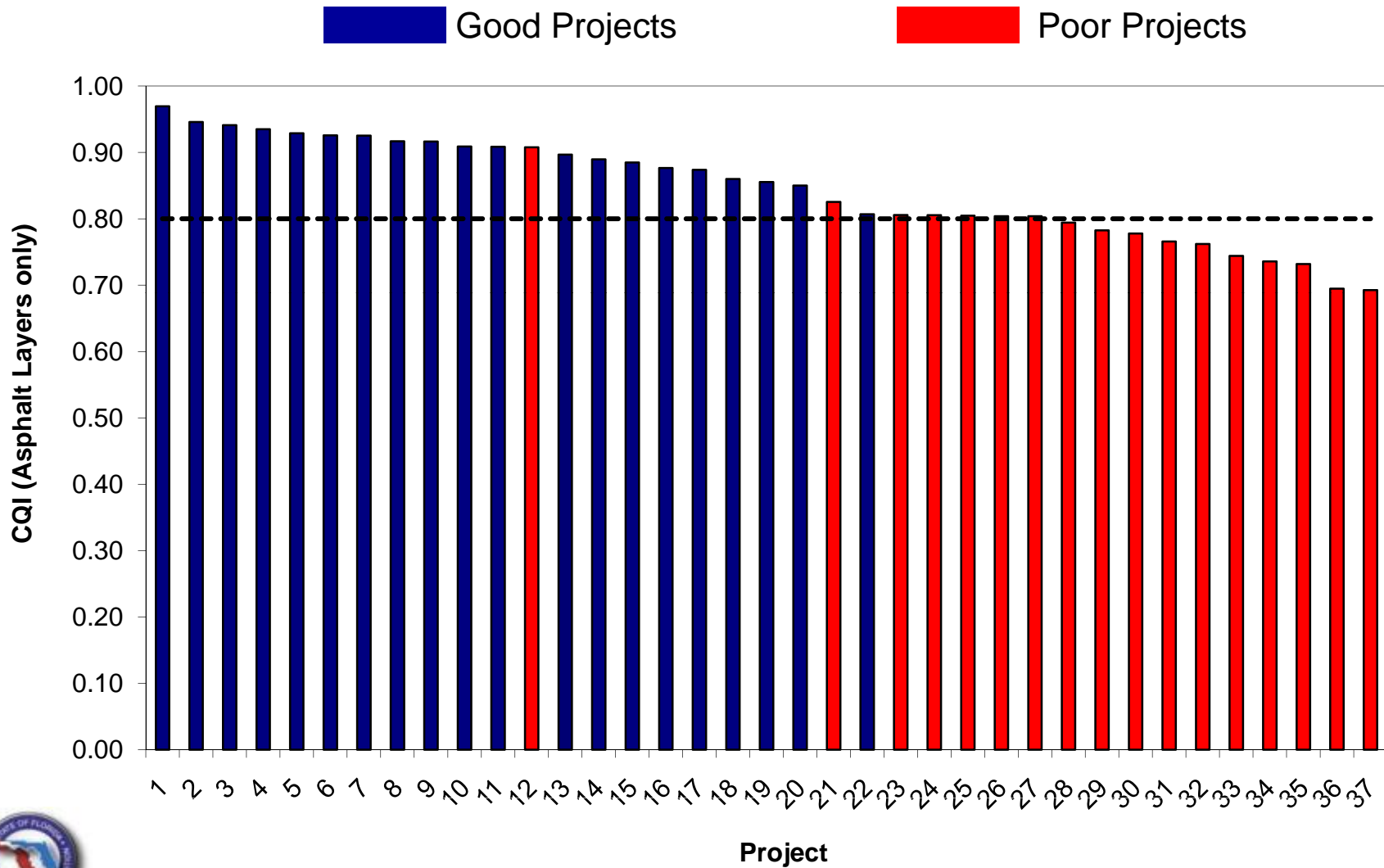


# ***Model Evaluation for Flexible Pavements***

- ◆ 37 projects identified with sufficient data
  - ✓ 20 'good' and 17 'poor'
  - ✓ 8 new construction projects
  - ✓ 29 resurfacing projects



# CQI Rating for Flexible Projects



# ***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

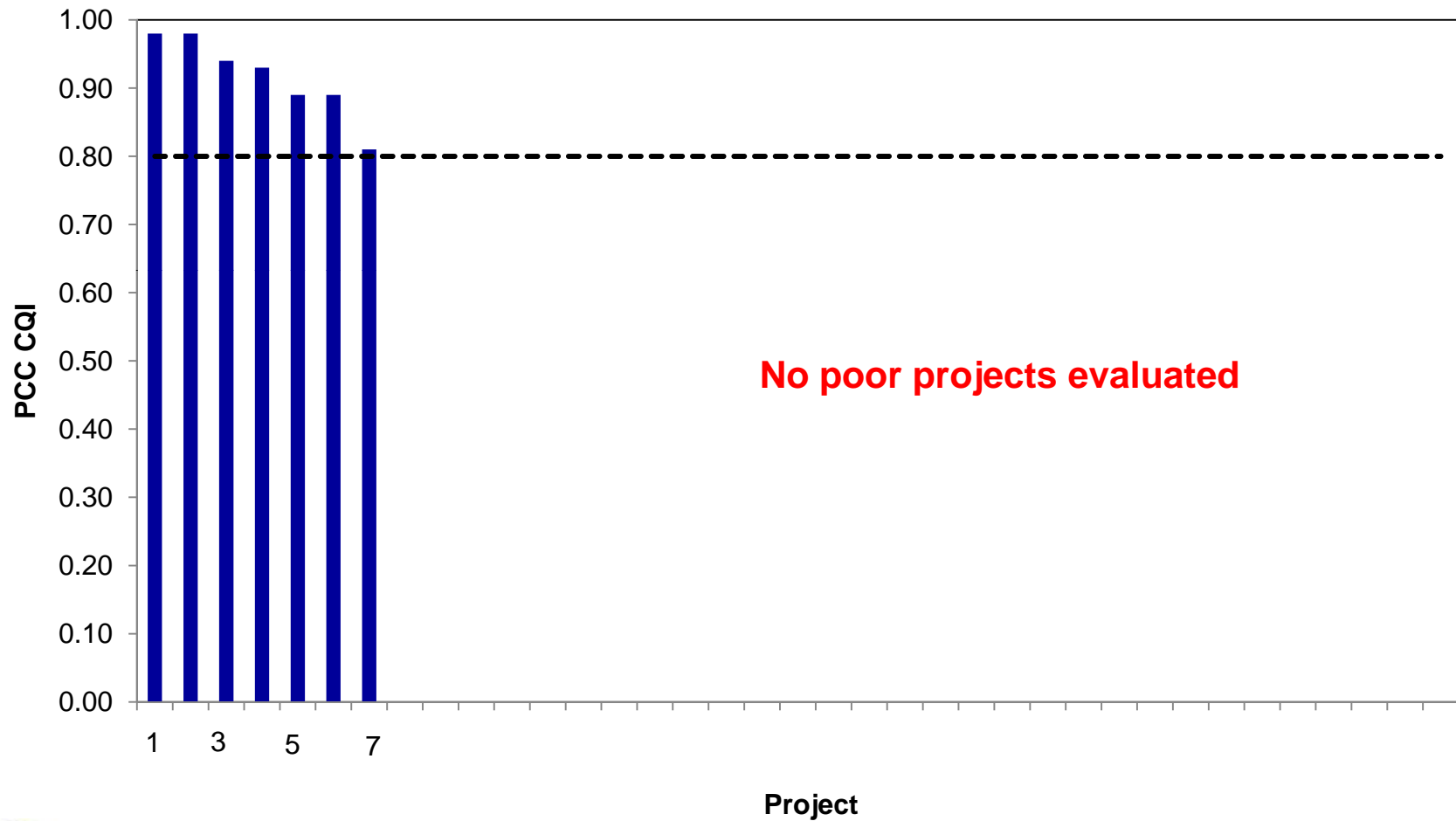


# ***Model Evaluation for Rigid Pavements***

- ◆ 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*



# CQI Calculator

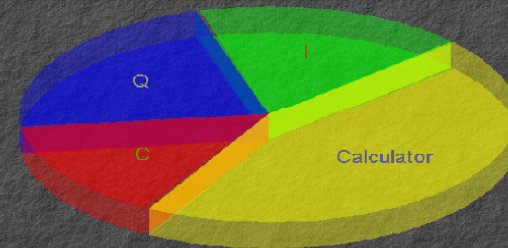
*Florida Department of Transportation  
Construction Quality Index Calculator v2.0a*

New Project

Load Project

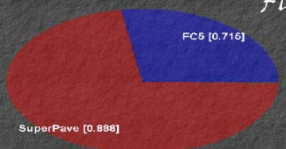
Companion

Exit



# CQI Calculator

Florida Department of Transportation  
Construction Quality Index Calculator v2.0a



1F19730925201

- Embankment
- Stabilized Subgrade
- Granular Base
- Superpave Base
- FC35
- FC5
- FC125
- SuperPave

Buttons: Generate Report, Project Details, Expand, Back, Main Menu



## Construction Quality Index Report

1F19730925201

Date: Mon Sep 10 10:03:48 EDT 2007

Project Number:  
State Road Number:  
Pavement Type: Flexible  
Comments:

### CQI Breakdown:

Layer / Test Name	CQI	Weight	CQI x Weight
FC5	0.7151	0.2760	0.1974
4464A	0.7151	1.0000	
Passing 3/8"	0.9915	0.1510	
Passing #4	0.8689	0.1070	
Passing #8	0.6971	0.0960	
Asphalt Content	0.9639	0.3330	
Ride Number	0.2699	0.3130	
EAST	0.3207	0.5000	
WEST	0.2191	0.5000	
SuperPave	0.8882	0.7240	0.6431
3305E	0.8818	0.3172	
Passing #200	1.0000	0.0890	
Passing #8	0.9981	0.0890	
Air Voids	0.9796	0.2690	
Asphalt Content	1.0000	0.2370	
Density	0.6438	0.3160	
4585A	0.8912	0.6828	
Passing #200	0.9938	0.0890	
Passing #8	0.8557	0.0890	
Air Voids	0.8420	0.2690	
Asphalt Content	0.9836	0.2370	
Density	0.8449	0.3160	

Total

0.8404

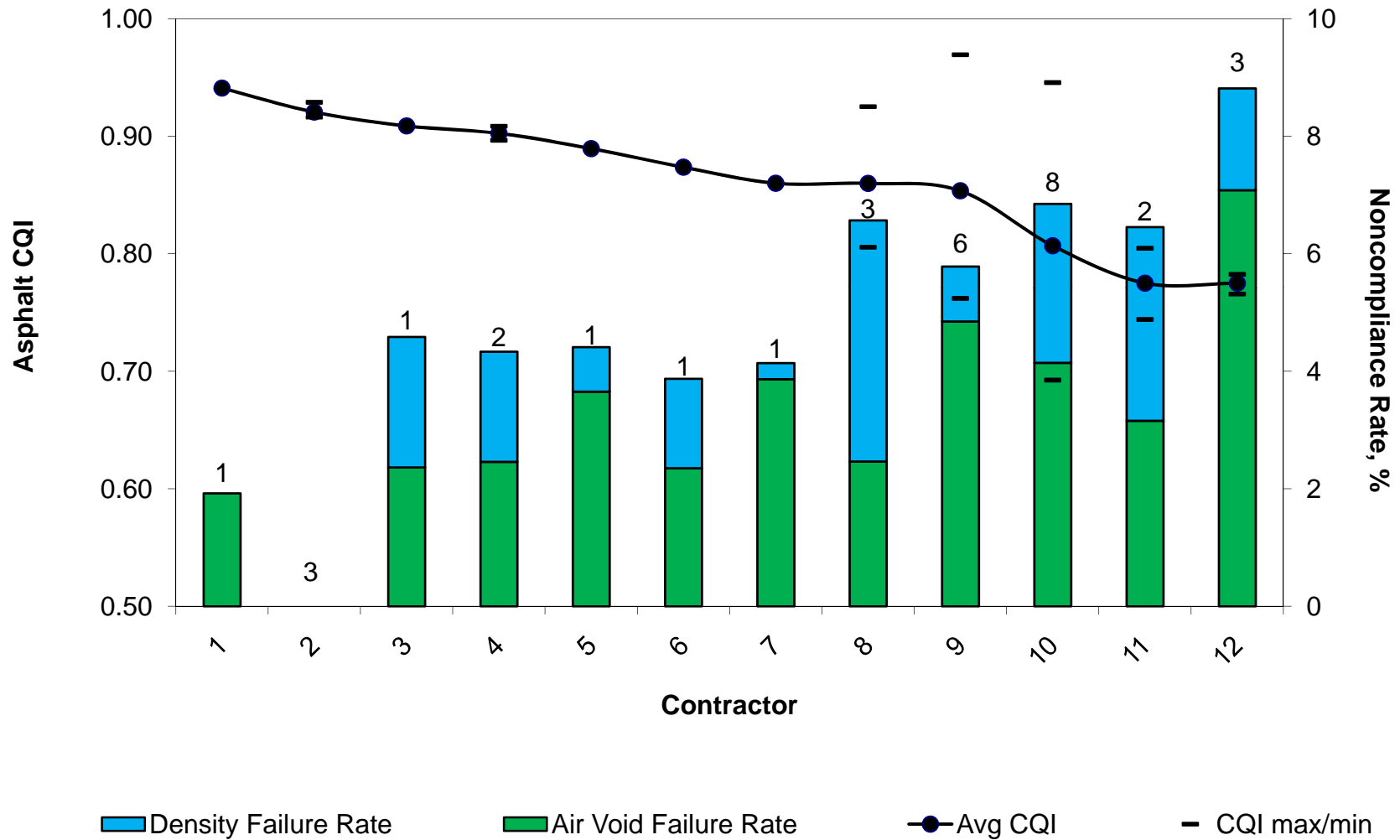


# ***Pavement Performance***

- ◆ 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



