STATE OF FLORIDA

Statewide Test of Construction Quality Index for Pavement Software

Final Report
Contract PR1575813

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October 2008

STATE MATERIALS OFFICE

DISCLAIMER

SI (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

SYMBOL	WHEN YOU KNOW	MULTIPLY BY	TO FIND	SYMBOL
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km

SYMBOL	WHEN YOU KNOW	MULTIPLY BY	TO FIND	SYMBOL
		AREA		
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yard	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2

SYMBOL	WHEN YOU KNOW	MULTIPLY BY	TO FIND	SYMBOL
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
NOTE: volumes greater than 1000 L shall be shown in m^3				

SYMBOL	WHEN YOU KNOW	MULTIPLY BY	TO FIND	SYMBOL
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")

SYMBOL	WHEN YOU KNOW	MULTIPLY BY	TO FIND	SYMBOL
		TEMPERATURE (exact degrees)		
°F	Fahrenheit	5 (F-32)/9 or (F-32)/1.8	Celsius	°C

SYMBOL	WHEN YOU KNOW	MULTIPLY BY	TO FIND	SYMBOL
		ILLUMINATION		
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	candela/m^2	cd/m^2

SYMBOL	WHEN YOU KNOW	MULTIPLY BY	TO FIND	SYMBOL
		FORCE and PRESSURE or STRESS		
lbf	poundforce	4.45	newtons	N
lbf/in^2	poundforce per square inch	6.89	kilopascals	kPa

APPROXIMATE CONVERSIONS TO SI UNITS

SYMBOL	WHEN YOU KNOW	MULTIPLY BY	TO FIND	SYMBOL
LENGTH				
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd

SYMBOL	WHEN YOU KNOW	MULTIPLY BY	TO FIND	SYMBOL
AREA				
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
ha	hectares	2.47	acres	ac

SYMBOL	WHEN YOU KNOW	MULTIPLY BY	TO FIND	SYMBOL
VOLUME				
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	cubic meters	35.314	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3

SYMBOL	WHEN YOU KNOW	MULTIPLY BY	TO FIND	SYMBOL
MASS				
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or "t")	megagrams (or "metric ton")	1.103	short tons (2000 lb)	T

SYMBOL	WHEN YOU KNOW	MULTIPLY BY	TO FIND	SYMBOL
TEMPERATURE (exact degrees)				
ºC	Celsius	1.8C+32	Fahrenheit	ºF

SYMBOL	WHEN YOU KNOW	MULTIPLY BY	TO FIND	SYMBOL
ILLUMINATION				
lx	lx	lx	lx	lx
cd/m^2	cd/m^2	cd/m^2	cd/m^2	cd/m^2

SYMBOL	WHEN YOU KNOW	MULTIPLY BY	TO FIND	SYMBOL
FORCE and PRESSURE or STRESS				
N	newtons	0.225	pound force	lbf
kPa	kilopascals	0.145	pound force per square inch	lbf/in^2

*SI is the symbol for the International System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380.

TECHNIAL REPORT DOCUMENTATION

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle Statewide Test of Construction Quality Index for Pavement Software		5. Report Date October 2008
		6. Performing Organization Code
7. Author(s) James Greene, Michael Hammons, Bruce Santier, Edward Minchin, Junyong Ahn		8. Performing Organization Report No.
9. Performing Organization Name and Address Applied Research Associates, Inc. 5000 NW 27th Court, Suite E Gainesville, FL 32606		10. Work Unit No. (TRAIS)
		11. Contract or Grant No.
12. Sponsoring Agency Name and Address Florida Department of Transportation 605 Suwannee Street Tallahassee, FL 32399-0450		13. Type of Report and Period Covered Final Report June 2007 to October 2008
		14. Sponsoring Agency Code
15. Supplementary Notes		

16. Abstract

All Florida Department of Transportation (FDOT) pavement projects are accepted in accordance with one or more construction specifications. The purposes of these specifications are to provide guidance and establish minimum requirements that enable a quality product to be built. The final product must meet the expectations of the designer to protect public safety and provide the expected level of service.

A construction quality index (CQI) is a rational measure of the overall quality of a constructed facility, calculated by determining the quality of the individual components and linking them together to obtain a composite quality index for the job. The CQI can be used to rate the quality of the product produced by the contractor, to determine the contractor's compensation, or to lower or eliminate a contractor's qualification status.

The CQI model was implemented in the Microsoft Windows® operating system as a stand-alone application called *CQI Calculator*. The application runs from one window and displays several screens to simplify and organize data entry. Data can be easily imported or exported from text files, and reports in HTML format can be produced from the input data.

17. Key Word Construction Quality Index, Quality Control, Quality Assurance, Specification Compliance	18. Distribution Statement No Restrictions

19. Security Classif. (of this report) Unclassified	20. Security Classif. (of this page) Unclassified	21. No. of Pages 76	22. Price

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1 Introduction

1.1 Background

State highway agencies are developing strategies that improve the quality of the transportation infrastructure while coping with changes in business models and reductions in agency personnel. Changes in policy regarding the use of contractor conducted testing in quality assurance (QA) decisions and a continuing reduction in agency personnel has increased the need for quality driven contractors. This change, coupled with more agencies adopting performance based and performance related specifications, places more requirements on contractors to know and use quality management in their field operations. With more contractors providing the quality control (QC) function, the agency's role has changed to a QA role. There is a need for rational, comprehensive methods to evaluate a contractor's end-product from a quality perspective; thus, there is a need for examining quality performance measurement techniques and approaches.

All Florida Department of Transportation (FDOT) projects are accepted in accordance with one or more construction specifications. The purposes of these specifications are to provide guidance and establish minimum requirements that enable a quality product to be built. The final product produced must meet the expectations of the designer to provide the expected level of service and protect public safety.

Researchers have found that owners and contractors agree that low-quality construction work often is treated no differently than high-quality construction work. For example, assume that Contractor A produces a product that nominally meets the minimum requirements of the specification with considerable variability in quality, while Contractor B produces the same product with higher quality materials and exercises superior quality control (less variability in product quality). Clearly, Contractor B's product is superior to Contractor A's product. This observation gives rise to a number of salient questions:

- How can the differences in construction quality be quantified objectively?
- How can quality indicators required by the specifications and stored in FDOT's Laboratory Information System (LIMS) database be linked rationally to formulate quality discriminators?
- What acceptance quality characteristics are most important in determining contractor quality?
- What is the relationship between contractor quality and performance of constructed facilities?
- How can the various components of a pavement construction project be combined to develop an overall indicator of construction quality?
- Can concepts from performance-related specifications be used to assess construction quality?

Some of these questions can be answered by adopting a construction quality index (CQI) - a rational measure of the overall quality of a constructed facility, calculated by determining the quality of the individual components and linking them together to obtain a composite quality index for the job. The CQI can be used to rate the quality of the product produced by the contractor, to determine the contractor's compensation, or to lower or eliminate a contractor's qualification status.

1.2 Objective

The objective of this research was to develop a practical and effective pavement CQI. The CQI should be implemented without substantial modification to FDOT's current test and measurement system. As a minimum, the CQI should address material, structural, and pavement smoothness characteristics. It should be applicable for both new and rehabilitation projects. Soils, bound and unbound granular base materials, asphalt, and concrete should be considered.

FDOT's goal is for the CQI to be used as an objective tool to evaluate the quality of pavement construction. Its formulation must be objective, that is, it must be based upon quality characteristics that are explicitly addressed in the construction specifications and directly within the control of the contractor.

The CQI formulation must be transparent and easily understood. This can be accomplished by applying concepts consistent with those already used by FDOT and familiar to the contractor such as percent within limits. To the greatest extent possible, the CQI should use data from the LIMS, which serves as FDOT's enterprise database system for all construction quality data.

1.3 Scope

In keeping with a straightforward approach, the CQI only addresses quality factors for the major components of pavement construction, such as:

- Flexible pavements
- Rigid pavements
- Base course
- Subgrade
- Embankment

Other aspects of contractor performance (e.g., financial resources, ownership of equipment or ability to lease equipment, adherence to schedule, job safety, past performance) are not included in the CQI formulation.

The CQI model has been formulated in a modular fashion. The model is flexible allowing it to be scaled to all pavement construction projects, from routine mill and overlay rehabilitation to major new highway pavements construction. Additionally, other components of highway construction (such as structures, deep foundations, drainage, signage, etc.) can be added in the future.

Finally, the CQI was developed with a vision for the future, which inevitably will include aspects of mechanistic-empirical (M-E) analysis. However, the research team is aware of on-going research efforts nationally and in Florida to evaluate, revise, validate, and calibrate the new Mechanistic-Empirical Pavement Design Guide (MEPDG). While M-E concepts allow the analyst to directly link fundamental material quality measures to facility performance, we do not believe that the evolution of M-E procedures is sufficiently mature for widespread acceptance of a CQI based solely upon these concepts. Therefore, our modular approach will facilitate replacing the purely empirically based performance measures with mechanistic based performance measures in the future. We believe that adopting an M-E based approach before sufficient evaluation, validation, and calibration jeopardizes acceptance of the CQI by skeptics of the MEPDG as it is currently proposed.

2 Literature Review

2.1 Introduction

A survey of state highway agencies was conducted to determine what their plans or policies are in this area. The results are summarized in the Appendix A. Most agencies are using subjective measures to pre-qualify contractors. Often these ratings are used to determine a prequalification amount or bid amount.

Hybert (1996) reviewed quality problems in owners that use a contracting process to provide customized, large-scale systems or products. This can be extended to quality problems on many construction projects. He asserts that current bid practices may deemphasize the importance of partnership between the contractor and owner so that both work toward the same end. Instead, these practices put the contractor and owner in an adversarial relationship, possibly putting one party in a position where it needs to take drastic measures to recover. Too often, contractors are winning contracts by underbidding, exaggerating delivery capabilities, underestimating the project risks, or under-solving the technical problems, just to get a lower price than their competitors. In turn, they are rewarded by change orders for their ability to argue specification interpretation issues.

The concept of teaming or partnering (in a non-legal sense) stresses having fewer suppliers and working closely with them so they understand the customer's needs well. This way, both the customer and the supplier have a stake in each other's success. There are risks to both parties in a teaming approach, since it requires mutual trust. Teaming can reduce the need for costly risk management tactics (change orders, claims, using the specifications as a shield to avoid work requirements, etc.).

2.2 Performance-Related Specifications

Transportation agencies are switching from end result specifications that define end product quality to performance related specifications that specify quality in terms of desired long term performance. Performance related specifications describe the desired levels of key construction quality characteristics that correlate with engineering properties and apply mathematical models to predict future pavement performance.

The FWHA (2001) listed the following benefits of using performance related specifications:

- Establishes a direct relationship between quality characteristics and product performance
- Identifies an optimum level of quality
- Provides a rational basis to set the appropriate level of penalty/bonus for inferior/superior quality
- Provides a critical link between construction and engineering management systems.

Also, performance related specifications help transportation agencies forecast future performance, maintenance requirements, and life-cycle costs.

An assumption that legitimate mathematical relationships have been established between characteristics measured at the job site and the expected performance of the construction activity is required in order to determine an appropriate amount of pay reduction/addition as penalties/bonuses of inferior/superior construction quality. However, for most factors, there are no such convenient or simple relationships. Therefore, a method to develop the required relationships is required.

A comprehensive approach for the development of performance models for network-level Pavement Management System (PMS) using Long Term Pavement Performance (LTPP) data was presented by Bekheet et al. (2005). Conventionally, historical performance and inventory data have been used for developing these pavement performance models. However, historical data may not be appropriate to use because field data collection equipment has been continually improved, and inventory records may be incomplete.

As an alternate reliable source of data for developing pavement performance models, the LTTP was used. Once a baseline pavement performance models have been developed, they can be adapted to agency-specific experience and data to render agency-specific models. (Bekheet et al. 2005)

Buttlar and Harrell (1998) reported the state highway agencies efforts to develop and implement end result and performance related specifications in Illinois. They stated that performance related specifications provided the ultimate method of compensation for a delivered product even though such a system could be challenging to develop. They suggested development and implementation of a specification that combined elements of end result and performance related specifications considering the existing technology level, available materials, and test equipment. As key steps for developing the combination specification, the authors presented the following:

1. Make an initial move to statistical quality QC/QA.
2. Develop a comprehensive end result specification to consider all relevant quality characteristics.
3. Monitor and foster development of primary and secondary prediction relationships.
4. Develop performance-related pay factors.
5. Compare performance related pay factors with end result pay factors, which were developed based upon experience.
6. Periodically repeat steps 3, 4, and 5 to move from end result to performance related specifications.

Noureldin (1997) presented an approach to estimate the deviation from pavement performance life caused by any deviation in the as-built characteristics from the as-designed characteristics. The deviations can be used to set up the basis for measuring the rational pay adjustment. To perform the estimation, key quality control aspects in asphalt pavement construction such as asphalt content, aggregate characteristics, pavement layer thickness and their degree of compaction, and initial pavement smoothness are quantified using a partial derivatives approach. While Noureldin's approach is generally applicable, his published relationships are only valid for one particular scenario in Saudi Arabia.

Weed (1998) proposed a method for developing pay schedules based upon the need for a rational method to relate as-built quality to expected performance and ultimate value as the basis for reliable and defensible pay schedules. The pay factor in the method can be expressed as a monetary value rather than as a percentage of the bid price of the pavement. This method is believed to more appropriately reflect the true value of departures from the design level of quality since the actions upon which the pay reduction is based are not a function of the thickness of the pavement layer itself or bid price.

In order to develop mathematical models to predict pavement performance, analytical data and survey data can be used and several examples are shown. Then, the models were combined with other models which relate expected life to present value to obtain rational and practical pay schedules.

In later work, Weed (2000) presented a method for combining the effects of multiple deficiencies. Air voids and thickness of HMA pavement are factors used to decide if a hot mix asphalt (HMA) pavement lot is rejectable or not. In the current New Jersey DOT specification for HMA pavement, the rejectable quality level (RQL) for both air voids and thickness is 75 (in terms of percent defective), which means that if any one RQL of the two characteristics is more than 75, then the agency reserves the right to order removal and replacement of the deficient pavement. This might not consistently distinguish poor quality pavement from acceptable quality pavement, because a pavement job with two items rated as having poor quality levels but each barely within the acceptable range may be a worse case than another pavement job with an excellent quality level for one characteristic but a quality level below the RQL in another characteristic. To determine an appropriate method to assess the combined effect of deficiencies in air voids and thickness, survey data were used. Based on the performance model with combined effects, several pay equations were presented.

Weed and Tabrizi (2005) explained the development of a statistical acceptance procedure for HMA pavement smoothness using the international roughness index (IRI). As procedural steps, Weed and Tabrizi (2005) suggested the following.

- Select a quality characteristic that relates to performance.
- Select a statistical quality measure upon which acceptance will be based.
- Select an appropriate mathematical form for the performance model.
- Obtain data to calibrate the performance model.
- Apply life-cycle-cost analysis to determine appropriate pay levels.
- Convert this information into an appropriate pay schedule.
- Define lot size and sample size.
- Finalize the prototype specification.

A rational and feasible method for quantitatively formulating pay factors was described by Monismith et al. (2004) for asphalt concrete construction. Performance models were developed for fatigue and rutting based on the analysis of accelerated pavement tests from the Caltrans Heavy Vehicle Simulator (HVS) and the WesTrack accelerated pavement performance test program.

The development of pay factors in the research considers the economic impacts to the highway agency. The amount of penalty/bonus was sought under the assumption that the penalty should be the extra cost to the agency and the bonus should not be greater than the added savings to the agency.

For new construction, these costs/savings to the agency are related mainly to prospective pavement rehabilitation. Inferior construction amplifies the present worth of future rehabilitation costs; contrarily, superior construction decreases the present worth of the costs. Differences in the present worth of future rehabilitation costs between as-built and as-designed are applicable to set the appropriate level of penalty/bonus for inferior/superior pavement construction quality. However, the authors admitted that penalties/bonuses might be too low because only the first rehabilitation cycle was considered in their performance model. The performance-based approach highlights the importance of uniformity in both materials and placement and the importance of sticking to the design target value.

Killingsworth (2004) argued that of 13 factors analyzed only five proved to have a significant influence on the overall performance of HMA pavement and should be included in performance-related HMA construction specifications. The selected factors are segregation, initial ride quality, in-place pavement density, density at longitudinal joints, and permeability. These quality characteristics of as-produced and as-constructed hot mix asphalt directly affect as-designed performance quality and life. Practical test methods for measuring these five quality characteristics, specification criteria, and threshold values are suggested for performance related specifications.

Whiteley et al. (2005) developed a method for obtaining pay factors based on pavement life cycle cost (LCC) by establishing the relationship between design life and LCC, as well as between LCC and pay factors. The following are results of the research:

- Overlay thickness increases result in increased pavement service life.
- More than 80 percent of the contribution to the variance in pavement service life predictions are made by overlay thickness whereas less than 20 percent of the variance are contributed by combined variables of accumulated ESALs after eight years and total prior cracking.
- Regardless of overlay thickness distribution type, the resulting life cycle costs show a normal distribution.
- The pay factor values presented in the research shows that disincentives for inferior performance are greater than incentives for superior performance.

2.3 Analytical Hierarchical Process

The Analytic Hierarchy Process (AHP) is comprehensive, logical, and structured decision making process to help decision makers set priorities and make the best decision when both qualitative and quantitative aspects of a decision need to be considered (Saaty 1980). The AHP is designed to consider a variety of tangible and intangible strategic goals and manage conflicting stakeholders.

The AHP relies on three fundamental assumptions:

- Preferences for different alternatives depend on separate criteria which can be reasoned about independently and given numerical scores.
- The score for a given criteria can be calculated from sub-criteria. That is, the criteria can be arranged in a hierarchy, and the score at each level of the hierarchy can be calculated as a weighted sum of the lower level scores. The model can be as many levels deep as necessary to model the information appropriately.
- At a given level, suitable scores can be calculated from only pair wise comparisons.

The decision problem may involve social, political, technical, and economic factors. Complex decisions are approached by decomposing the problem in a hierarchical structure involving goals, criteria, and alternatives. A series of one-on-one comparisons are made, and the results are synthesized to determine the priorities of the alternatives with respect to each criterion and the weights of each criterion with respect to the goal. For each pairing, participants are asked to rank, on a scale from -9 to +9, how important that criterion is compared with the other one. The mathematical model calculates a relative weight for each criterion, and the summation is normalized to 100 percent. The incorporation of all relevant decision criteria and their pair-wise comparison allows the decision maker to determine the trade-offs among objectives. This procedure recognizes and incorporates the knowledge and expertise of the participants by making use of their subjective judgments.

The AHP has been used within transportation engineering by Smith and Tighe (2006) as a tool for infrastructure management. Specific examples cited by Smith and Tighe include the use of AHP to compare fast tract concrete repair products based on priorities set by an agency and use of AHP to compare maintenance, rehabilitation, and reconstruction strategies for asphalt pavements. Smith, et al., (1995) used the AHP to characterize bridge material selection decisions of stakeholders, specifically as it relates to using timber as a bridge material.

An acceptance quality characteristic (AQC) is defined by FHWA (1999) as an inherent measurable pavement characteristic that significantly affect pavement performance, is under the direct control of the contractor, and is measurable at or near the time of construction. The AQC's for this project were selected to be identical to those currently used by FDOT for acceptance of pavement materials at the mine, plant or roadway based upon the FDOT *2007 Standard Specifications for Road and Bridge Construction*. These are listed in Appendix B.

3 Model Formulation and Implementation

3.1 Model Formulation

3.1.1 Model Concept

The values of the AQCs will be stochastic. It will be assumed that the results of tests to measure and AQC's will be normally distributed with a calculable mean and standard deviation. Using the mean and standard deviations of the various AQCs, a mechanistic-empirical model in a Monte Carlo simulation process may be used to depict a distribution of pavement life as illustrated in Figure 1.

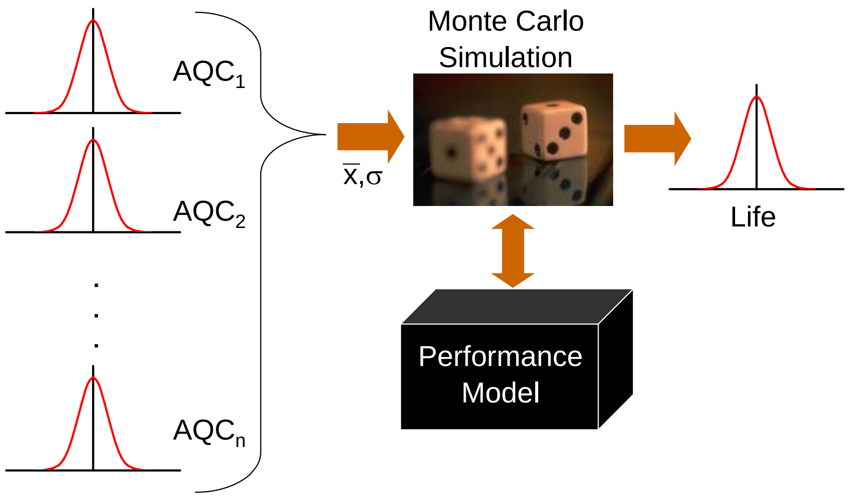

Figure 1. Ideal Concept for CQI Formulation.

The performance model would need to be able to accept the inputs from the Monte Carlo driver, calculate the pavement response, and predict the pavement life. One such model potentially capable of performing these calculations is the MEPDG currently under review by AASHTO. However, the MEPDG must be calibrated for local conditions. There are advantages to this approach, the most notable of which is that it is based upon a rigorous analytical approach using the best available technology. However, there are also significant disadvantages:

- The model must be calibrated for local conditions.
- The analytical models in the MEPDG are currently undergoing review and revision.
- The computational requirements are quite large.

For these reasons, the current CQI formulation is based upon a much simpler approach described in the following paragraphs.

The diagram in Figure 2 shows a conceptual pavement system consisting of a series of *n* layers. Note that the model formulation does not require that all existing layers in the pavement system be a part of the construction project. For example, a typical flexible pavement resurfacing project may involve rehabilitation of the friction course (Layer 1) and a portion of the structural course (Layer 2). In this case, the maximum number of layers considered in the CQI is two, and all other layers are not considered in the calculations. A new flexible construction would consider all bound and unbound layers.

Figure 2. Schematic of a Pavement Structure with *n* Layers

The general form of the CQI for a layered pavement system is given by

$$CQI = \sum_{\text{layers}} W_{layer} \times CQI_{layer} \qquad \text{(Equation 3-1)}$$

where W_{layer} = weighting factor for layer i
CQI_{layer} = construction quality index for layer i

For each layer, the CQI is based upon the sum of the Acceptance Quality Characteristics (AQC) for each layer times a weighting factor:

$$CQI_{layer} = \sum_{AQC} w_{ACQ} \times cqi_{AQC} \qquad \text{(Equation 3-2)}$$

where w_{AQC} = weighting factor for AQC $_i$
cqi_{AQC} = construction quality index for AQC $_i$

Finally, the construction quality index for each AQC is given by

$$(cqi)_{AQC} = (PWL)_{AQC} \qquad \text{(Equation 3-3)}$$

where *(PWL)*$_{AQC}$ is the percent within limits. *(PWL)*$_{AQC}$ is calculated based upon statistical principles assuming that random samples are taken from a normally-distributed population using the procedures outlined in *Evaluation Procedures For Quality Assurance Specifications* (Burati et al. 2004).

A *Q* statistic is determined from the difference between the sample mean ($\overline{X}$) and lower specification limit (*LSL*) or upper specification limit (*USL*) divided by the sample's standard deviation (*s*):

$$Q_L = \frac{\overline{X} - LSL}{s} \quad and \quad Q_U = \frac{USL - \overline{X}}{s} \qquad \text{(Equation 3-4)}$$

The *Q* statistic is a quality index for its specification limit. For one-sided limits, the appropriate *Q* value is calculated and cross-referenced in the PWL table (Appendix C) to find the PWL of that sample. Two-sided limits require both *Q* values to be calculated and cross-referenced in the table. The two-sided percent within limits is then given by the following relationship:

$$PWL_T = PWL_U + PWL_L - 100 \qquad \text{(Equation 3-5)}$$

3.1.2 Model Weighting Factors

A series of expert panel meetings were conducted in Gainesville, Orlando, and Tallahassee to solicit input from the FDOT, construction industry, academia, and consultants. The forms that were used in the meetings for flexible and rigid pavements are reproduced in Appendix D. The instructions given to the panel meetings were simple:

- Each response only represents your opinion concerning the relative importance of the pair of items on a single line.
- Fill out all portions of the form for which you feel qualified to have an opinion.
- Fill out the forms without discussion or collaboration with your neighbor.

The results of the survey are summarized in Appendix E for flexible and rigid pavements, respectively. The average values were used in the SuperDecisions software to determine the weighting factors for the CQI relationships. The weighting factors for flexible pavement are presented in Table 1 and for rigid pavements in Table 2. Note that the sum of the weighting factors in each case sum to unity.

There are plausible scenarios, typically for rehabilitation projects, in which one or more layers of the system will not be a part of the construction project. For example, in projects where an existing pavement is being rehabilitated by milling and overlaying, it is possible that only the structural Superpave and friction course layers will be constructed in the project, all other layers remaining undisturbed from previous construction projects. In such cases, revised layer weighting factors are calculated by weighting their respective contribution to the project as shown in Table 3.

3.1.3 Adaptation of the Model for More than One Superpave Mix

For construction projects with Superpave layers, often the project may involve several mixes with different target values for the certain AQCs. In this case the model was adapted as follows:

$$CQI_{SP} = \sum t_i \left(CQI_{mix}\right)_i \quad \text{Equation 3-6}$$

where t_i is a tonnage weighting factor given by

$$t_i = \frac{\text{tons of mix i}}{\text{total tons of Superpave}} \quad \text{Equation 3-7}$$

For example, suppose a construction project used three Superpave mixes, designated by SP1, SP2, and SP3. A total of 20,000 tons were placed on the example project: 4,000 tons of SP1, 10,000 tons of SP2, and 6,000 tons of SP3. **Error! Reference source not found.** presents the calculation of the layer CQI for this example.

3.2 Model Implementation

The CQI model was implemented in the Microsoft Windows® operating system as a stand-alone application called *CQI Calculator*. The application runs from one window and displays several screens to simplify and organize data entry. Data can be easily imported or exported from text files or spreadsheets, and reports in HTML format can be produced from the input data. At the current time, the application cannot read input files directly from LIMS. Appendix F presents a User's Guide for the *CQI Calculator*.

Table 1. Flexible Pavement Weighting Factors.

Pavement Component	**Weighting Factor, W_{layer}**
Embankment	0.046
Stabilized Subgrade	0.074
Base Course	0.175
SuperPave	0.400
Friction Course	0.305
Embankment	**Weighting Factor, w_i**
Density	1.000
Stabilized Subgrade	**Weighting Factor, w_i**
Density	0.617
LBR	0.383
Base	**Weighting Factor, w_i**
Density	1.000
SuperPave	**Weighting Factor, w_i**
Passing #200	0.089
Passing #8	0.089
Air Voids	0.269
Asphalt Content	0.237
Density	0.316
FC-5	**Weighting Factor, w_i**
Passing #8	0.096
Passing #4	0.107
Passing 3/8"	0.151
Asphalt Content	0.333
Ride Number	0.313
FC-9.5	**Weighting Factor, w_i**
Passing #200	0.073
Passing #8	0.073
Air Voids	0.241
Asphalt Content	0.200
Density	0.198
Ride Number	0.215
FC-12.5	**Weighting Factor, w_i**
Passing #200	0.073
Passing #8	0.073
Air Voids	0.241
Asphalt Content	0.200
Density	0.198
Ride Number	0.215

Table 2. Rigid Pavement Weighting Factors.

Pavement Component	**Weighting Factor, W_{layer}**
Embankment	0.075
Stabilized Subgrade	0.099
Base Course	0.212
PCC	0.614
Embankment	**Weighting Factor, w_i**
Density	1.000
Stabilized Subgrade	**Weighting Factor, w_i**
Density	0.617
LBR	0.383
CTPB	**Weighting Factor, w_i**
Cement Factor	0.260
Gradation	0.327
Water-cement ratio	0.413
ATPB	**Weighting Factor, w_i**
Binder Content	0.333
Gradation	0.667
PCC	**Weighting Factor, w_i**
Air Content	0.039
Slump	0.058
Water-cement Ratio	0.133
Compressive Strength	0.176
Thickness	0.266
Profile Index	0.328

Table 3. Example Calculation of Revised Layer Weighting Factors.

Layer	**Layer Weighting Factor**	**Calculation of Revised Layer Weighting Factor**
Friction Course	$W_{FC} = 0.305$	$W_{FC\ revised} = 0.305/0.705 = 0.433$
Superpave	$W_{SP} = \underline{0.400}$	$W_{SP\ revised} = 0.400/0.705 = \underline{0.567}$
Total	**0.705**	**1.000**

Table 4. Example Calculation for Multiple Superpave Mixes.

Mix	**Tons Produced**	**Mix CQI**	**Calculation of t_i**	**Calculation of CQI_{SP}**
SP1	4,000	0.958	t_{SP1} = 4,000/20,000 = 0.200	CQI_{SP1} = 0.200×0.958 = 0.192
SP2	10,000	0.923	t_{SP2} = 10,000/20,000 = 0.500	CQI_{SP2} = 0.500×0.923 = 0.462
SP3	6,000	0.976	t_{SP3} = 6,000/20,000 = 0.300	CQI_{SP3} = 0.300×0.976 = 0.293
Total	**20,000**			**CQI_{SP} = 0.947**

4 Model Validation

4.1 Introduction

In order to validate the CQI, the research team worked with the FDOT State Material Office and Construction and Materials officials to gather projects to study. It was requested that the projects be recent enough to be relevant (having used current methods such as Superpave), but old enough that sufficient post-construction testing would have been performed. An additional requirement was for the projects to have their relevant data stored in the LIMS database. Finally, it was requested that FDOT provide a "level of satisfaction," or "rating" of each project provided. Further directions requested that the rating be based solely on a material quality or specifications viewpoint.

4.2 LIMS Issues

The research team experienced difficulty with many aspects of LIMS. Once gaining access to LIMS, the team found that many data had not been entered into LIMS or found many cases where the number of samples was so low that it seemed that there were many missing test results. However, in order to perform the research, sometimes these few samples had to represent the ACQ's CQI. In the cases where the sample numbers were so small as to violate the assumptions of the model, the project was not included in the analysis. There was also a problem with missing layers and ACQ's. For example, several asphalt construction projects were missing air void or density data.

Currently, the geotechnical data (i.e., limerock base, stabilized subgrade, and embankment) within LIMS is incomplete. For the most part, only laboratory data has been stored in LIMS. Field test data can only be examined by locating and reviewing the construction log book for each particular project. Due to the large volume of data this would require locating, reviewing, and manually transferring from the log book to CQI calculator, only a select number of new construction projects were evaluated with complete geotechnical data. Additionally, thickness and profile index data for rigid projects are not stored in LIMS. Furthermore, these data sets are not routinely stored and can be difficult to locate. Table 5 includes each pavement component and describes the test data source.

Finally, in some cases, it was apparent that some data had been entered to the wrong place. For instance, much of the asphalt data included erroneous values for the percent passing sieve #8. Fortunately, through the course of the project, this error was able to be corrected.

Table 5. Pavement Component and Source of Data.

Layer	Source	Comments
Bituminous Friction course Superpave structural Superpvae base ATPB	All flexible data is available in LIMS except for the ride number and mix design target values.	Mix design and ride number data available from the SMO. For Districts 4 and 6, ride number data is collected and stored by district.
Concrete	All rigid data is available in LIMS except for thickness and profile index.	Thickness and profile index may be stored with project information, but may be difficult to locate. Contact the project engineer to locate this data. Some thickness data was found in the final estimates documents in the EDMS (Hummingbird). Finally, the contractor that collected the data may need to be contacted.
Soil layers Base Subgrade Embankment	LIMS Laboratory data including maximum density and LBR Density Log Book Field density	Density log books available on loan from project engineers.

4.3 Flexible Projects

Each district bituminous engineer was requested to provide three 'good' and three 'poor' flexible projects for inclusion in the study. Good and poor project ratings were based on specification compliance. Since the ratings were determined by the bituminous engineers, it was expected that the ratings mostly reflected the compliance of the bituminous layers. After a review of the data, 19 good and 19 poor projects were found to have sufficient bituminous data for analysis. As stated before, only limited soil layer data was available in LIMS. Details of these projects can be seen in Table 6.

Table 6. Flexible Construction Projects.

Project Number	District	State Road	Construction Type	FDOT Rating
197252-2	1	37	Resurfacing	Good
197679-1	1	25	Add Lanes & Reconstruct	Poor
197279-2	1	25	Resurfacing	Poor
208718-2	2	134	Resurfacing	Good
210432-2	2	45	Resurfacing	Good
209137-3	2	5	Resurfacing	Poor
209648-3	2	228	Resurfacing	Poor
210384-3	2	24	Resurfacing	Poor
213335-1	2	I-295	Resurfacing	Good
220442-5	3	87	Add Lanes & Reconstruct	Poor
228180-1	4	736	Resurfacing	Good
228188-1	4	7	Resurfacing	Good
231921-1	4	7	Add Lanes & Reconstruct	Poor
413583-1	5	200	Resurfacing	Good
415514-1	5	434	Resurfacing	Good
415526-1	5	40	Resurfacing	Good
417163-1	5	500	Resurfacing	Poor
417166-1	5	5	Resurfacing	Poor
409016-1	3	65	Resurfacing	Good
413438-1	3	390	Resurfacing	Good
411395-1	3	173	Resurfacing	Good
409021-1	3	85	Resurfacing	Poor
403930-1	3	65	Resurfacing	Good
242531-1	5	I-4	Interchange	Poor
411603-1	5	25	Resurfacing	Good
417165-1	5	46	Resurfacing	Poor
249648-1	6	826	Add Lanes & Reconstruct	Poor
256322-1	7	52	Add Lanes & Reconstruct	Good
256888-1	7	55	Add Lanes & Reconstruct	Poor
257076-1	7	693	Resurfacing	Poor
411332-1	7	7	Resurfacing	Good
406092-1	TP	91	Add Lanes & Reconstruct	Good
406147-1	TP	869	Add Lanes & Reconstruct	Poor
413670-1	TP	91	Resurfacing	Poor
417017-1	TP	589	Resurfacing	Good
411533-3	TP	91	Resurfacing	Poor
406153-1	TP	91	Add Lanes & Reconstruct	Poor
417024-1	TP	91	Resurfacing	Good

4.4 Validation Process for Flexible Projects

The available data for each of the 38 projects were fed into the CQI model. As explained in Chapter 3, a project's CQI is the sum of each layer's CQI of the project. Each layer of the pavement system has its weight and the sum of the layer's weights is 100 percent, or 1.00.

Of course, all projects do not have data for every possible layer. For example, in resurfacing-type construction, layers of embankment, subgrade, or base do not exist. Therefore, when there are missing layers, a weight correction of the layers with data should be considered. In order to make the sum of remaining layers' weights 100 percent or 1.00, when there are missing layers, the missing layers' weights are divided and added to the remaining layers' weights by the proportion of the remaining layers' weights. This rule is equally applied at the parameter level, too. For example, some projects were missing air void and density data for asphalt layers (both friction and structural courses). For these cases, the CQI for this layer will represent all parameters excluding the missing AQC. This arrangement is not ideal, but it is the best that can be accomplished when key data is missing from the LIMS database.

4.4.1 Bituminous Layers

Since geotechnical data was difficult to retrieve; only two new construction projects were evaluated using all layers. Therefore, this section describes the performance of the bituminous layers only. Since the projects were submitted and ranked by the District Bituminous Engineers, evaluating the FDOT rating with the bituminous layer CQI is reasonable.

Overall, the model appeared to perform quite well. Table 7 and Figure 3 summarize the model performance. In Figure 3, the data has been sorted so that the projects with the greatest CQI are on the right side of the plot, while those projects with the lowest CQI are found on the left. The projects have also been color coded so that black represents good projects and the black and white hatch represents poor projects. Most good projects consistently have a CQI greater than approximately 0.800 while poor projects consistently have a CQI less than 0.800. Three poor ratings can be found from 0.800 to 0.900.

Table 7. Model Performance For Flexible Projects.

Project Number	District	State Road	FDOT Rating	CQI
197252-2	1	37	Good	0.8600
197679-1	1	25	Poor	0.7358
197279-2	1	25	Poor	0.7318
208718-2	2	134	Good	0.9457
210432-2	2	45	Good	0.9088
209137-3	2	5	Poor	0.8038
209648-3	2	228	Poor	0.8068
210384-3	2	24	Poor	0.6925
213335-1	2	I-295	Good	0.9349
220442-5	3	87	Poor	0.8500
228188-1	4	7	Good	0.9694
231921-1	4	7	Poor	0.8989
413583-1	5	200	Good	0.9252
415514-1	5	434	Good	0.8253
415526-1	5	40	Good	0.8737
417163-1	5	500	Poor	0.7657
417166-1	5	5	Poor	0.8038
409016-1	3	65	Good	0.9163
413438-1	3	390	Good	0.9289
411395-1	3	173	Good	0.9256
409021-1	3	85	Poor	0.8056
403930-1	3	65	Good	0.9167
242531-1	5	I-4	Poor	0.7825
411603-1	5	25	Good	0.9085
417165-1	5	46	Poor	0.7778
228180-1	4	736	Good	0.9410
249648-1	6	826	Poor	0.7942
256322-1	7	52	Good	0.8966
256888-1	7	55	Poor	0.6947
257076-1	7	693	Poor	0.9077
411332-1	7	7	Good	0.8553
406092-1	TP	91	Good	0.8847
406147-1	TP	869	Poor	0.7441
413670-1	TP	91	Poor	0.7620
417017-1	TP	589	Good	0.8895
411533-3	TP	91	Poor	0.8047
406153-1	TP	91	Poor	0.8054
417024-1	TP	91	Good	0.8764

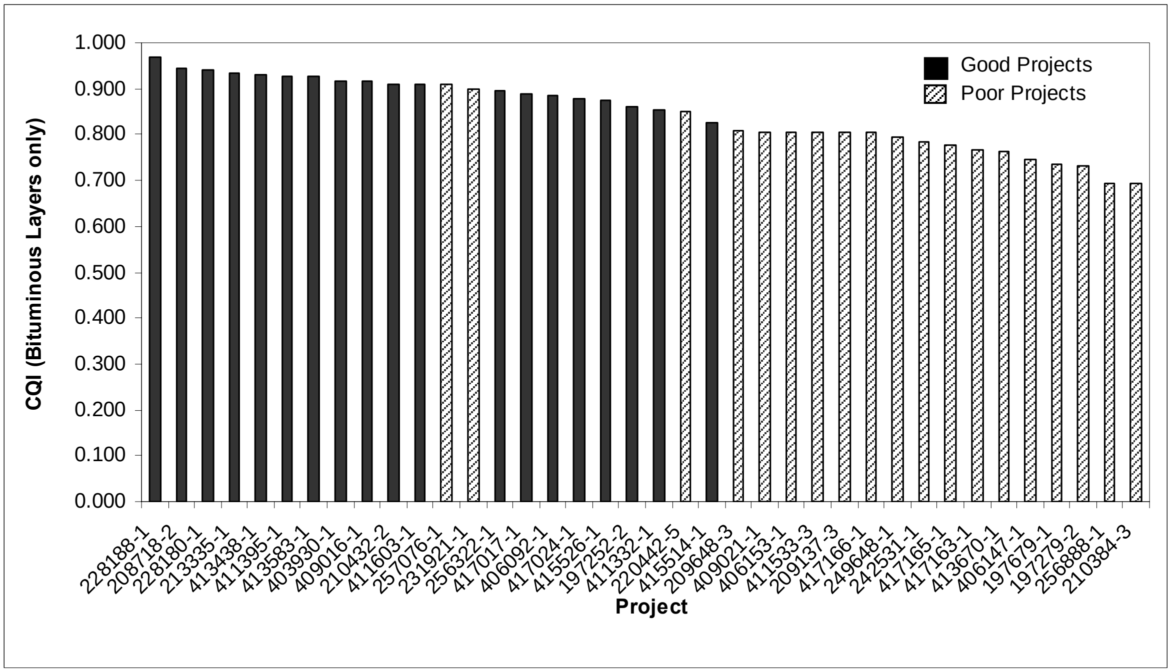

Figure 3. CQI and FDOT Rating for Flexible Projects.

In order to determine if a particular AQC was responsible for the poor projects, each individual AQC for the friction course and Superpave layers was examined. The analysis is summarized in Table 8 and Table 9 and illustrated in Figure 4, Figure 5, Figure 6, and Figure 7. The pavement components with the greatest difference in CQI for good and poor projects include the ride number and density for both friction and Superpave courses. A summary of the differences is shown below.

- Average Ride Number CQI
  - Good projects: 0.9446
  - Poor projects: 0.5143
- Average Density CQI
  - Good projects
    - Superpave friction course: 0.8794
    - Superpave structural course: 0.8518
  - Poor projects
    - Superpave friction course: 0.5751
    - Suparpve structural course: 0.6449

Table 8. CQI Breakdown for Good Flexible Projects.

Component	Average	Maximum	Minimum

Friction Course (SP12.5, SP9.5)	0.9046	0.9758	0.8005
Passing #8	0.8413	1.0000	0.5765
Passing #200	0.9254	1.0000	0.7041
Asphalt Content	0.9208	1.0000	0.7321
Air Voids	0.9064	1.0000	0.6865
Density	0.8794	1.0000	0.5612
Friction Course (FC-5)	0.8949	0.9821	0.8297
Passing 3/8 in	0.9090	0.9970	0.7589
Passing #4	0.9085	0.9863	0.8312
Passing #8	0.9517	1.0000	0.8232
Asphalt Content	0.8880	0.9878	0.7840
Ride	0.9446	1.0000	0.6760
Superpave	0.9075	0.9659	0.8577
Passing #8	0.8476	0.9868	0.5311
Passing #200	0.9322	1.0366	0.7798
Asphalt Content	0.9299	1.0000	0.8244
Air Voids	0.9401	1.0000	0.8651
Density	0.8518	1.0000	0.3160

Table 9. CQI Breakdown for Poor Flexible Projects.

Component	Average	Maximum	Minimum
Friction Course (SP12.5, SP9.5)	0.7497	0.8871	0.5031
Passing #8	0.7538	1.0000	0.2113
Passing #200	0.8361	1.0000	0.5202
Asphalt Content	0.8128	0.9780	0.2590
Air Voids	0.8510	0.9953	0.4031
Density	0.5751	0.9656	0.0000
Friction Course (FC-5)	0.7369	0.9011	0.6061
Passing 3/8 in	0.8386	0.9848	0.6413
Passing #4	0.9136	0.9898	0.8003
Passing #8	0.9023	1.0000	0.6476
Asphalt Content	0.7755	0.9727	0.4456
Ride	0.5143	1.0000	0.0528
Superpave	0.8072	0.9463	0.5922
Passing #8	0.8032	0.9736	0.6043
Passing #200	0.8987	0.9944	0.7218
Asphalt Content	0.9016	0.9883	0.7553
Air Voids	0.8452	1.0000	0.6906
Density	0.6449	0.9245	0.1933

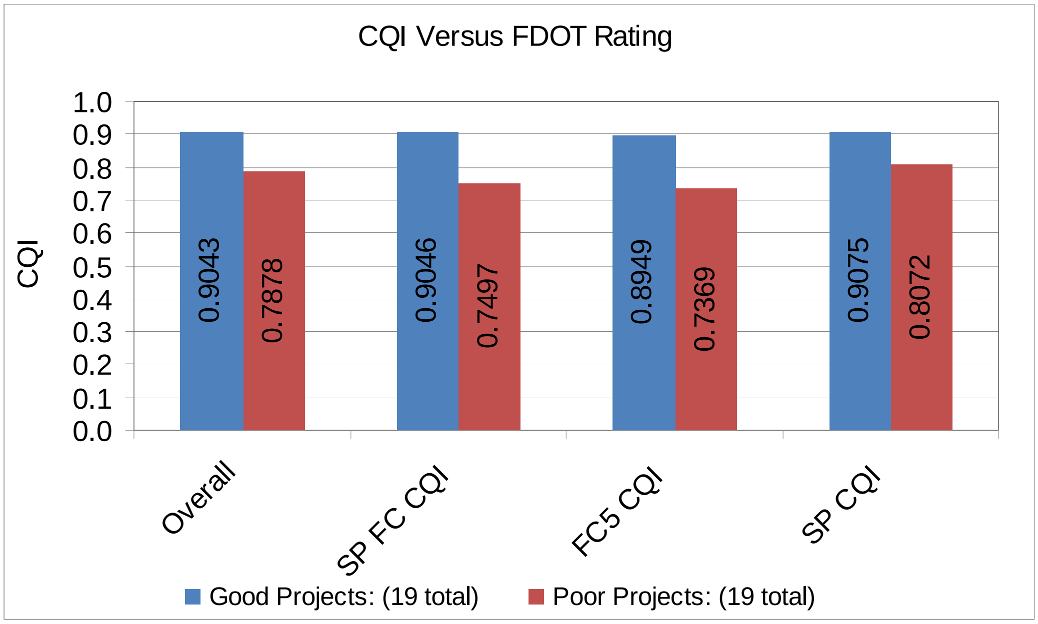

Figure 4. CQI Versus FDOT Rating for Bituminous Layers.

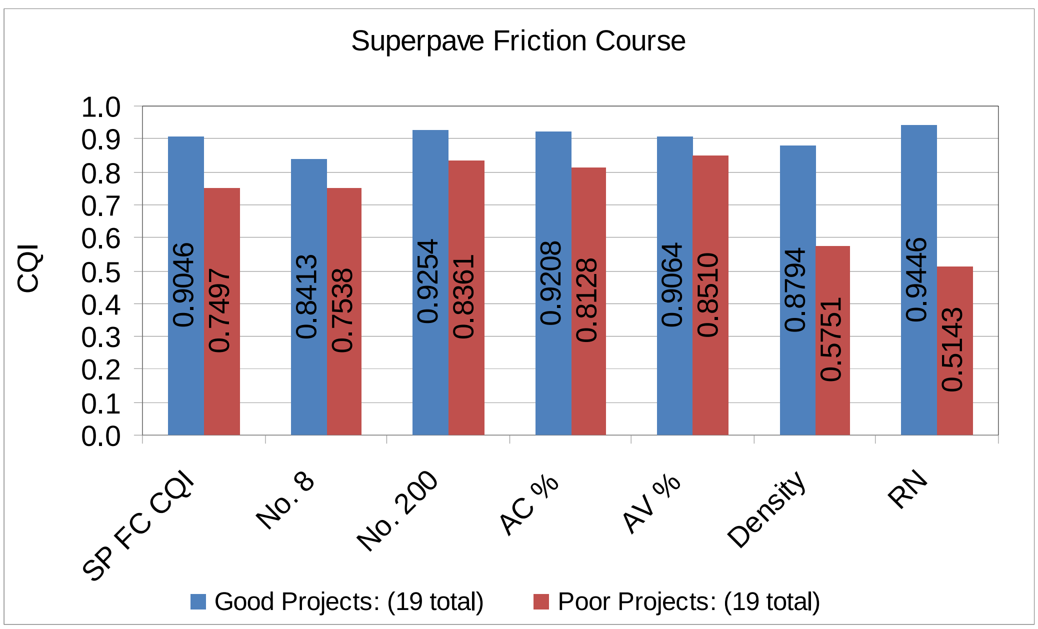

Figure 5. CQI of Superpave Friction Course Components.

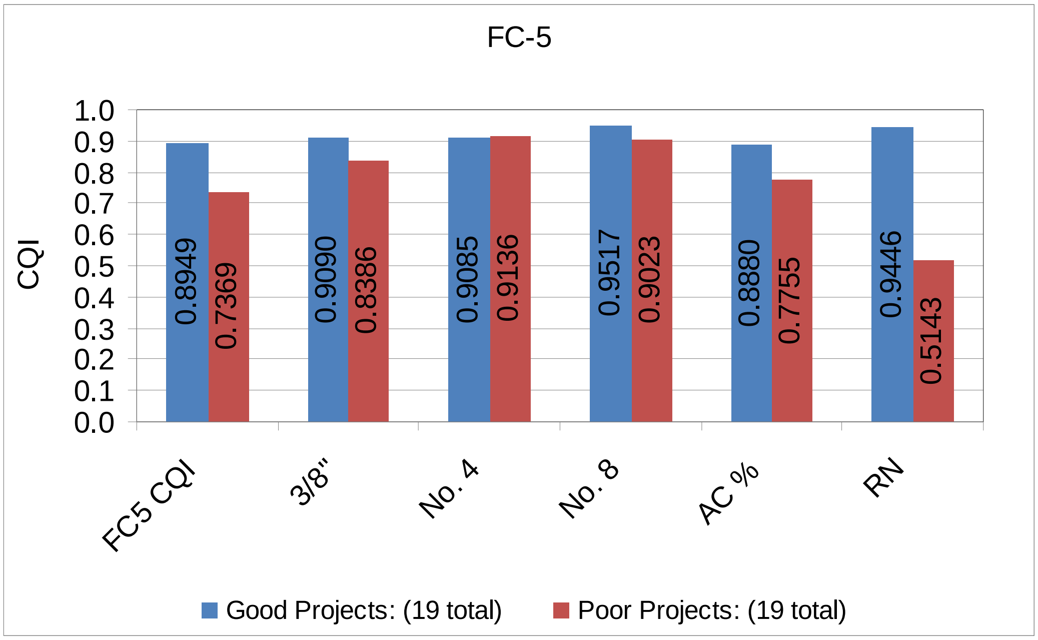

Figure 6. CQI of FC-5 Friction Course Components.

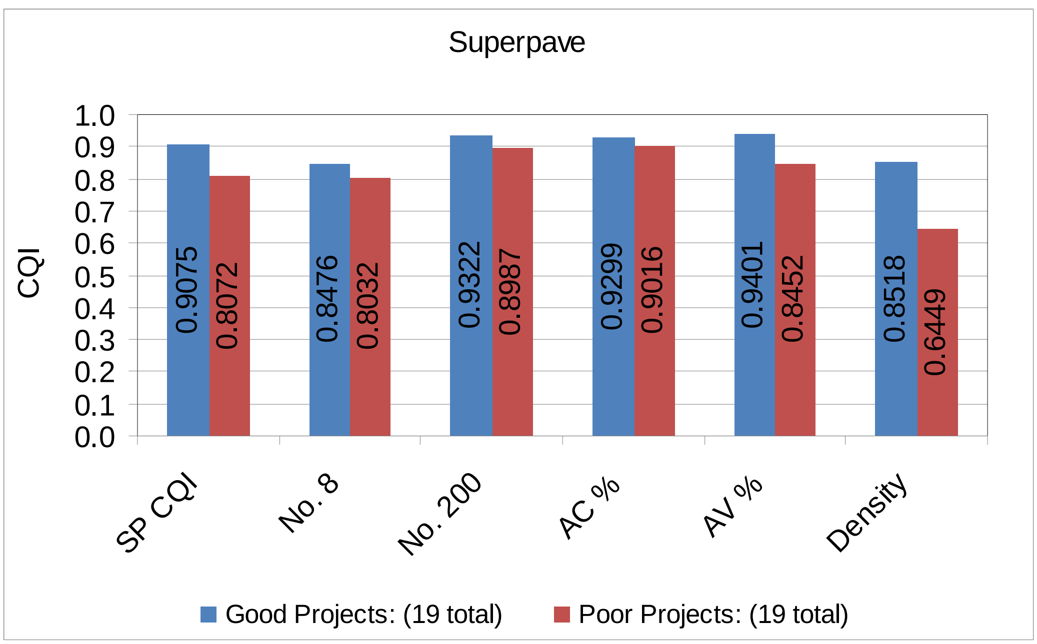

Figure 7. CQI of Superpave Components.

4.4.2 New Flexible Construction with Geotechnical Data

As stated above, only two projects with geotechnical data were available for review. Several attempts to locate other construction log books were made, but were unsuccessful. Table 10 summarizes the CQI of the two projects with geotechnical data.

Table 10. New flexible construction with geotechnical data.

Financial Project Number	**220442-5**	**231921-1**
District	3	4
State Road	87	9
FDOT Rating	Poor	Poor
Overall CQI	**0.8386**	**0.8728**
Surface Layers	**0.8989**	**0.8500**
Friction Course	0.7718	--
Superpave	0.8850	0.8980
Superpave Asphalt Base	**0.9065**	**--**
Passing #200	0.8913	--
Passing #8	0.8994	--
Air Voids	0.8496	--
Asphalt Content	0.9429	--
Density	0.9085	--
Base	**--**	**0.9581**
Density	--	0.9581
Stabilized Subgrade	**0.8507**	**0.7363**
Density	0.7878	0.6136
LBR	0.9505	0.9338
Embankment	**0.6003**	**0.5409**
Density	0.6003	0.5409

4.5 Rigid Projects

As with the flexible projects, district materials engineers were requested to provide good and poor rigid projects to be studied. Again, good and poor project ratings were based on specification compliance and it was expected that the ratings reflected the compliance of primarily the rigid layers. Initially, 14 projects were submitted for review and are listed in Table 11. However, many of these projects were not found in LIMS. Ultimately, only seven projects contained any data in LIMS, and many of these were not complete.

Table 11. Rigid Construction Projects.

Project	**District**	**State Road**	**Construction Type**	**FDOT Rating**

Number				
197574-1	1	SR 659	Interchange Reconstruction	Good
201213-1	1	SR 400	Interchange Reconstruction	Good
201213-1	1	SR 400	Interchange Reconstruction	Good
209513-4	2	SR 212	Add Lanes/Reconstruction	Poor
209600-1	2	SR 9A	New Construction	Good
213273-1	2	SR 9A	Add lanes and rehabilitate	Good
213290-1	2	SR 9A	Interchange Major	Good
228515-1	4	SR 510	Realignment	Good
411321-3	4	SR 93	Resurfacing	Good
405506-5	5	SR 9	Add Lanes/Rehabilitation	Good
249648-1	6	SR 826	Add Lanes/Reconstruction	Poor
258401-1	7	SR 400	Add Lanes/Reconstruction	Good
258642-1	7	SR 93	Rehabilitation	Good
258660-1	7	SR 93	PCC Resurfacing	Good

4.5.1 Validation Process for Rigid Projects

Unfortunately, all of the projects with available data were rated as good so it is impossible to correlate the CQI with the project engineer rating. Furthermore, concrete thickness and profile index data as well as most geotechnical data were unavailable in LIMS. Project engineers were contacted to locate the missing data, but most attempts were unsuccessful. Table 12 summarizes the CQI model performance for the PCC portion of the rigid projects. All CQI values are greater than 0.8099, which generally agrees with the values that corresponded to good flexible projects.

Table 12. Model Performance for Rigid Projects.

Project Number	District	State Road	FDOT Rating	PCC CQI
201213-1	1	SR 400	Good	0.9386*
209600-1	2	SR 9A	Good	0.9316
213273-1	2	SR 9A	Good	0.8903+@
213290-1	2	SR 9A	Good	0.8885+
258401-1	7	SR 400	Good	0.8099+
258642-1	7	SR 93	Good	0.978+
258660-1	7	SR 93	Good	0.9781*+
* Missing thickness data + Missing profile index data @ Includes ATPB				

4.6 Implementation Recommendations

Since all of the required data is unavailable in LIMS, the CQI model cannot be used as originally planned. Furthermore, it is often difficult to locate data unavailable in LIMS. Construction log books may contain several hundred handwritten pages that require manual transfer into the CQI software. These difficulties currently make efficient use of the CQI Calculator impractical. However, data sets such as geotechnical information are continually being uploaded into LIMS. Automated uploading procedures are also being developed to make this process more efficient. In the future, LIMS should contain complete specification compliance data for all projects. With this in mind, the CQI model may be implemented in the following two manners:

1. Contractor performance
2. Predict future performance

Rating contractor performance can be a straightforward process. Predicting future performance; however, is a complicated procedure in which specification compliance is only one of many factors. Other factors that are typically addressed in the pavement design such as expected versus actual traffic and environmental damage may play a larger role in overall pavement performance.

4.6.1 Contractor Performance

The CQI provides a rational and objective method to assess the quality of construction. Based on the data analyzed in this study, a CQI above 0.800 would indicate good quality construction while a CQI below 0.800 would indicate poor quality construction. Various options exist to address inadequate contractor performance. A contractor's average CQI may be used to determine the following:

1. A pre-qualification amount
2. Years of qualification
3. Discipline process via pay or probation period
4. If bonus is applicable

4.6.2 Predict Future Performance

Many transportation agencies are switching form end-result specifications to performance-related specifications. Unfortunately, there are no legitimate relationships to correlate characteristics measured at the construction site and expected performance. A combination of end-result and performance-related specifications are likely to be the best approach until these relationships are established. Relationships that correlate CQI with pavement performance should be established and continually reviewed and revised.

5 Conclusions and Recommendations

5.1 Conclusions

A practical and effective pavement CQI has been developed. The CQI formulation is transparent and easily understood because it relies on concepts consistent with those already used by FDOT and familiar to the pavement contractor. The CQI uses data from the Laboratory Information Management System (LIMS), which serves as FDOT's enterprise database system for all construction quality data. The CQI addresses material, structural, and pavement smoothness characteristics and is applicable for both new and rehabilitation projects. Soils, bound and unbound granular base materials, HMA, and PCC are considered.

Because a pavement system is composed of one or more material layers, the CQI formulation is based upon a summation of the CQI of each individual layer multiplied by a weighting factor that takes into account the relative importance of that layer in the overall pavement system performance. The CQI of each layer is similarly determined by summing the products of the percent within limits of each acceptance quality characteristic multiplied by an appropriate weighting factor. All weighting factors were determined from information gathered at expert panel meetings consisting of experts from FDOT, the construction industry, and academia. Other aspects of contractor performance (e.g., financial resources, ownership of equipment or ability to lease equipment, adherence to schedule, job safety, past performance) are not included in this CQI formulation.

The CQI model was formulated in a modular fashion. The model is flexible allowing it to be scaled to all pavement construction projects, from routine mill and overlay rehabilitation to major new highway pavements construction.

The CQI model was implemented in the Microsoft Windows® operating system as a stand-alone application called *CQI Calculator*. The application runs from one window and displays several screens to simplify and organize data entry. Data can be easily imported or exported from text files, and reports in HTML format can be produced from the input data. At the current time, the application cannot read input files directly from LIMS.

FDOT was asked to provide flexible and rigid projects to the research team along with an associated subjective quality rating for each project. The projects submitted by FDOT were to be ones that had data entered into the LIMS database. The LIMS database did not contain as much data as had been anticipated by FDOT or the research team. Subsequently, the study was limited to studying primarily the surface layers, i.e. bituminous and concrete layers. Furthermore, concrete data within LIMS was incomplete and did not include thickness or profile index. Most data for unbound layers were not found in LIMS and are currently only available in construction log books.

Based on the flexible projects analyzed in this study, a CQI greater than 0.800 indicates good quality construction while a CQI less than 0.800 indicates poor quality construction. The pavement components with the greatest difference in CQI for good and poor flexible construction projects include ride number and density for both friction and Superpave courses. A summary of the differences is shown below.

- Average Ride Number CQI
  - Good projects: 0.9446
  - Poor projects: 0.5143
- Average Density CQI
  - Good projects
    - Superpave friction course: 0.8794
    - Superpave structural course: 0.8518
  - Poor projects
    - Superpave friction course: 0.5751
    - Suparpve structural course: 0.6449

Unfortunately, all of the rigid projects with available data were rated as good so it is impossible to correlate the CQI with the project engineer rating. All seven CQI values for the rigid projects are greater than 0.8099, which generally agrees with the values that corresponded to good flexible projects.

5.2 Recommendations

It is recommended that approximately 10 projects be considered for long term evaluation. These projects should be new construction or rehabilitation efforts and should include at least three projects with a CQI that range from 0.7 to 0.8, three projects that range from 0.8 to 0.9, and three greater than 0.9. For these projects, significant effort should be made to record and upload all specification compliance into LIMS, including all geotechnical data. At the minimum, all specification compliance data should be made available for review and ideally should be in an electronic format. Furthermore, all design data should be reviewed for each project selected. Finally, pavement performance and applied traffic should be monitored annually. Pavement performance monitoring should include deflection, rut, ride and crack measurements. These projects will serve as a baseline for developing relationships with CQI and pavement performance.

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Appendix A: Survey of State Highway Agency Policy and Practice

State or Territory	Contact	Construction Quality Index
Alabama	ALDOT Construction Engineer	None
Alaska	AASHTO Liaison	None
Arizona	Assistant State Engineer	None
Arkansas	State Construction Engineer's Office	None
California	Division of Construction Specialist for Project Progression	None statewide some regions rate for particular jobs.
Colorado	Branch Manager of Contracts and Market Analysis Branch	About to start a pilot program.
Connecticut	Transportation Engineer 2	Inspectors rate subjectively once a year using attached form. If average drops below thresh hold contractor has meet with DOT.
Delaware	Quality Engineer	None
Georgia	State Construction Engineer	None
Hawaii	Engineering Program Manager w/in Construction and Maintenance	None
Idaho	Chief Engineer	None for contractors, but do rate their consultants.
Illinois	Pre-qualification Engineer	Very detailed subjective, but does include workmanship. Creates coefficient that increases or decreases amount of money company can bid.
Indiana	State Construction Engineer	Uses attached form to rate contractors
Iowa	Construction Office Director	Uses a subjective contractor evaluation form that creates a coefficient to decrease or increase bidding capacity.
Kansas	Bureau of Construction and Maintenance	Uses a subjective contractor evaluation form that creates a coefficient to decrease or increase bidding capacity.
Kentucky	NA	NA
Louisiana	Chief of Construction Section	None for contractors but do rate plans.
Maine	Pre-qualification Coordinator	Uses a subjective contractor evaluation form that is subjectively used to determine how many years of qualification.
Maryland	Assistant Construction Engineer	Subjective yearly questionnaire creates a grade. Depending upon grade retention is held for a variable amount of time.
Massachusetts	NA	NA
Michigan	Construction Contracts Engineer	Subjective sheet have three tier prior to effecting pre-qualification amount.
Minnesota	Engineer Senior Administrative	Do not rate contractors, but rate overall project based upon cost versus quality.
Mississippi	Construction Division Head	None

State or Territory	Contact	Construction Quality Index
Missouri	Senior Information Specialist for Construction Department	Uses a subjective questionnaire that creates a percentage. Based upon that percentage a contractor can be put on probation or suspended for one year
Montana	Construction Section	NA
Nebraska	Construction Department	Uses a subjective check list that goes into a weighted database based on job size. Data base creates a coefficient that affects the amount that can be bid.
Nevada	Chief Construction Engineer	Subjective report that is input into a formula to effect pre-qualification amount
New Hampshire	District Engineer	Subjective form affects pre-qualification amount.
New Jersey	NA	NA
New Mexico	State Construction Engineer	Developing a system, currently have a simple pre-qualification form that is more like an application.
New York	Co-Assistant Director of Construction	None, are in the process of trying to create one.
North Carolina	State Construction Engineer	Basic pre-qualification safety and environmental index but no performance grade.
North Dakota	Assistant Construction Engineer	Financial pre-qualification, no rating system.
Ohio	Contractor Pre-qualification	NA
Oklahoma	State Construction Engineer	Have a subjective form that is saved, but not applied to anything currently.
Oregon	Contract Administration Engineer	Subjective form just changed to more effective form. Once contractor drops below set average they are put into a discipline process.
Pennsylvania	Contract Evaluation Engineer	Every six months a subjective form is filled out that effects amount that can be bid, if scores are extremely low in particular areas can not bid that type of job.
Rhode Island	NA	NA
South Carolina	NA	NA
South Dakota	NA	NA
Tennessee	Construction Contracts Officer	Do not currently do anything, hope to by beginning of 2007.
Texas	Contract Letting and Processing	Financial pre-qualification, no rating system.
Utah	Manager Contracts Estimates/Agreements	Subjective form on each job to let contractor know how they are doing, only used in deciding who to hire for design-build jobs.
Vermont	Construction Engineer	NA
Virginia	Contract Engineer Assistant Division Administrator	Subjective form that effects pre-qualification only, score and safety effect pre-qualification. Revamping form by end of fall 2006.
Washington	Contracts Engineer	NA

State or Territory	Contact	Construction Quality Index
West Virginia	Construction Engineer	Subjective form effects pre-qualification amount.
Wisconsin	Contracts Engineer	NA
Wyoming	Construction Branch	Subjective form that affects pre-qualification amount,
Washington DC	Construction Office	None
Puerto Rico	Area de Construction	Trying to implement but currently have none.

Appendix B: FDOT Pavement Acceptance Quality Characteristics

Table B-1. Acceptance Quality Characteristics for Flexible Pavements

Specification	Layer	AQC	Units	Upper Range	Target	Lower Range
Section 120: Excavation and Embankment	Embankment	Density	Percent Standard Proctor Maximum Density	None	100	0
Section 160: Stabilizing	Stabilized Subgrade	Bearing Value	LBR (soaked)	None	40	5
		Bearing Value	LBR (soaked)	None	35	4
		Bearing Value	LBR (soaked)	None	< 30	2.5
		Bearing Value	LBR = 40 (unsoaked)	None	43	0
		Mixing Depth	inches	2	Per plans	0
		Density	Percent Modified Proctor Density	None	98	0
Section 200: Rock Base	Base Course	Density	Percent Modified Proctor Density	None	98	0
Section 204: Graded Aggregate Base	Base Course	Density	Percent Modified Proctor Density	None	98	0
Section 234: Superpave Asphalt Base	Base Course	Passing No. 8 Sieve	Percent	3.1	Per plans	3.1
		Passing No. 200 Sieve	Percent	1.0	Per plans	1.0
		Asphalt Content	Percent	0.40	Per plans	0.40
		Air Voids (Coarse Mix)	Percent	1.40	4.00	1.40
		Air Voids (Fine Mix)	Percent	1.20	4.00	1.20
		Density (Coarse)	Percent Gmm	1.30	94.50	1.30
		Density (Fine)	Percent Gmm	2.00	93.00	1.20

Table B-1. Acceptance Quality Characteristics for Flexible Pavements (Continued)

Specification	Layer	AQC	Units	Upper Range	Target	Lower Range
Section 283: Reclaimed Asphalt Base	Base Course	Density	Percent Modified Proctor Density	None	95	0
Section 334: Superpave Asphalt Concrete	Structural Course	Passing No. 8 Sieve	Percent	3.1	Per plans	3.1
		Passing No. 200 Sieve	Percent	1.0	Per plans	1.0
		Asphalt Content	Percent	0.40	Per plans	0.40
		Air Voids (Coarse Mix)	Percent	1.40	4.00	1.40
		Air Voids (Fine Mix)	Percent	1.20	4.00	1.20
		Density (Coarse)	Percent Gmm	1.30	94.50	1.30
		Density (Fine)	Percent Gmm	2.00	93.00	1.20

Table B-1. Acceptance Quality Characteristics for Flexible Pavements (Concluded)

Specification	Layer	AQC	Units	Upper Range	Target	Lower Range
Section 337: Asphalt Concrete Friction Courses	FC-5	Asphalt Binder Content	Percent	0.45	Per plans	0.45
		Passing 3/8 in Seive	Percent	6.00	Per plans	6.00
		Passing No. 4 Sieve	Percent	4.50	Per plans	4.50
		Passing No. 8 Seive	Percent	2.50	Per plans	2.50
	FC-9.5	Passing No. 8 Sieve	Percent	3.10	Per plans	3.10
		Passing No. 200 Sieve	Percent	1.00	Per plans	1.00
		Asphalt Content	Percent	0.40	Per plans	0.40
		Air Voids (Coarse Mix)	Percent	1.40	4.00	1.40
		Air Voids (Fine Mix)	Percent	1.20	4.00	1.20
		Density (Coarse)	Percent Gmm	1.30	94.50	1.30
		Density (Fine)	Percent Gmm	2.00	93.00	1.20
	FC-12.5	Passing No. 8 Sieve	Percent	3.10	Per plans	3.10
		Passing No. 200 Sieve	Percent	1.00	Per plans	1.00
		Asphalt Content	Percent	0.40	Per plans	0.40
		Air Voids (Coarse Mix)	Percent	1.40	4.00	1.40
		Air Voids (Fine Mix)	Percent	1.20	4.00	1.20
		Density (Coarse)	Percent Gmm	1.30	94.50	1.30
		Density (Fine)	Percent Gmm	2.00	93.00	1.20
Ride Number	Friction Course	Ride Number		None	5	1

Table B-2. Acceptance Quality Characteristics for Rigid Pavements

Specification	Layer	AQC	Units	Upper Range	Target	Lower Range
Section 120: Excavation and Embankment	Embankment	Density	Percent standard proctor paximum density	None	100	0
Section 160: Stabilizing	Stabilized Subgrade	Bearing Value	LBR (soaked)	None	40	5
		Bearing Value	LBR (soaked)	None	35	4
		Bearing Value	LBR (soaked)	None	< 30	2.5
		Bearing Value	LBR = 40 (unsoaked)	None	43	0
		Mixing Depth	inches	2	Per plans	0
		Density	Percent modified proctor density	None	98	0
Section 287: Asphalt Treated Permeable Base	Permeable Base	Passing Control Sieve†	Percent	10	Per plans	10
		Binder Content	Percent	0.5	Per plans	0.45
Section 288: Cement Treated Permeable Base	Permeable Base	Passing Control Sieve†	Percent			
		Water-Cement Ratio	None	0.00	0.4	None
		Cement Factor	lb/ft^3	2.00	9.00	2.00
Section 346: Portland Cement Concrete	Pavement Concrete	28-day Comp. Strength	psi	None	3000.00	0.00
		Slump	inches	None	2.00	0.00
		Air Content	Percent	2.50	3.50	2.50
		Water-Cement Ratio	None	0	0.5	None
Section 350: Cement Concrete Pavement	Pavement Concrete	Thickness	inches	None	Per Plans	0
Section 352: Grinding Concrete Pavement	Pavement Concrete	Profile Index *	inches/mile	3	2	2
		Profile Index **	Inches/mile	3	4	4

† For asphalt treated permeable bases with #57 stone, control sieve is 1/2 inch sieve. For asphalt treated permeable bases with #67 stone, control sieve is 3/8 inch sieve.

* For curvature radius ≥ 2000 ft

** For curvature radius ≥ 1000 ft but < 2000 ft

Appendix C: PWL Table

The PWL table gives the percent within limits values for any Q value (quality index) and any sample size. These values were obtained through a computer simulation. Using the table avoids complex computations each time the percent within limits is calculated.

To use the table, the quality index must be calculated. A Q value is determined from the difference between the sample mean ($\overline{X}$) and the lower or upper specification limit (*LSL* / *USL*) divided by the sample's standard deviation (s):

$$Q_L = \frac{\overline{X} - LSL}{s} \quad and \quad Q_U = \frac{USL - \overline{X}}{s}$$

Two-sided limits require both Q values to be calculated. The two-sided percent within limits is then given by the difference between the sum of those two values and one hundred:

$$PWL_T = PWL_U + PWL_L - 100$$

The parameter *n* in the table represents sample size. Once the sample size and the quality index are known, the quality index is found in the column representing the appropriate sample size. The row in which the quality index appears indicates the percent within limits for that quality index. Should the quality index be larger than the first row's value, the percent within limits is recognized as 100 percent.

PWL	n = 3	n = 4	n = 5	n = 6	n = 7	n = 8	n = 9	n = 10 to 11
100	1.16	1.50	1.79	2.03	2.23	2.39	2.53	2.65
99	-	1.47	1.67	1.80	1.89	1.95	2.00	2.04
98	1.15	1.44	1.60	1.70	1.76	1.81	1.84	1.86
97	-	1.41	1.54	1.62	1.67	1.70	1.72	1.74
96	1.14	1.38	1.49	1.55	1.59	1.61	1.63	1.65
95	-	1.35	1.44	1.49	1.52	1.54	1.55	1.56
94	1.13	1.32	1.39	1.43	1.46	1.47	1.48	1.49
93	-	1.29	1.35	1.38	1.40	1.41	1.42	1.43
92	1.12	1.26	1.31	1.33	1.35	1.36	1.36	1.37
91	1.11	1.23	1.27	1.29	1.30	1.30	1.31	1.31
90	1.10	1.20	1.23	1.24	1.25	1.25	1.26	1.26
89	1.09	1.17	1.19	1.20	1.20	1.21	1.21	1.21
88	1.07	1.14	1.15	1.16	1.16	1.16	1.16	1.17
87	1.06	1.11	1.12	1.12	1.12	1.12	1.12	1.12
86	1.04	1.08	1.08	1.08	1.08	1.08	1.08	1.08
85	1.03	1.05	1.05	1.04	1.04	1.04	1.04	1.04
84	1.01	1.02	1.01	1.01	1.00	1.00	1.00	1.00
83	1.00	0.99	0.98	0.97	0.97	0.96	0.96	0.96
82	0.97	0.96	0.95	0.94	0.93	0.93	0.93	0.92
81	0.96	0.93	0.91	0.90	0.90	0.89	0.89	0.89
80	0.93	0.90	0.88	0.87	0.86	0.86	0.86	0.85
79	0.91	0.87	0.85	0.84	0.83	0.82	0.82	0.82
78	0.89	0.84	0.82	0.80	0.80	0.79	0.79	0.79
77	0.87	0.81	0.78	0.77	0.76	0.76	0.76	0.75
76	0.84	0.78	0.75	0.74	0.73	0.73	0.72	0.72
75	0.82	0.75	0.72	0.71	0.70	0.70	0.69	0.69
74	0.79	0.72	0.69	0.68	0.67	0.66	0.66	0.66
73	0.76	0.69	0.66	0.65	0.64	0.63	0.63	0.63
72	0.74	0.66	0.63	0.62	0.61	0.60	0.60	0.60
71	0.71	0.63	0.60	0.59	0.58	0.57	0.57	0.57
70	0.68	0.60	0.57	0.56	0.55	0.55	0.54	0.54
69	0.65	0.57	0.54	0.53	0.52	0.52	0.51	0.51
68	0.62	0.54	0.51	0.50	0.49	0.49	0.48	0.48
67	0.59	0.51	0.47	0.47	0.46	0.46	0.46	0.45
66	0.56	0.48	0.45	0.44	0.44	0.43	0.43	0.43
65	0.52	0.45	0.43	0.41	0.41	0.40	0.40	0.40
64	0.49	0.42	0.40	0.39	0.38	0.38	0.37	0.37
63	0.46	0.39	0.37	0.36	0.35	0.35	0.35	0.34
62	0.43	0.36	0.34	0.33	0.32	0.32	0.32	0.32
61	0.39	0.33	0.31	0.30	0.30	0.29	0.29	0.29
60	0.36	0.30	0.28	0.27	0.27	0.27	0.26	0.26

59	0.32	0.27	0.25	0.25	0.24	0.24	0.24	0.24
58	0.29	0.24	0.23	0.22	0.21	0.21	0.21	0.21
57	0.25	0.21	0.20	0.19	0.19	0.19	0.18	0.18
56	0.22	0.18	0.17	0.16	0.16	0.16	0.16	0.16
55	0.18	0.15	0.14	0.14	0.13	0.13	0.13	0.13
54	0.14	0.12	0.11	0.11	0.11	0.11	0.10	0.10
53	0.11	0.09	0.08	0.08	0.08	0.08	0.08	0.08
52	0.07	0.06	0.06	0.05	0.05	0.05	0.05	0.05
51	0.04	0.03	0.03	0.03	0.03	0.03	0.03	0.03
50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

PWL	*n* = 12 to 14	*n* = 15 to 18	*n* = 19 to 25	*n* = 26 to 37	*n* = 38 to 69	*n* = 70 to 200	*n* = 201 to ∞
100	2.83	3.03	3.20	3.38	3.54	3.70	3.83
99	2.09	2.14	2.18	2.22	2.26	2.29	2.31
98	1.91	1.93	1.96	1.99	2.01	2.03	2.05
97	1.77	1.79	1.81	1.83	1.85	1.86	1.87
96	1.67	1.68	1.70	1.71	1.73	1.74	1.75
95	1.58	1.59	1.61	1.62	1.63	1.63	1.64
94	1.50	1.51	1.52	1.53	1.54	1.55	1.55
93	1.44	1.44	1.45	1.46	1.46	1.47	1.47
92	1.37	1.38	1.39	1.39	1.40	1.40	1.40
91	1.32	1.32	1.33	1.33	1.33	1.34	1.34
90	1.26	1.27	1.27	1.27	1.28	1.28	1.28
89	1.21	1.22	1.22	1.22	1.22	1.22	1.23
88	1.17	1.17	1.17	1.17	1.17	1.17	1.17
87	1.12	1.12	1.12	1.12	1.12	1.13	1.13
86	1.08	1.08	1.08	1.08	1.08	1.08	1.08
85	1.04	1.04	1.04	1.04	1.04	1.04	1.04
84	1.00	1.00	1.00	1.00	0.99	0.99	0.99
83	0.96	0.96	0.96	0.96	0.95	0.95	0.95
82	0.92	0.92	0.92	0.92	0.92	0.92	0.92
81	0.89	0.88	0.88	0.88	0.88	0.88	0.88
80	0.85	0.85	0.85	0.84	0.84	0.84	0.84
79	0.82	0.81	0.81	0.81	0.81	0.81	0.81
78	0.78	0.78	0.78	0.78	0.77	0.77	0.77
77	0.75	0.75	0.75	0.74	0.74	0.74	0.74
76	0.72	0.71	0.71	0.71	0.71	0.71	0.71
75	0.69	0.68	0.68	0.68	0.68	0.68	0.67
74	0.66	0.65	0.65	0.65	0.65	0.64	0.64
73	0.62	0.62	0.62	0.62	0.62	0.61	0.61
72	0.59	0.59	0.59	0.59	0.59	0.58	0.58
71	0.57	0.56	0.56	0.56	0.56	0.55	0.55
70	0.54	0.53	0.53	0.53	0.53	0.53	0.52
69	0.51	0.50	0.50	0.50	0.50	0.50	0.50
68	0.48	0.48	0.47	0.47	0.47	0.47	0.47
67	0.45	0.45	0.45	0.44	0.44	0.44	0.44
66	0.42	0.42	0.42	0.42	0.41	0.41	0.41
65	0.40	0.39	0.39	0.39	0.39	0.39	0.39
64	0.37	0.36	0.36	0.36	0.36	0.36	0.36
63	0.34	0.34	0.34	0.34	0.33	0.33	0.33
62	0.31	0.31	0.31	0.31	0.31	0.31	0.31
61	0.29	0.29	0.28	0.28	0.28	0.28	0.28
60	0.26	0.26	0.26	0.26	0.26	0.25	0.25
59	0.23	0.23	0.23	0.23	0.23	0.23	0.23
58	0.21	0.21	0.20	0.20	0.20	0.20	0.20
57	0.18	0.18	0.18	0.18	0.18	0.18	0.18
56	0.16	0.15	0.15	0.15	0.15	0.15	0.15
55	0.13	0.13	0.13	0.13	0.13	0.13	0.13
54	0.10	0.10	0.10	0.10	0.10	0.10	0.10
53	0.08	0.08	0.08	0.08	0.08	0.08	0.08
52	0.05	0.05	0.05	0.05	0.05	0.05	0.05
51	0.03	0.03	0.03	0.03	0.03	0.03	0.02
50	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Appendix D: Expert Panel Meeting Forms

FDOT CONSTRUCTION QUALITY INDEX

EXPERT PANEL RATING SHEET

FLEXIBLE PAVEMENT

Name: ______________________________

Location: ______________________________

Date: ______________________________

Affliation:
- ☐ **Florida Department of Transportation**
- ☐ **Construction Industry**
- ☐ **Consultant**
- ☐ **Academia**
- ☐ **Other** ______________________________

Concerning: **Flexible 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																		Stablized Subgrade
Embankment																		Base
Embankment																		Superpave
Embankment																		Friction Course
Stablized Subgrade																		Base
Stablized Subgrade																		Superpave
Stablized Subgrade																		Friction Course
Base																		Superpave
Base																		Friction Course
Superpave																		Friction Course

Concerning: **Stablized 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

Concerning: **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
Density																		Thickness

Concerning: **SuperPave**

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 Voids																		Passing #200
Air Voids																		Asphalt Content
Air Voids																		Thickness
Air Voids																		Roadway Density
Passing #200																		Asphalt Content
Passing #200																		Thickness
Passing #200																		Roadway Density
Asphalt Content																		Thickness
Asphalt Content																		Roadway Density
Roadway Density																		Thickness

CONTINUED ON NEXT PAGE

FDOT CONSTRUCTION QUALITY INDEX
EXPERT PANEL RATING SHEET

FLEXIBLE PAVEMENT

Concerning: **FC-5**

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
Binder Content																		Passing 3/8 in.
Binder Content																		Passing #4
Binder Content																		Passing #8
Binder Content																		Ride Number
Passing 3/8-in.																		Passing #4
Passing 3/8-in.																		Passing #8
Passing 3/8-in.																		Ride Number
Passing #4																		Passing #8
Passing #4																		Ride Number
Passing #8																		Ride Number

Concerning: **FC-9.5/FC-12.5**

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 Voids																		Passing #200
Air Voids																		Asphalt Content
Air Voids																		Thickness
Air Voids																		Roadway Density
Air Voids																		Ride Number
Passing #200																		Asphalt Content
Passing #200																		Thickness
Passing #200																		Roadway Density
Passing #200																		Ride Number
Asphalt Content																		Thickness
Asphalt Content																		Roadway Density
Asphalt Content																		Ride Number
Ride Number																		Roadway Density
Ride Number																		Thickness
Roadway Density																		Thickness

FDOT CONSTRUCTION QUALITY INDEX
EXPERT PANEL RATING SHEET
RIGID PAVEMENT

Name: ______________________

Location: ______________________

Date: ______________________

Affliation:
- [ ] Florida Department of Transportation
- [ ] Construction Industry
- [ ] Consultant
- [ ] Academia
- [ ] Other ______________________

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
Embanmkent																		Stabilized Subgrade
Embankment																		Treated Permeable Base
Embankment																		PCC
Stabilized Subgrade																		Treated Permeable Base
Stabilized Subgrade																		PCC
Treated Permeable Base																		PCC

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

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

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

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
Air Content																		Water-Cement Ratio
Compressive Strength																		Profile Index
Compressive Strength																		Slump
Compressive Strength																		Thickness
Compressive Strength																		Water-Cement Ratio
Profile Index																		Slump
Profile Index																		Thickness
Profile Index																		Water-Cement Ratio
Slump																		Thickness
Slump																		Water-Cement Ratio
Thickness																		Water-Cement Ratio

Appendix E: Tabulation of Results from Expert Panel Meetings

FDOT CONSTRUCTION QUALITY INDEX

FLEXIBLE PAVEMENT

	Construction Industry								FDOT									Academia			Other	GRAND MEAN
- +	1	2	3	4	5	6	7	AVG	8	9	10	11	12	13	14	15	AVG	17	18	AVG	19	
Flexible Pavement System Components																						
Embankment vs. Stabilized Subgrade	1	2	3	3	3	0	0	1.71	5	1	2	2	7	4	0	2	2.88	7	2	4.50	(4)	2.22
Embankment vs. Base	2	2	6	8	1	1	0	2.86	6	2	2	6	8	6	0	6	4.50	7	6	6.50	4	4.06
Embankment vs. Superpave	3	4	8	6	8	(1)	0	4.00	6	3	2	8	8	7	(3)	7	4.75		3	3.00	4	4.29
Embankment vs. Friction Course	0	4	8	6	8	(2)	0	3.43	6	4	6	8	8	8	(4)	5	5.13	4	0	2.00	4	4.06
Stabilized Subgrade vs. Base	1	2	5	8	8	0	0	3.43	4	1	2	3	6	1	0	2	2.38	1	5	3.00	4	2.94
Stabilized Subgrade vs. Superpave	2	2	8	6	8	(1)	0	3.57	4	2	2	8	7	3	(3)	5	3.50		4	4.00	4	3.59
Stabilized Subgrade vs. Friction Course	0	2	8	6	8	(2)	0	3.14	3	3	6	8	7	3	(4)	6	4.00	4	1	2.50	4	3.50
Base vs. Superpave	1	2	8	(4)	8	(2)	0	1.86	4	2	2	6	5	0	(3)	5	2.63		0	0.00	4	2.24
Base vs. Friction Course	0	2	8	(4)	8	(2)	0	1.71	3	3	6	6	6	0	(7)	3	2.50	1	(6)	(2.50)	0	1.50
Superpave vs. Friction Course	(1)	(1)	(6)	(4)	0	(3)	0	(2.14)	(3)	4	0	2	2	4	(4)	2	0.88		(3)	(3.00)	0	-0.65
Stabilized Subgrade																						
Density vs. LBR	2	1	(5)	4	(1)	0	0	0.14	(7)	0	0	(1)		0	(7)	2	(1.86)	6	0	3.00	0	-0.35
Density vs. Thickness	1	0	(2)	(4)	(1)	2	2	(0.29)	(1)	0	(2)	4		(5)	(7)	(1)	(1.71)	6	0	3.00	(4)	-0.71
LBR vs. Thickness	0	0	2	(4)	1	1	2	0.29	8	0	(2)	5		(4)	7	(1)	1.86	0	3	1.50	4	1.29
Base																						
Density vs. Thickness	0	0		4	(8)	2	1	(0.17)	(3)	0	0	2		(3)	(6)	2	(1.14)	5	(2)	1.50	(4)	-0.63
Superpave																						
Air Voids vs. Passing #200	(4)	0	0	0	(8)	0	1	(1.57)	1	(3)	(2)	(5)	(8)	(3)	0	(5)	(3.13)	0	3	1.50	(4)	-2.06
Air Voids vs. Asphalt Content	2	0	0	0	(2)	0	1	0.14	2	0	(2)	(2)	(3)	(1)	0	1	(0.63)	0	3	1.50	(1)	-0.11
Air Voids vs. Thickness	4	1	1	3	(8)	2	1	0.57	0	1	0	0	(2)	(2)	0	(2)	(0.63)	(3)	2	(0.50)	0	-0.11
Air Voids vs. Roadway Density							1									(1)	(1.00)					0.00
Passing #200 vs. Asphalt Content	4	0	2	(2)	5	1	(1)	1.29	2	2	0	0	8	5	3	2	2.75	0	0	0.00	1	1.78
Passing #200 vs. Thickness	8	1	(2)	3	(6)	2	(1)	0.71	(1)	3	2	2	8	3	3	3	2.88	0	1	0.50	(2)	1.50
Passing #200 vs. Roadway Density							(1)									4	4.00					1.50
Asphalt Content vs. Thickness	8	1	(1)	3	(8)	2	0	0.71	(1)	0	2	1	0	0	0	2	0.50		1	1.00	(3)	0.41
Asphalt Content vs. Roadway Density							0									2	2.00					1.00
Roadway Density vs. Thickness							0									1	1.00					0.50
FC-5																						
Binder Content vs. Passing 3/8 in.	(3)	(2)	(1)	2	(4)	(1)	0	(1.29)	(6)	0	0	(2)	(5)	0	(4)	(4)	(2.63)	(1)	(2)	(1.50)	(4)	-2.06
Binder Content vs. Passing #4	(6)	(2)	(1)	2	(4)	(1)	0	(1.71)	(6)	(1)	0	(3)	(5)	0	(4)	(5)	(3.00)	(1)	(2)	(1.50)	(4)	-2.39
Binder Content vs. Passing #8	(5)	(2)	(1)	2	(1)	(1)	0	(1.14)	(2)	(3)	0	(4)	(6)	0	(4)	(6)	(3.13)	(1)	(2)	(1.50)	(4)	-2.22
Binder Content vs. Ride Number	0	(2)	(4)	8	(4)	0	0	(0.29)	(2)	0	1	0	(2)	(2)	0	(2)	(0.88)	5	0	2.50	0	-0.22
Passing 3/8 in. vs. Passing #4	(2)	0	1	2	0	0	0	0.14	0	(3)	0	(2)	(1)	(2)	(4)	(4)	(2.00)		0	0.00	4	-0.65
Passing 3/8 in. vs. Passing #8	(2)	1	1		4	0	0	0.67	5	(4)	0	(1)	(4)	(2)	(4)	(6)	(2.00)		0	0.00	4	-0.50
Passing 3/8 in. vs. Ride Number	3	0	(4)	8	0	1	0	1.14	4	0	1	0	3	(1)	0	2	1.13	5	2	3.50	4	1.56
Passing #4 vs. Passing #8	0	1	1	2	4	0	0	1.14	5	(3)	0	0	(4)	(2)	(4)	(3)	(1.38)		0	0.00	0	-0.18
Passing #4 vs. Ride Number	3	0	(4)	8	(3)	1	0	0.71	4	2	1	0	3	(1)	4	2	1.88	5	2	3.50	(3)	1.33
Passing #8 vs. Ride Number	3	0	(4)	8	(3)	1	0	0.71	(1)	5	1	0	7	0	4	3	2.38	5	2	3.50	(3)	1.56
FC-9.5 and FC-12.5																						
Air Voids vs. Passing #200	(3)	0	0	0	(6)	0	0	(1.29)	1	(3)	0	(4)	(8)	(3)	0	(5)	(2.75)	(2)	2	0.00	(3)	-1.89
Air Voids vs. Asphalt Content	0	0	0	2	(2)	1	0	0.14	2	0	0	(1)	(3)	(2)	0	1	(0.38)	0	2	1.00	(1)	-0.06
Air Voids vs. Thickness	3	1	1	5	(6)	1	0	0.71	2	1	1	0	(2)	(2)	0	(2)	(0.25)	0	2	1.00	(3)	0.11
Air Voids vs. Roadway Density							0									(2)	(2.00)					-1.00
Air Voids vs. Ride Number	0	(2)	(4)	8	(6)	1	0	(0.43)	4	1	1	0	(3)	(2)	0	(2)	(0.13)	7	2	4.50	(3)	0.11
Passing #200 vs. Asphalt Content	2	0	1	1	3	1	0	1.14	3	2	0	0	8	2	2	2	2.38	0	0	0.00	2	1.61
Passing #200 vs. Thickness	4	1	(1)	5	(2)	1	0	1.14	3	3	1	0	8	2	0	2	2.38	7	0	3.50	(1)	1.83
Passing #200 vs. Roadway Density							0									2	2.00					1.00
Passing #200 vs. Ride Number	4	(1)	(4)	8	(1)	1	0	1.00	5	4	1	0	8	1	2	2	2.88	7	2	4.50	(1)	2.11
Asphalt Content vs. Thickness	0	1	(2)	5	(6)	0	0	(0.29)	(1)	0	0	0	0	0	0	(2)	(0.38)	0	0	0.00	(2)	-0.39
Asphalt Content vs. Roadway Density							0									2	2.00					1.00
Asphalt Content vs. Ride Number	1	(1)	(4)	8	(6)	1	0	(0.14)	(2)	0	1	0	0	0	0	1	0.00	7	0	3.50	(1)	0.28
Ride Number vs. Roadway Density							0									1	1.00					0.50
Ride Number vs. Thickness	2	1	4	(8)	(1)	0	0	(0.29)	(2)	0	(1)	0	0	1	0	(1)	(0.38)	(7)	2	(2.50)	(4)	-0.78
Roadway Density vs. Thickness							0									(1)	(1.00)					-0.50

FDOT CONSTRUCTION QUALITY INDEX
RIGID PAVEMENT

- +	Construction Industry						FDOT							Academia			Other	GRAND MEAN
	1	2	3	4	5	AVG	6	7	8	9	10	11	AVG	12	13	AVG	14	
Rigid Pavement System Components																		
Embankment vs. Stabilized Subgrade	2	3	3	(1)	0	1.40	4	2	3	2	(6)	4	1.50	4	0	2.00	(5)	1.07
Embankment vs. Treated Permeable Base	2	8	3	0	0	2.60	4	4	3	4	(6)	7	2.67	4	1	2.50	(5)	2.07
Embankment vs. PCC	2	8	8	0	0	3.60	8	8	7	5	0	3	5.17	3	1	2.00	4	4.07
Stabilized Subgrade vs. Treated Permeable Base	1	8	0	1	0	2.00	1	0	0	1	4	7	2.17	0	6	3.00	0	2.07
Stabilized Subgrade vs. PCC	1	8	8	0	0	3.40	5	8	7	2	6	1	4.83	0	6	3.00		4.00
Treated Permeable Base vs. PCC	(1)	8	8	0	0	3.00	3	7	7	1	6	(1)	3.83	0	1	0.50	4	3.07
Stabilized Subgrade																		
Density vs. LBR	2	1	4	(1)	0	1.20	(8)	(1)	2	0	(7)	(5)	(3.17)		7	7.00	0	(0.46)
Density vs. Thickness	0	0	(4)	0	0	(0.80)	(2)	0	(2)	0	(7)	(5)	(2.67)		7	7.00	(4)	(1.31)
LBR vs. Thickness	0	0	(4)	1	0	(0.60)	8	2	(5)	0	7	3	2.50		1	1.00	4	1.31
Cement Treated Permeable Base																		
Gradation vs. Water-Cement Ratio	0	3	(4)	2	2	0.60	3	(2)	1	2	(4)	(7)	(1.17)	0	7	3.50		0.23
Gradation vs. Cement Factor	0	5	2	1	2	2.00	3	(1)	2		0	(6)	(0.40)	0	7	3.50		1.25
Water-Cement Ratio vs. Cement Factor	0	4	0	0	1	1.00	1	(1)	0		4	1	1.00	0	(7)	(3.50)		0.25
Asphalt Treated Permeable Base																		
Asphalt Binder Content vs. Gradation	0	(4)	4		2	0.50	3			0	0	7	2.50	0	7	3.50	0	1.73
PCC																		
Air Content vs. Compressive Strength	3		8	1	0	3.00	8	0	2	(2)	5	7	3.33	0	7	3.50	4	3.31
Air Content vs. Profile Indedx	3		8	0	0	2.75	8	5	2		8	7	6.00	0		0.00	4	4.09
Air Content vs. Slump	3		(2)	0	0	0.25	3	(5)	2		5	7	2.40	(2)	7	2.50	0	1.50
Air Content vs. Thickness	3		8	2	0	3.25	8	0	2	2	5	7	4.00	3	8	5.50	(2)	3.54
Air Content vs. Water-Cement Ratio	3		2	2	0	1.75	8	(2)	2	2	5	7	3.67	3	7	5.00	6	3.46
Compressive Strength vs. Profile Index	(2)		4	(1)	0	0.25	(2)	0	2		0	3	0.60	0		0.00	4	0.73
Compressive Strength vs. Slump	(2)		(8)	(2)	0	(3.00)	(8)	(3)	(2)		(5)	(6)	(4.80)	(2)	1	(0.50)	(4)	(3.42)
Compressive Strength vs. Thickness	0		0	0	0	0.00	1	0	0	2	0	0	0.50	3	8	5.50	0	1.08
Compressive Strength vs. Water-Cement Ratio	(1)		(8)	(2)	0	(2.75)	0	(3)	1	2	3	(6)	(0.50)	3	1	2.00	1	(0.69)
Profile Index vs. Slump	0		(8)	0	0	(2.00)	(8)	(5)	(2)		(4)	(6)	(5.00)	(2)		(2.00)	(4)	(3.55)
Profile Index vs. Thickness	3		4	2	0	2.25	(1)	0	(2)		0	0	(0.60)	3		3.00	(4)	0.45
Profile Index vs. Water-Cement Ratio	2		(8)	1	0	(1.25)	(1)	(3)	(2)		0	(6)	(2.40)	0		0.00	(4)	(1.91)
Slump vs. Thickness	2		8	2	0	3.00	8	3	1		5	7	4.80	3	8	5.50	4	4.25
Slump vs. Water-Cement Ratio	2		3	0	0	1.25	8	0	2		5	6	4.20	3	8	5.50	4	3.42
Thickness vs. Water-Cement Ratio	(2)		(8)	(2)	0	(3.00)	0	(3)	0	(2)	0	(6)	(1.83)	0	8	4.00	0	(1.15)

Appendix F: CQI Calculator Users Guide

Introduction and Installation

This guide will assist in installing, using, and uninstalling the CQI Calculator software.

The CQI Calculator is designed to organize and evaluate data collected from pavements during construction to give a Construction Quality Index (CQI) that describes how well the pavement adheres to construction specifications. This process uses the concept of percent within limits (PWL) to estimate how many data points will fall within prescribed values given a small sample. The more data points that can be entered, the more accurate the estimate will be.

Each project is designed for one section of pavement. Depending on the type of pavement, different layers may be added to the project. Finally, depending on which layers are included in the project, different tests will become available. It is not required to have data for every layer and every test, and those not included will not have an effect on the CQI calculation.

The CQI Calculator comes with an installation program for ease of distribution. The installation program will start when the CD is entered in the CD-ROM drive. If it does not start automatically, run the "Install.exe" file from the CD.

Once the installer is running, select whether to install the default templates, documentation, shortcuts, and project files. The default templates include data files for generating flexible and rigid pavement projects. If these are not installed, you will have to create your own templates. The documentation includes this manual and a simple walkthrough in PowerPoint about creating new projects. The project files include the data retrieved during the CQI evaluation project.

Choose an installation directory for the software. The calculator will be registered and an "Uninstall.exe" file will be generated in the selected directory. Running this will completely remove all files associated with the CQI Calculator, including shortcuts and saved projects, and will also remove the registration for it from the system. You can also uninstall the software from the Control Panel or from Start Menu shortcut, if you chose to install it.

The software requires at least version 1.6 of the Java JRE to run. Most computers come with this software pre-installed, but if not, the Java Runtime Environment (JRE) is free to download at www.sun.com under Downloads > Java SE. Choose the latest JRE. To make sure Java is installed properly, open a Command Prompt window under Start > Accessories > Command Prompt and type in, without the quotes, "java –version". You should get an answer displaying the installed Java version. This should be at least version 1.6.

CQI Calculator Overview

The CQI Calculator software is designed to store project test data in an organized and efficient way. Once the data is entered, the calculator can generate reports based on that data. All data and layer organization is maintained in text files, making the data and the project's structure easy to examine or modify even outside of the software.

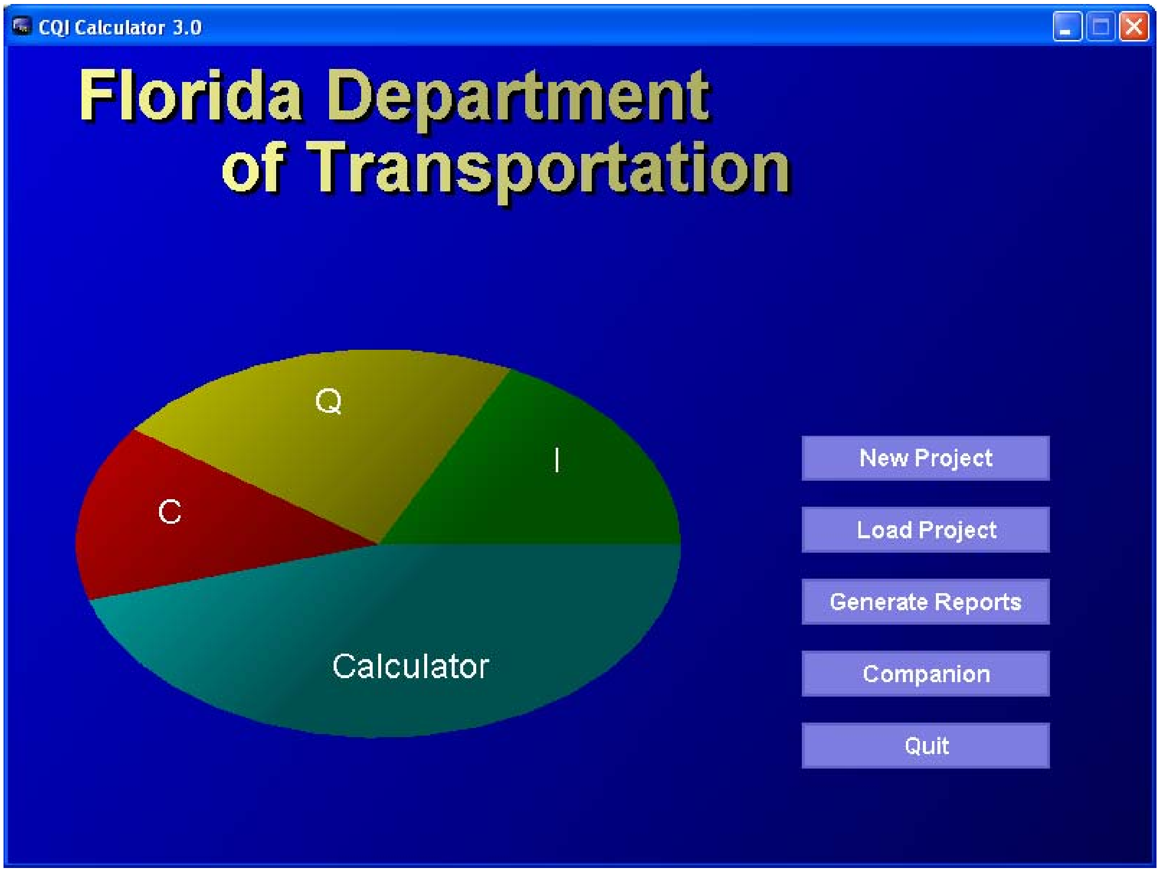
The CQI Calculator runs in a small 800x600 window. Mouse and keyboard support is provided for all screens. Buttons will light up when the mouse is moved over them if they are enabled. Note that some buttons may not always be enabled. Light blue boxes are text fields. Clicking on a text field will place the cursor there and future key presses will be registered in that box. For online help, right-click and hold over any button, text field, or image.

The software saves all work done on a project as data is entered. There is no need to explicitly save a project. The project will be saved as the file name specified in the project's information page. All projects are kept in the "projects" directory in the installation path. They can be safely copied, deleted, or moved from here at any time.

Template files are kept in the "templates" directory in the installation path. These look similar to project files, but without data. They are meant to define the skeleton structure of a particular type of project. These can be edited in the Companion module using the software. Again, files here can be deleted, copied, or moved safely at any time.

Reports generated with the software appear in the "reports" directory. These are simple HTML files, viewable with any web browser. These can also be copied, deleted, or moved any time. When printing a report, it is advisable to select the option of fitting the entire report to one page width.

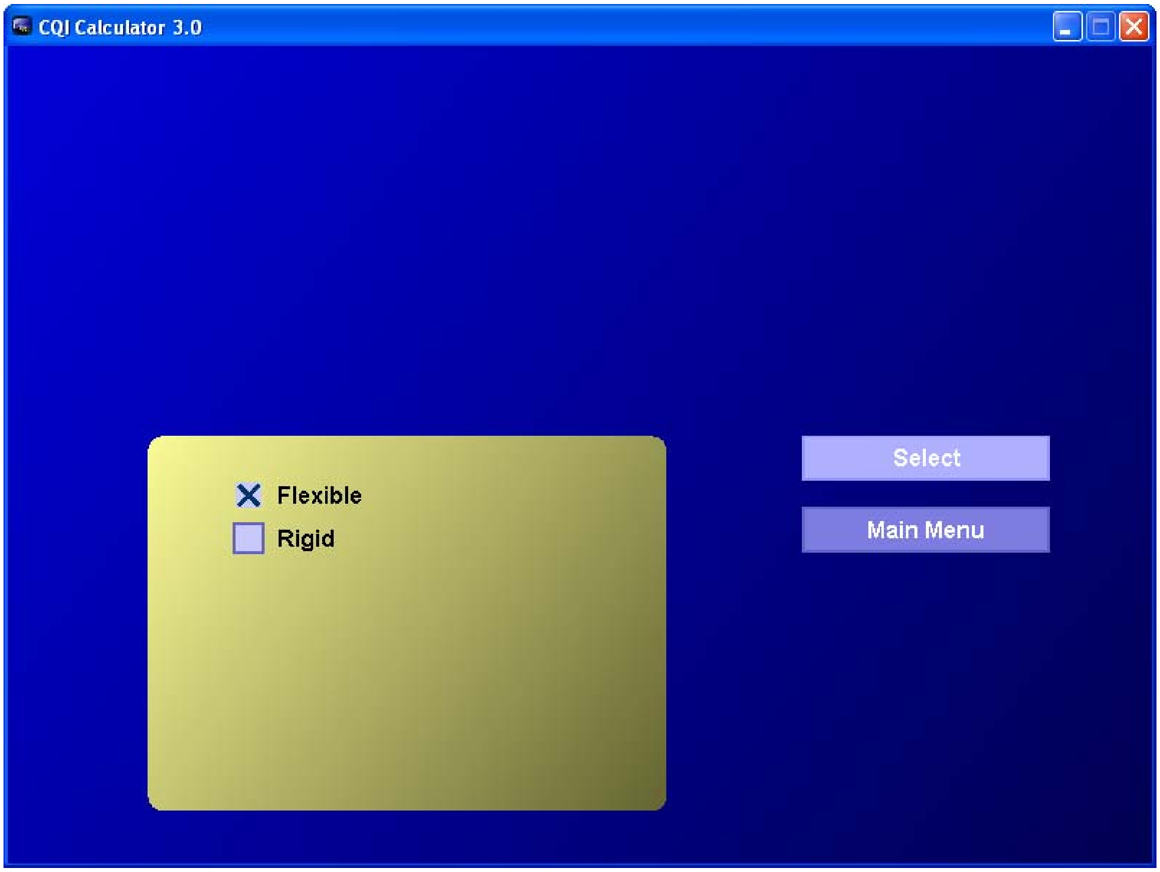
The Main Menu



The main menu will appear as soon as the software is started and provides access to all of the basic functionality the software can perform. Click on the buttons on the right hand side to perform any of these actions:

- Create new projects from existing templates by clicking the "New Project" button.
- Load an existing project by clicking "Load Project".
- The "Generate Reports" button will generate a report for every existing project. This may take some time if there are a lot of projects.
- Press the "Companion" button to create or edit templates.
- The "Quit" button closes the program.

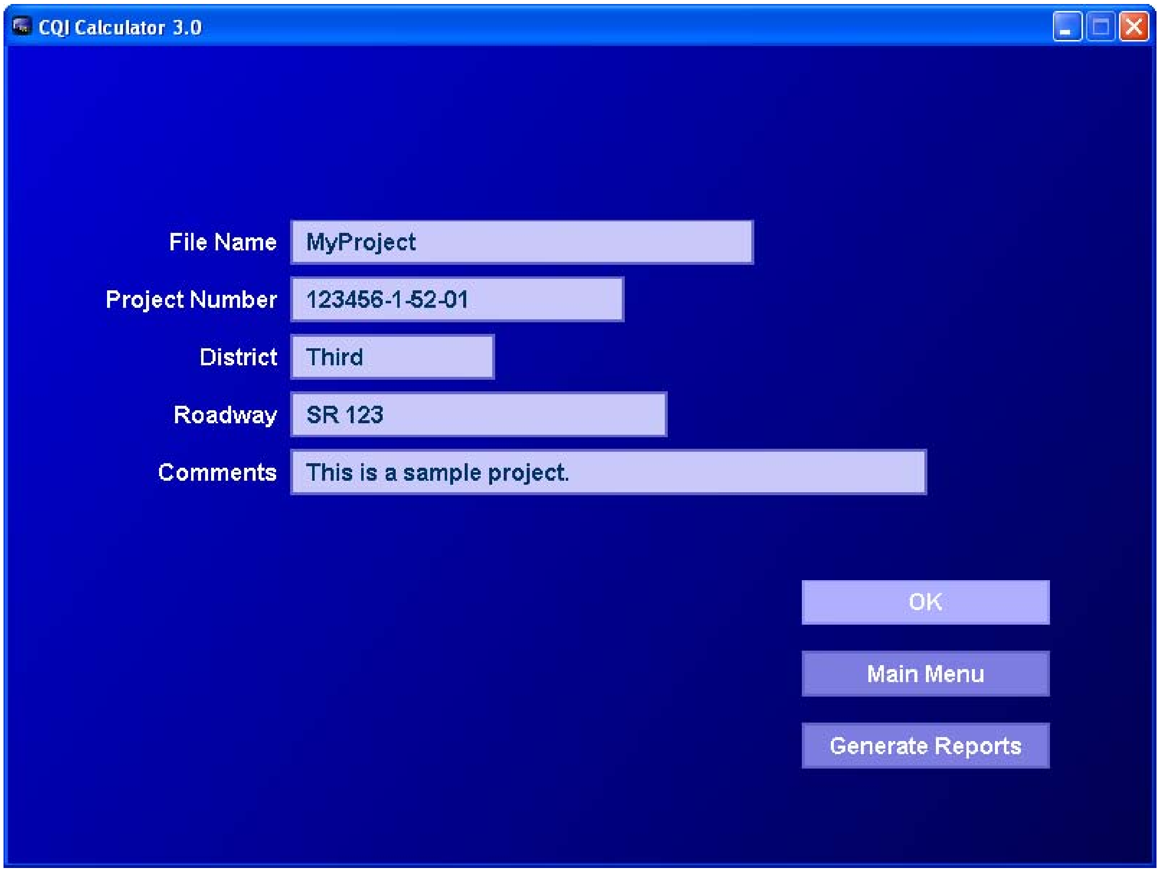
Creating a New Project



Click the "New Project" button at the main menu to arrive here. A small box will appear to the left listing out all existing templates.

- Select a template by clicking on it or in the box next to it and press the "Select" button to create a new project with that template.
- Select "Main Menu" to return you to the main menu.

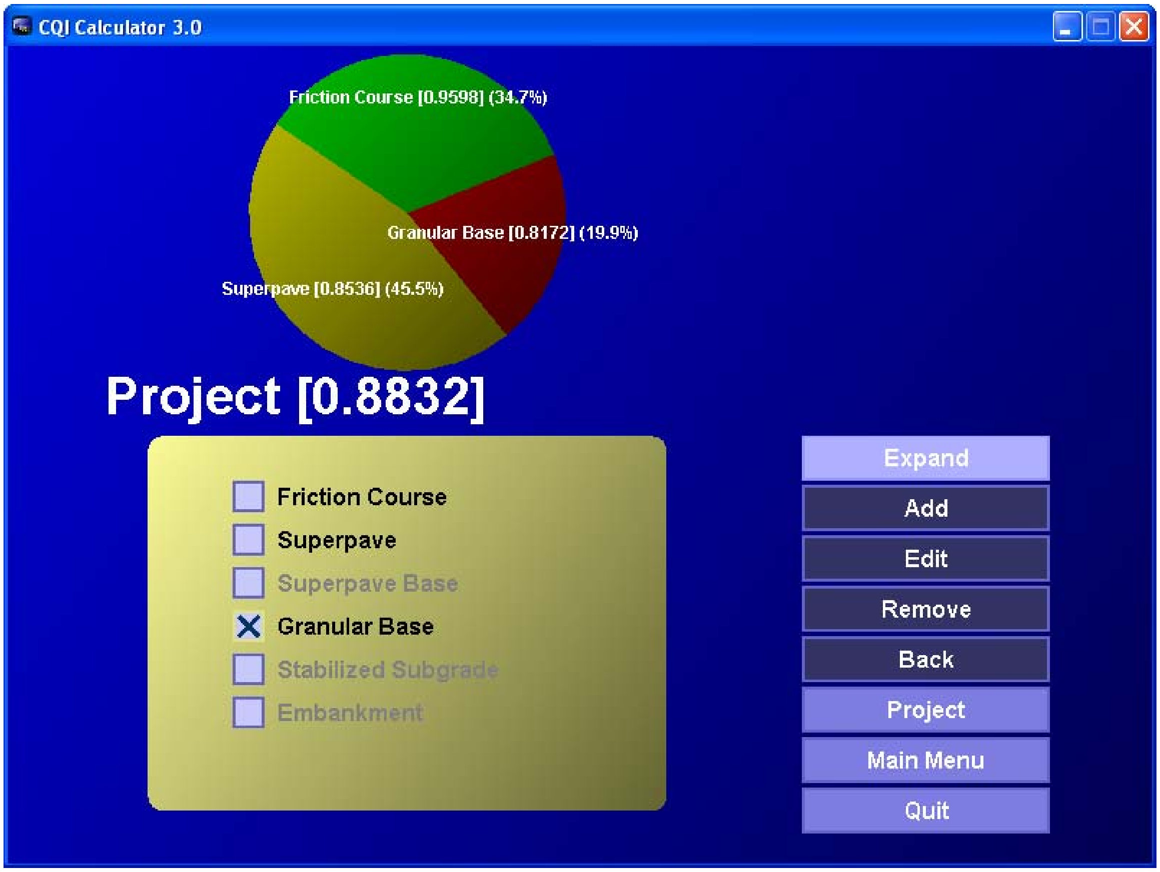
Editing Project Information



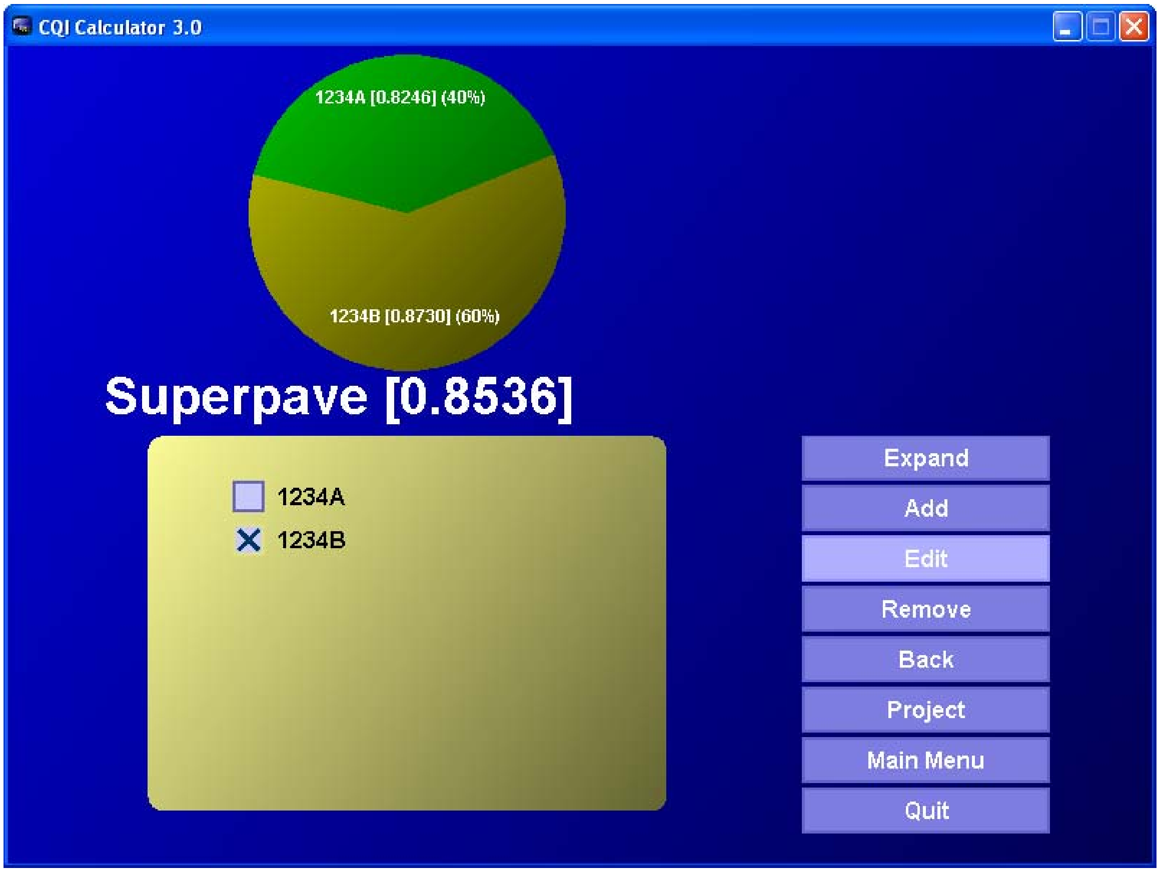
This menu will appear after creating a new project or clicking the “Project” button while editing a project. It allows information about the current project to be changed. Click on any text box to change its contents.

- The “OK” button will resume project editing.
- Select “Main Menu” to return to the main menu.
- “Generate Reports” will generate reports for the current project only.

Navigating Through a Project

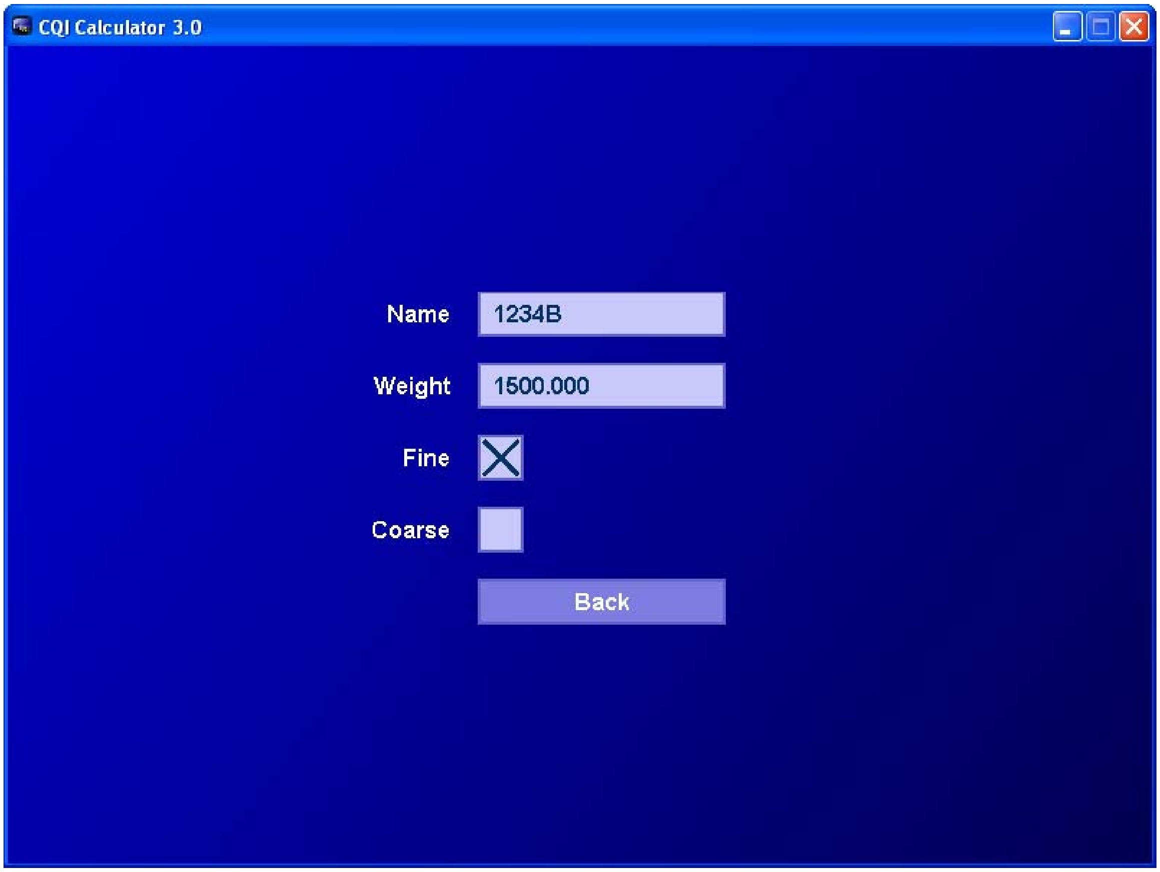


When editing a project, the current layer's sublayers or test types will be shown. The pie chart shows the influence of each sublayer towards the overall CQI value in parenthesis and each sublayer's quality value in brackets. Each sublayer is also listed in a small box on the bottom left of the screen. Sublayers with no data (or not enough data to perform a percent within limits calculation) are grayed out, but can still be selected and edited.



- Select a sublayer and click “Expand” to edit that sublayer’s data.
- Click “Add” to add a customizable sublayer if it is supported by the current layer. The button will be disabled (dark) if the current layer does not support customization.
- Select a customizable sublayer and click “Edit” to edit that sublayer’s information. The button will remain disabled if the current layer does not support customization.
- Select a customizable sublayer and click “Remove” to remove that sublayer. The button will remain disabled if the current layer does not support customization.
- Click the “Back” button to go up one level in the project. This button will be disabled if the current layer is the highest layer in the project.
- Click “Project” to edit the current project’s information.
- Click “Main Menu” to return to the main menu.
- Clicking “Quit” will close the program.

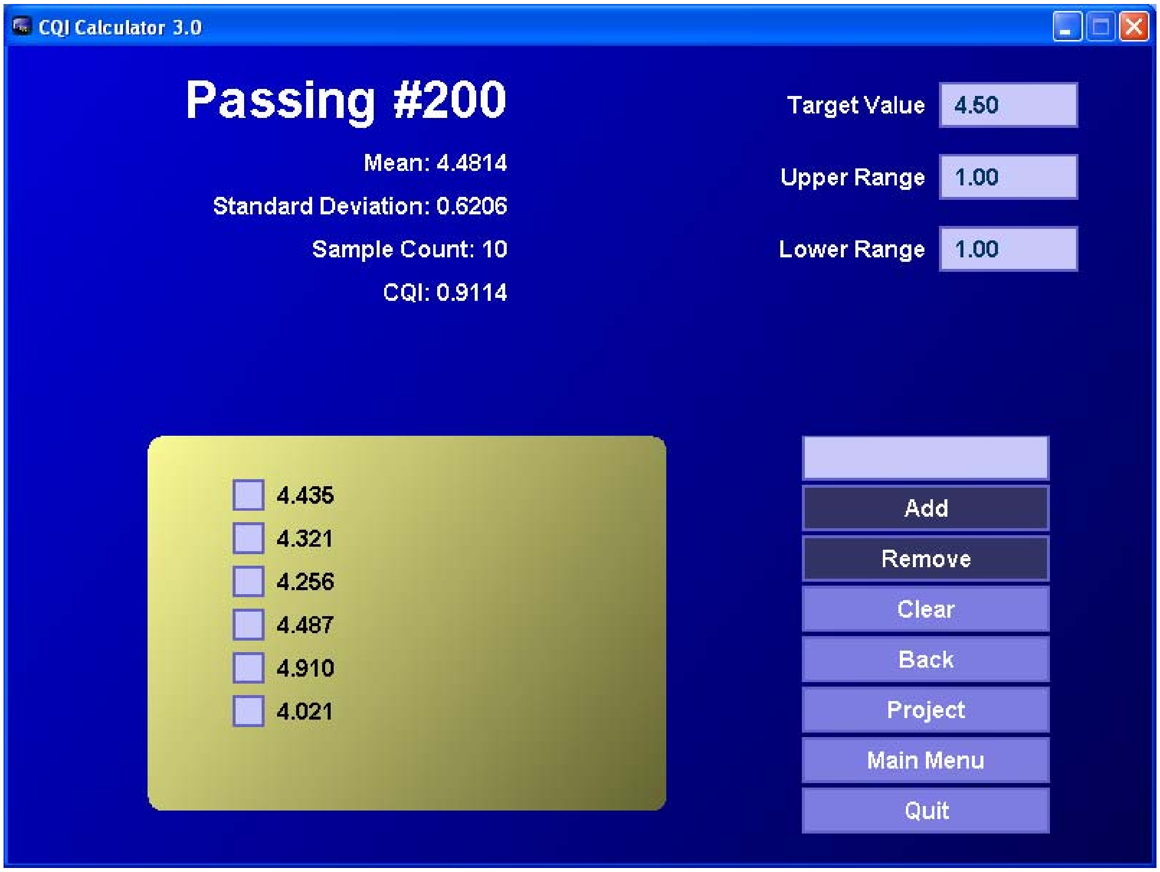
Editing a Customizable Layer



Customizable sublayers can be edited by selecting them and clicking “Edit”. This will allow you to specify how to weigh individual sublayers as well as rename them. Note that some sublayers may be fine or coarse – this selection affects the default target values and ranges for tests in that sublayer.

Click on a text box to change its value. Click “Back” to resume editing the current project.

Editing Test Data



When editing test data, statistical information will be displayed and updated as data is entered. Recall that there must be at least three data points for statistical data to be valid – it will not be displayed otherwise.

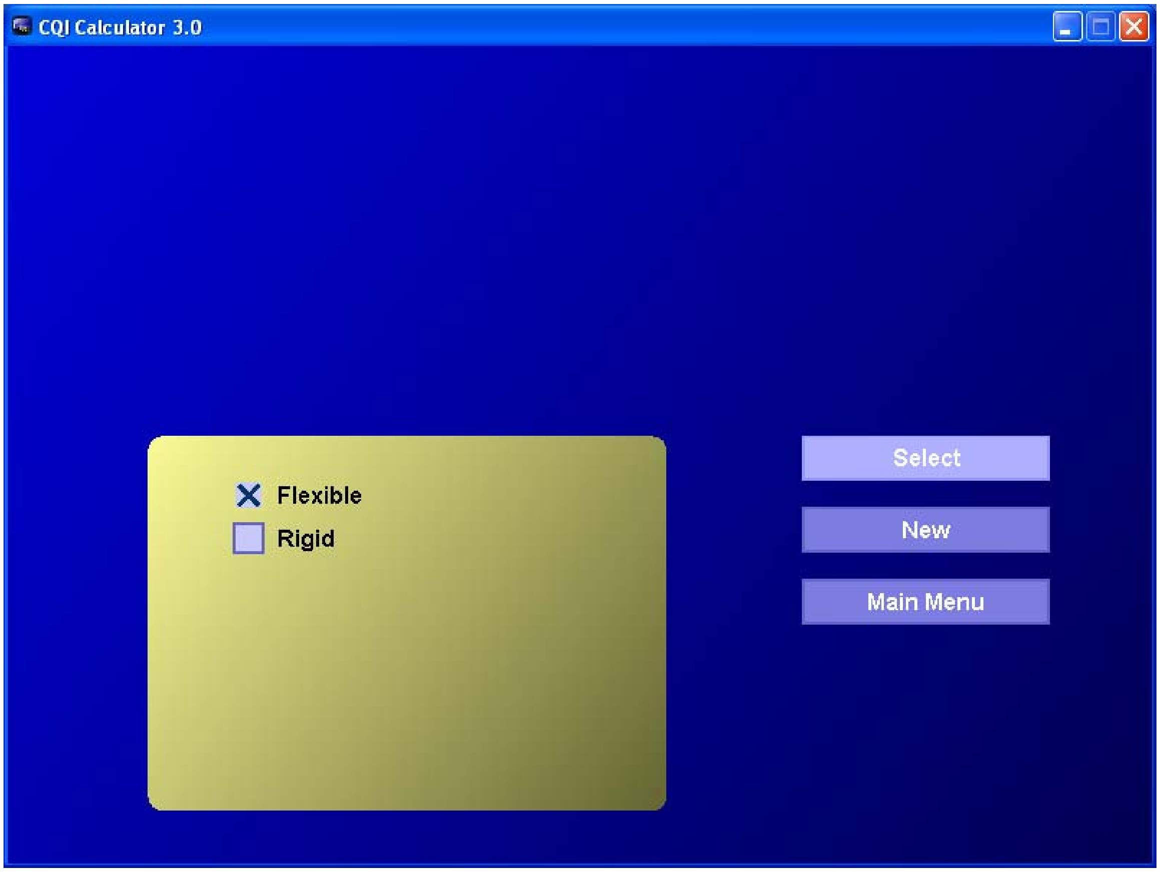
- Select "Add" after entering a data point into the text box to add that data point.
- Select an existing data point and click "Remove" to remove that data point.
- Select "Clear" to remove all data points.
- Select "Back" to go up one level to the parent layer.
- Select "Project" to open the project's information, as it does on other menus.
- "Main Menu" will return you to the main menu.
- "Quit" will close the program completely.

Note that data can also be copied from a project and pasted into a project from this screen. Use Ctrl-C or Ctrl-Ins to copy all data points or Ctrl-V or Shift-Ins to paste data. Pasted data can come from Excel or any tab delimited text and will append itself to existing data. Copied data can be pasted in Excel, any text editor, or another test.

Reading Reports

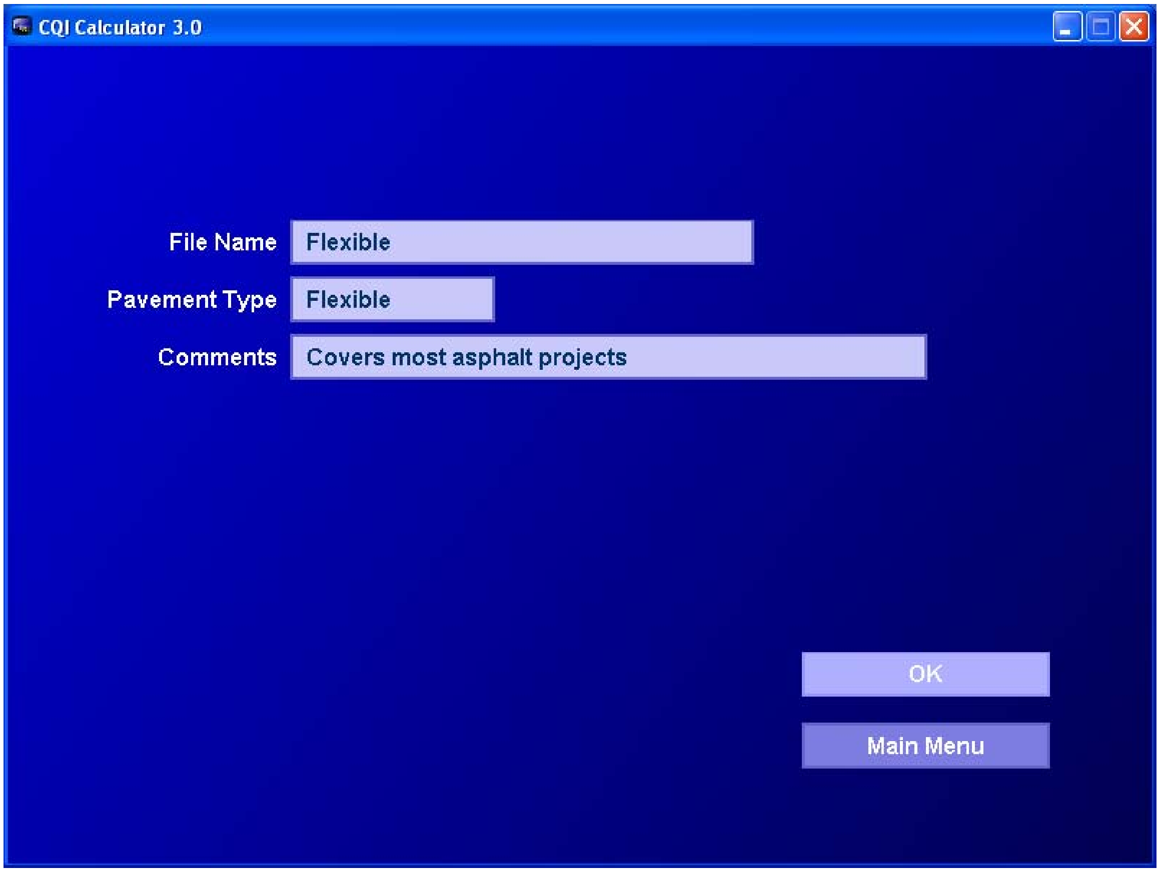
Reports are generated into the "reports" folder in the installation directory. Reports can be viewed using any web browser. Two kinds of reports are generated: a main report named after the project only, and several sub-reports named after the project and extended with "-T#" where # is the layer number. These sub-reports show the details of each main layer in the project. When printing a report, be sure to specify that it should be shrunk to fit horizontally on one single page.

The Companion



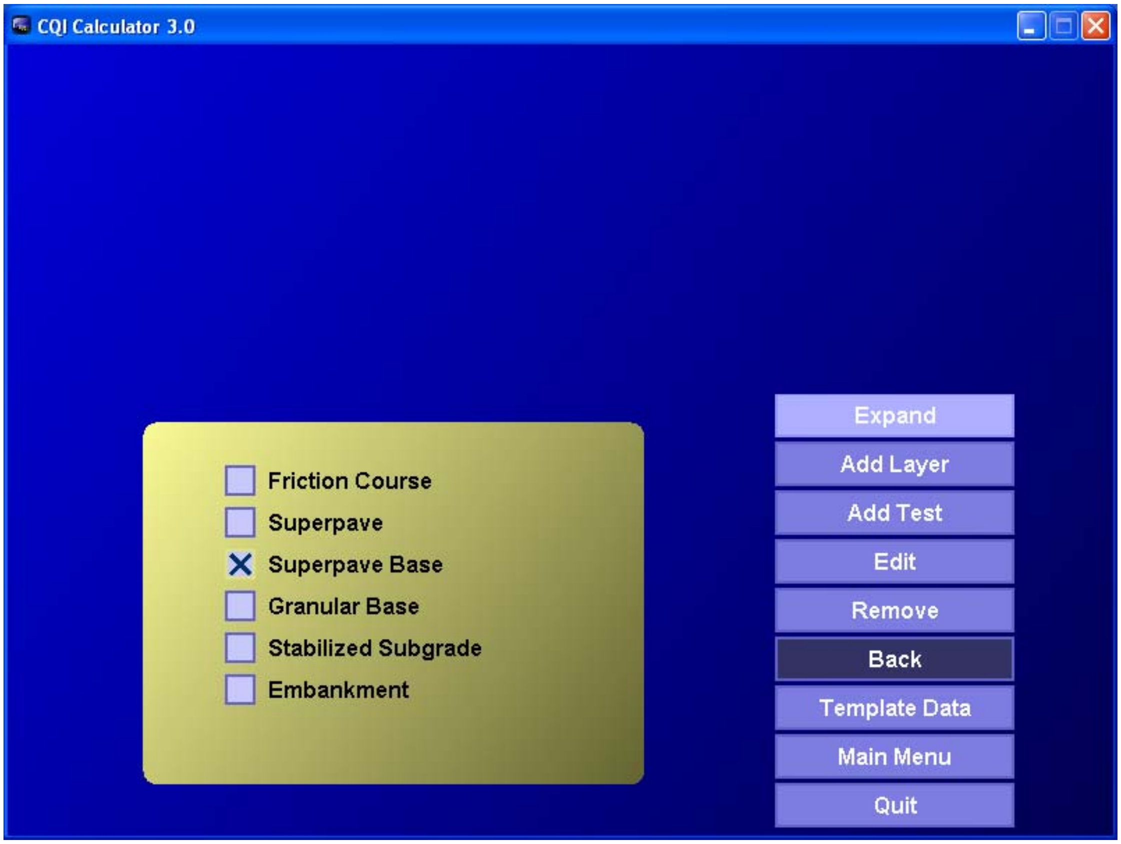
To edit existing templates or to create new templates, use the Companion accessible from the main menu by selecting the "Companion" button. From this menu, you can edit an existing template by selecting it and clicking "Select" or create a new template by pressing "New."

Editing Template Information



Information about the template can be edited here by clicking in a text box and entering the appropriate information. Press "OK" to continue. This menu can be accessed later by clicking "Template Data" while in the Companion.

Editing Template Layers

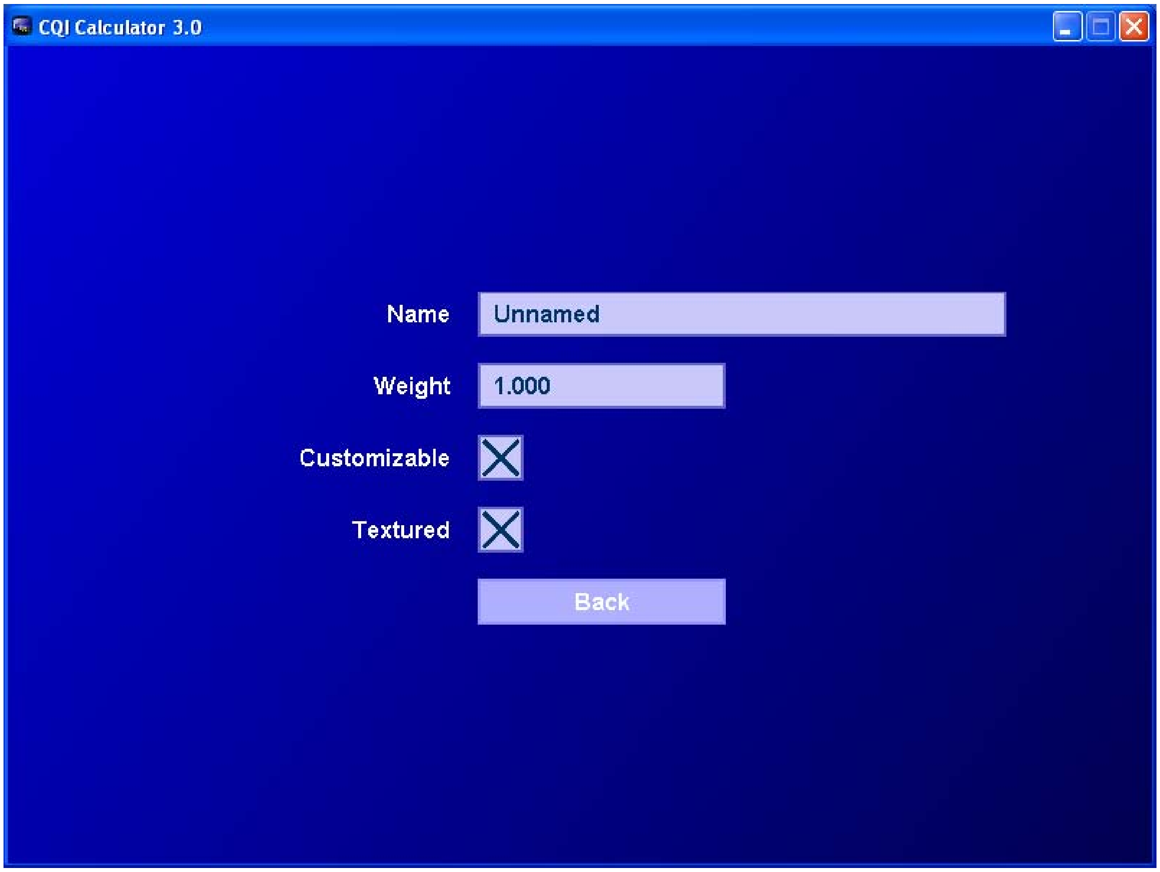


All sublayers are displayed in the scrolling box to the left. To select a sublayer or test, click on it.

- The "Expand" button expands the currently selected sublayer or test. If a sublayer or test is not selected, this will be disabled.
- "Add Layer" adds a sublayer to the current layer. It will appear in the list with the others.
- "Add Test" adds a test to the current layer. It will appear in the list with the others.
- To edit a sublayer or test's information, select it and click "Edit." This will be disabled if no sublayer or test is selected.
- To remove an existing sublayer or test, select it and press "Remove." This will be disabled if a sublayer or test is not selected.
- "Back" will move up one level. This will be disabled if the current layer is the top layer.
- Press "Template Data" to edit the basic information for the current template.
- "Main Menu" returns to the main menu.

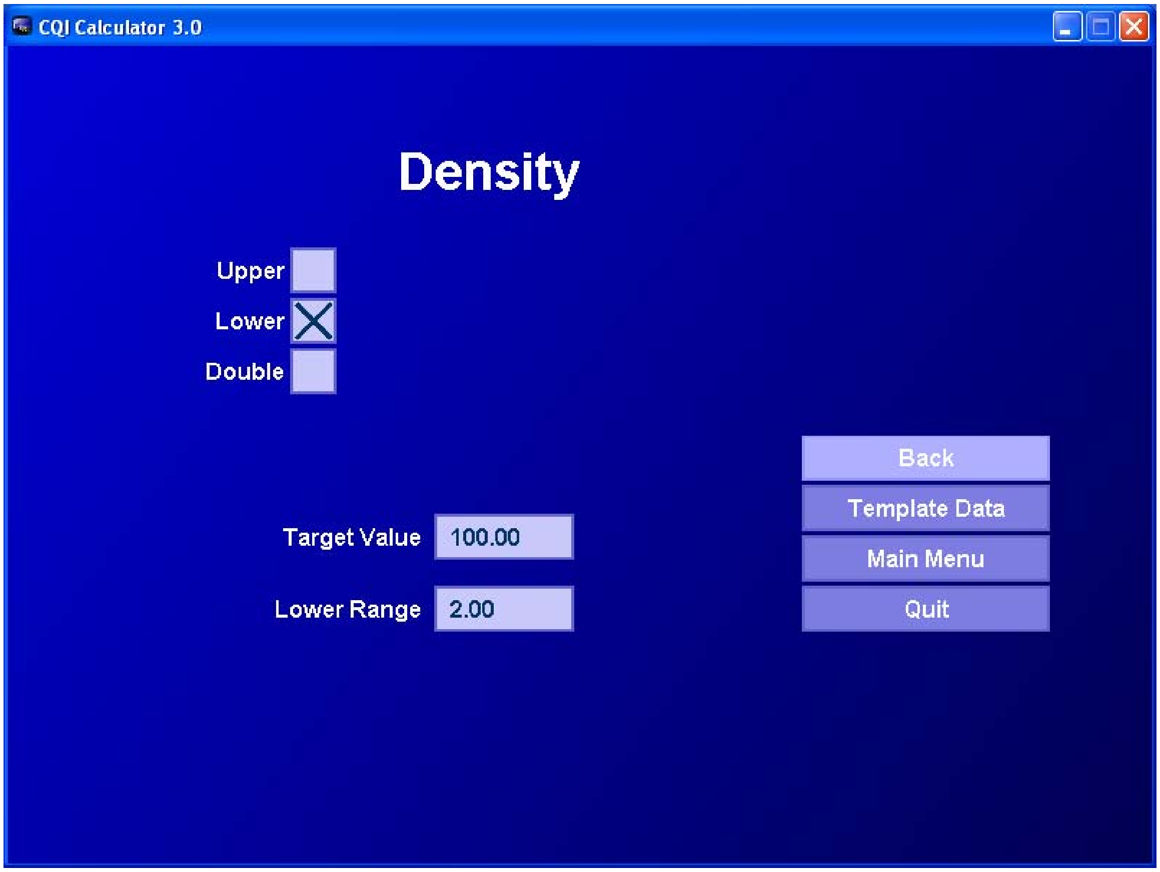
- “Quit” closes the program completely.

Editing Template Sublayers and Tests



To edit a sublayer or test's specific information, select it and click "Edit." You will be able to change its name and base weight, as well as define whether it can be customized (i.e. duplicate copies can be added to the project) and whether the sublayer or test is textured (i.e. it can be "fine" or "Coarse"). Textured sublayers will have their target values adjusted based on their texture automatically. To change an option, click on the text box and type or click the check box to toggle it.

Editing Template Test Characteristics



When a test is expanded, you will be able to edit its characteristics. This includes the type of limit to use ("Upper", "Lower", or "Double") and its target value and range(s). note that the selection of ranges varies based on the type of limit. To change a target value or range, click on the text box and type in the new value. To change the limit type, click the check box next to the appropriate type.

Example Project Reports

Project Number: 231921-1
Pavement Type: Flexible
District: 4
Road: SR 9 / I-95
Comments: Hardrives / Poor Project

	Quality	Weight	Contribution
Superpave:	0.8989	0.5755	0.5174
Granular Base:	0.9581	0.2518	0.2413
Stabilized Subgrade:	0.7363	0.1065	0.0784
Embankment:	0.5409	0.0662	0.0358
Overall CQI:			0.8728

CQI Breakdown:

Layer:	Samples:	Target:	Average:	StdDev:	Quality:	Corrected Weight:	CQI Contribution:
Superpave					0.8989	0.5755	0.5174
4363A					0.8981	0.9194	0.8256
Passing #8	101	38.0000	36.4861	1.6831	0.8207	0.0890	0.0730
Passing #200	100	3.6000	3.5693	0.4592	0.9713	0.0890	0.0864
Air Voids	96	4.0000	3.3999	0.6805	0.8757	0.2690	0.2356
Asphalt Content	96	6.1000	5.9894	0.1928	0.9264	0.2370	0.2195
Density	74	94.5000	94.3854	0.7924	0.8970	0.3160	0.2835
2929A					0.9091	0.0806	0.0733
Passing #8	7	44.0000	45.0100	0.8169	1.0000	0.0890	0.0890
Passing #200	7	3.6000	3.8500	0.1818	1.0000	0.0890	0.0890
Air Voids	7	4.0000	4.1629	0.5793	0.9823	0.2690	0.2642
Asphalt Content	7	6.0000	6.0214	0.1279	1.0000	0.2370	0.2370
Density	6	93.0000	92.9200	1.4056	0.7273	0.3160	0.2298
Granular Base					0.9581	0.2518	0.2413
Density	223	98.0000	100.9417	1.7009	0.9581	1.0000	0.9581
Stabilized Subgrade					0.7363	0.1065	0.0784
Density	198	100.0000	100.5556	1.9103	0.6136	0.6170	0.3786
LBR	49	40.0000	73.3469	22.3705	0.9338	0.3830	0.3577
Embankment					0.5409	0.0662	0.0358
Density	522	100.0000	100.3410	3.3161	0.5409	1.0000	0.5409

Project Number: 220442-5
Pavement Type: Flexible
District: 3
Road: SR 87
Comments: Anderson Columbia / Poor

	Quality	Weight	Contribution
Friction Course:	0.7718	0.3050	0.2354
Superpave:	0.8850	0.4000	0.3540
Superpave Base:	0.9065	0.1750	0.1586
Stabilized Subgrade:	0.8501	0.0740	0.0629
Embankment:	0.6003	0.0460	0.0276
Overall CQI:			0.8386

CQI Breakdown:

Layer:	Samples:	Target:	Average:	StdDev:	Quality:	Corrected Weight:	CQI Contribution:
Friction Course					0.7718	0.3050	0.2354
FC5					0.7529	0.5000	0.3765
3664C					0.7529	1.0000	0.7529
Passing 3/8"	19	68.0000	68.7674	5.4302	0.7262	0.1510	0.1096
Passing #4	19	23.0000	22.2484	3.3194	0.8188	0.1070	0.0876
Passing #8	19	8.0000	9.5947	0.9561	0.8267	0.0960	0.0794
Asphalt Content	19	5.9000	5.7926	0.3888	0.7375	0.3330	0.2456
Ride Number					0.7371	0.3130	0.2307
NB&SB	71	5.0000	4.0803	0.1272	0.7371	1.0000	0.7371
FC12.5					0.7907	0.5000	0.3954
3849A					0.6856	0.2941	0.2016
Passing #8	8	42.0000	40.0800	1.2057	0.8347	0.0730	0.0609
Passing #200	8	5.2000	4.5200	0.2375	0.9179	0.0730	0.0670
Air Voids	8	4.0000	5.2788	0.3537	0.4158	0.2410	0.1002
Asphalt Content	8	4.7000	4.8150	0.1159	1.0000	0.2000	0.2000
Density	7	93.0000	91.8000	0.8298	0.5000	0.1980	0.0990
Ride Number					0.7371	0.2150	0.1585
NB&SB	71	5.0000	4.0803	0.1272	0.7371	1.0000	0.7371
3849B					0.8345	0.7059	0.5891
Passing #8	12	42.0000	40.5892	2.0878	0.7782	0.0730	0.0568
Passing #200	12	5.2000	5.0275	0.3603	0.9928	0.0730	0.0725
Air Voids	12	4.0000	4.2458	0.4368	0.9913	0.2410	0.2389
Asphalt Content	12	5.0000	4.9417	0.1974	0.9592	0.2000	0.1918
Density	11	93.0000	91.9955	0.8579	0.5859	0.1980	0.1160
Ride Number					0.7371	0.2150	0.1585
NB&SB	71	5.0000	4.0803	0.1272	0.7371	1.0000	0.7371

Superpave					0.8850	0.4000	0.3540
3440A					0.9396	0.2270	0.2132
Passing #8	45	47.0000	46.3264	2.0183	0.8577	0.0890	0.0763
Passing #200	45	3.8000	3.6582	0.3229	0.9931	0.0890	0.0884
Air Voids	45	4.0000	4.1556	0.5712	0.9591	0.2690	0.2580
Asphalt Content	45	5.0000	5.0722	0.2283	0.9083	0.2370	0.2153
Density	16	93.0000	93.0494	0.7468	0.9545	0.3160	0.3016
3783A					0.8742	0.2057	0.1798
Passing #8	39	41.0000	42.9172	1.3118	0.8154	0.0890	0.0726
Passing #200	39	3.6000	3.6715	0.4101	0.9828	0.0890	0.0875
Air Voids	39	4.0000	3.7895	0.4855	0.9762	0.2690	0.2626
Asphalt Content	39	5.3000	5.2374	0.2486	0.8846	0.2370	0.2096
Density	31	93.0000	92.5848	1.0346	0.7656	0.3160	0.2419
3976A					0.8260	0.0142	0.0117
Passing #8	4	45.0000	45.6675	1.8000	0.9505	0.0890	0.0846
Passing #200	4	3.5000	4.3150	0.1907	0.8234	0.0890	0.0733
Air Voids	4	4.0000	3.7875	0.6285	1.0000	0.2690	0.2690
Asphalt Content	4	5.3000	4.8050	0.2121	0.3507	0.2370	0.0831
Density	4	93.0000	93.3375	0.7041	1.0000	0.3160	0.3160
4005A					0.8236	0.0355	0.0292
Passing #8	7	48.0000	47.0243	1.8247	0.8810	0.0890	0.0784
Passing #200	7	3.9000	4.1000	0.6058	0.9068	0.0890	0.0807
Air Voids	7	4.0000	3.7957	0.5041	0.9925	0.2690	0.2670
Asphalt Content	7	5.1000	5.2143	0.1872	0.9509	0.2370	0.2254
Density	7	93.0000	94.9100	0.7523	0.5448	0.3160	0.1722
4227A					0.8679	0.0567	0.0492
Passing #8	13	50.0000	48.8408	1.8000	0.8533	0.0890	0.0759
Passing #200	13	4.0000	3.8131	0.4535	0.9688	0.0890	0.0862
Air Voids	13	4.0000	4.3715	0.5694	0.9316	0.2690	0.2506
Asphalt Content	13	5.2000	5.0346	0.1054	0.9918	0.2370	0.2351
Density	12	93.0000	93.1508	1.5339	0.6965	0.3160	0.2201
4298A					1.0000	0.0142	0.0142
Passing #8	3	53.0000	53.9867	1.7044	1.0000	0.1301	0.1301
Passing #200	3	4.5000	4.1633	0.2875	1.0000	0.1301	0.1301
Air Voids	3	4.0000	3.9267	0.1856	1.0000	0.3933	0.3933
Asphalt Content	3	5.5000	5.5500	0.1136	1.0000	0.3465	0.3465
Density	0	N/A	N/A	N/A	N/A	N/A	N/A
4393B					0.8783	0.0426	0.0374
Passing #8	10	52.0000	53.0310	3.4521	0.6064	0.0890	0.0540
Passing #200	10	5.0000	4.7800	0.6617	0.8608	0.0890	0.0766
Air Voids	10	4.0000	4.2960	0.4479	0.9888	0.2690	0.2660
Asphalt Content	10	5.5000	5.4590	0.1737	0.9886	0.2370	0.2343
Density	9	93.0000	92.7178	1.1093	0.7829	0.3160	0.2474
4473A					0.9515	0.0496	0.0472
Passing #8	30	45.0000	43.8710	1.9915	0.8232	0.0890	0.0733
Passing #200	30	4.5000	4.9247	0.2788	0.9832	0.0890	0.0875
Air Voids	30	4.0000	3.8307	0.6126	0.9471	0.2690	0.2548
Asphalt Content	30	4.8000	4.7570	0.1693	0.9786	0.2370	0.2319
Density	19	93.0000	93.0947	0.7251	0.9622	0.3160	0.3040
4981A					0.8616	0.2411	0.2078
Passing #8	50	46.0000	47.5304	1.7806	0.8030	0.0890	0.0715
Passing #200	50	5.0000	4.8694	0.3562	0.9886	0.0890	0.0880
Air Voids	50	4.0000	4.2446	0.6765	0.9071	0.2690	0.2440
Asphalt Content	50	5.3000	5.2224	0.1590	0.9765	0.2370	0.2314
Density	24	93.0000	94.2150	1.2248	0.7175	0.3160	0.2267
5003A					0.8336	0.1064	0.0887
Passing #8	21	41.0000	41.5319	2.3440	0.8072	0.0890	0.0718
Passing #200	21	6.4000	5.8990	0.4459	0.8698	0.0890	0.0774
Air Voids	21	4.0000	4.1438	0.8264	0.8531	0.2690	0.2295
Asphalt Content	21	5.7000	5.6081	0.1663	0.9704	0.2370	0.2300
Density	15	93.0000	93.1847	1.4912	0.7116	0.3160	0.2249
5568A					0.9203	0.0071	0.0065
Passing #8	3	51.0000	50.3067	1.1082	1.0000	0.1301	0.1301
Passing #200	3	5.8000	4.7200	0.1997	0.3874	0.1301	0.0504
Air Voids	3	4.0000	4.4967	0.3372	1.0000	0.3933	0.3933
Asphalt Content	3	5.8000	5.8267	0.1124	1.0000	0.3465	0.3465
Density	0	N/A	N/A	N/A	N/A	N/A	N/A
Superpave Base					0.9065	0.1750	0.1586
Passing #8	28	53.0000	53.2575	1.9029	0.8994	0.0890	0.0800
Passing #200	28	4.7000	4.3068	0.3004	0.9813	0.0890	0.0873
Air Voids	28	4.0000	4.4864	0.6682	0.8496	0.2690	0.2285
Asphalt Content	28	5.2000	5.2068	0.2157	0.9429	0.2370	0.2235
Density	10	93.0000	93.1860	0.9753	0.9085	0.3160	0.2871
Stabilized Subgrade					0.8501	0.0740	0.0629
Density	32	98.0000	99.1562	1.4393	0.7878	0.6170	0.4861
LBR	151	40.0000	88.1457	32.5046	0.9505	0.3830	0.3640
Embankment					0.6003	0.0460	0.0276
Density	686	100.0000	100.4825	1.9238	0.6003	1.0000	0.6003