FINAL REPORT

Cost and Quality Effectiveness of Material and Non-Material Models in Contractor Quality Control (CQC) System

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16. Abstract

The Florida Department of Transportation utilizes two verification testing models in Contractor Quality Control (CQC) system; the Material and non-Material Models. The basic difference between the two models is that, under the Material Model, the verification testing of CQC is outsourced and conducted by external material consultants/verification technicians. The main objectives of this study are to (1) collect available data about the Material and non-Material Models; (2) analyze the quality performance of both models; (3) perform a risk analysis study on the non-detection of failing materials; and (4) conduct a cost analysis study to compare the overall costs involved in both models. The analysis shows that the application of the Material Model system results in the same level of quality associated with the non-Material Model. The two models also appeared to have comparable levels of low risk. Although the cost analysis shows there are some cost savings if the Material Model is to be used, the cost comparison is not conclusive due to the unavailability of detailed cost breakdown data for the districts representing the non-Material Model.

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Executive Summary

The Florida Department of Transportation (FDOT) currently utilizes two Verification Testing (VT) models in Contractor Quality Control (CQC) system, namely, the Material and non-Material Models. The basic difference between the two models is that under the Material Model verification testing of CQC is delegated to external VT technicians or material consultants. Under the non-Material Model, the Construction Engineering Inspection (CEI) team is responsible for testing field materials. The goals of the study are summarized as follows:

(1) Collect available data about the Material and non-Material Models;
(2) Analyze the overall performance of both models;
(3) Perform a risk analysis study on the non-detection of failing materials;
(4) Conduct a cost analysis study to compare between the two models in terms of the overall involved costs.

The methodology used to conduct this study includes collecting data from all available FDOT resources; surveying districts about the characteristics of the two models; utilizing a variety of quality parameters to compare the quality of the two models; identifying possible risk sources for material failures; and using Activity Based Costing (ABC) technique to analyze and compare the costs associated with each model.

The main findings of the study are summarized as follows:

(1) Statewide survey provided anecdotal subjective experience of materials and construction personnel in dealing with materials and non-material models. The survey highlighted differences (advantages or otherwise) between the two models.
(2) Quality Indicators formulated in this study are related to the testing indexes (ratios of independent verification, verification and QC tests) and the long-term performance indexes (asphalt Crack, Ride, Rutting, and MRP Ratings).

    a. Testing Parameters formulated are IV/V and QC/V indexes. These were calculated for field and lab material testing from the data available in the LIMS. The LIMS has no significant data before 2004 to analyze and consequently, the analysis was limited to 2004 to 2008. Many of the indexes were statistically insignificant while few were significant and occurred in both models and no definitive conclusion can be drawn about the model preference.
    b. Performance Indexes for Crack, Ride, Rutting, Pavement Condition (PCR) and MRP data (both roadway and roadside): These data were analyzed from 2000 to 2008. The analysis indicated that there are no statistically significant differences in all these categories between the Materials Model and Non-Material Models. (During 2000 to 2003, within D-2, the analysis showed that two parameters were better in Material Model and one in Non-Material Model and as such not definitive enough to conclude any model preference).

(3) Five risk factors were identified by the District construction and material personnel to have medium severity impact on quality.

These factors are:

i. Biased collection of good samples.
ii. Collection of specimens not meeting specifications.
iii. Use of faulty testing equipment.
iv. Inadequate maintenance of testing equipment.
v. Testing materials not according to the standards.

Other identified risk factors were rated to have low severity impact on the cost, quality, and time of completing construction activities.

(4) Cost analysis:

The original cost analysis methodology intended to compare the two models according to the breakdown of the cost for testing and sampling of materials from the two sampled Districts. This cost was to include personnel and overhead expenses for CEI and in-house personnel. As the research began, District-2 was able to provide a detailed breakdown of their expenses due to the availability of resident offices that were capable of distinguishing between the types of cost. On the other hand, District-5 was not able to provide a detailed breakdown of their cost due to their adoption of a different operations structure in which many of the district operation facilities were consolidated under the same budget entity. As such, it is impossible at this time for D-5 to distinguish the differences in cost and provide their data in a form similar to that provided by D-2. This lead to the adoption of a cost analysis methodology that depended on estimating testing and sampling costs for an example project under each of the two models. The adopted cost analysis approach showed there are some cost savings if the Material Model is to be used. However, the FDOT does not consider this result conclusive due to the inability to obtain the same type of data for the two districts.

The main outcomes of the study are summarized in the following points:

(1) The Material and non-Material Models systems offer quality levels that are comparable. No definitive conclusion as to the preference of model based on quality can be drawn.
(2) The two models have comparable levels of low risk.
(3) The study concludes that the application of the Material Model should have no negative effects on the quality of construction and should not increase the level of risk involved in FDOT projects. The Material Model holds these characteristics as long as CEIs are able to interpret test results, VT technicians continue to obtain certification, and there is no conflict of interest between material consultants and the verified contractor.

Based on these conclusions, the research team recommends the following:

1. The Department should continuously monitor the aforementioned five risk factors. This is necessary in order to allow for effective intervention in case any of these factors materialize during testing and verification.
2. Maintain data on the comparison of the Quality Indicators between both models.
3. Develop tools to obtain actual cost of testing during construction for the non-Material Model testing. As this tool becomes available and with more data on the Quality Indicators in hand, the Department can judge the preference of one model to another.

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Chapter One: Introduction

1.1 Background

The Florida Department of Transportation (FDOT) currently utilizes two testing procedures in Contractor Quality Control (CQC) system. These are: (1) the Material Model and (2) the non-Material Model systems.

The Material Model system is a testing procedure that was introduced in 2004 by District 2. District 2 is currently adopting this model in which the District Materials Office (DMO) is responsible for all materials verification sampling and testing (field and lab). These services are provided by DMO consultants (also known as in-house consultants) on an on-call basis. Under the Material Model, in-house consultants are responsible for verifying CQC, including (1) conducting sampling; (2) on-site testing of concrete, embankment, base, pipe backfill, wall backfill, top soil, and asphalt paving; (3) maintaining log books; (4) entering data into the Laboratory Information Management System (LIMS); (5) testing asphalt plants; (6) performing lab testing on materials; and (7) coordinating with asphalt plants.

The non-Material Model is a testing procedure in which the Construction Engineering Inspection (CEI) team is responsible for verifying CQC. Under the non-Material Model, CEI team is responsible for performing all the above-mentioned activities except for asphalt plant testing and lab testing which are performed by material consultants.

FDOT districts vary in the way they verify contractors. For example, District 2 is currently the only district applying the Material Model on a large scale. Districts 4, 6, and the Turnpike (TP) did some piloted projects on applying the Material Model. The TP reported some reduction in costs using the Material Model on some piloted projects. Districts 1, 3, 5, and 7 have not tried yet to apply the Material Model.

The main objectives and expected benefits of implementing the Material Model system are to (1) reduce the costs of testing and inspection; (2) enhance quality by relieving CEI to focus on inspection and administration. With these anticipated benefits, there are also some doubts about CEI losing important testing experience under the Material Model system.

As such, there is a need for a focused research study to investigate all the issues related to the new material Model system and compare its performance to the traditional non-Material Model system. The purpose of this study is to investigate the cost and quality effectiveness of Material and non-Material Models and to verify the appropriateness of the Material Model for contractor quality control.

1.2 Project Objectives

The objective of this study is to investigate the cost and quality effectiveness of Material and non-Material Models. Specifically this study aims to:

(1) Collect data about Material and non-Material Models from completed projects, projects in progress, FDOT quality control (QC) construction and materials personnel, State Construction Office, State Materials Office, District Construction Offices, District Materials Offices, consultants and contractors.
(2) Analyze the quality performance of Material Model projects against non-Material Model projects of comparable size, nature of the work performed, and types of materials used.
(3) Perform a risk analysis study on the non-detection of failing materials during the construction process in both the Material and non-Material Models.
(4) Conduct a cost analysis study to analyze and compare the overall costs of effort, time and human relations involved in both models.

This report documents the findings of this study.

Chapter Two: Literature Review

In order to clearly identify the basic differences between the Material and non-Material Models, currently used by the FDOT to verify contractors quality control, it deemed necessary to review the FDOT CQC program, the essence of QC versus VT, the roles of FDOT entities in the program, and the procedures followed in both models.

2.1 The FDOT CQC Program

The FDOT CQC program involves a set of procedures that contractors should follow in order to comply with FDOT quality control requirements and be approved for executing FDOT projects. CQC involves two main sets of documents identified as: 1) Quality Control Manual, and 2) Quality Control Plan (FDOT 2008a).

The Quality Control Manual includes the general guidelines of contractor’s quality control procedures adopted in executing work. This manual is submitted to the FDOT so that the contractor can be approved to work on a statewide basis. However, for each project, the contractor is still liable to submit a quality control plan in accordance to the guidelines of the FDOT. The approval of the quality control manual facilitates the approval of the contractor’s quality control plan later, while its rejection makes it hard for the contractor to be approved for his/her quality control procedures plan. The quality control manual may be referenced in the quality control plan to reduce the amount of information submitted for review. On the other hand, the quality control plan is a set of quality control procedures specific to a certain project. Usually the contractor’s quality control plan is prepared from the quality control manual. The quality control plan is submitted to the FDOT, which forwards it to the designated district for review and approval. Rejection of the quality control plan may lead to the rejection of the contractor (FDOT 2008a).

The quality control plan includes the specific procedures for inspection, sampling and testing carried out by the contractor in order to assess and adjust construction processes to achieve a defined level of quality. The FDOT, as part of its responsibilities under the Quality Assurance (QA) program, has technicians and inspectors who are responsible for monitoring, sampling, testing and inspecting contractor’s QC. The QA program also requires contractor personnel and laboratories to be qualified / certified in the same manner as the DOT personnel and laboratories. This is intended to provide confidence that all QC personnel are capable of performing their duties properly (FDOT 2008b). In general, FDOT uses sampling and testing to measure the effectiveness of the QC plan and the degree of compliance with the project documents. The Department designates various personnel to perform these tasks of verifying contractor’s quality control process. In summary, QC is used to control construction processes, while verification testing is used to verify the QC Results.

2.2 Purpose of CQC Program

The purpose of the CQC program is to ensure that contractors and producers have quality control and process control measures in place prior to producing and placing materials on the Department's projects. The Department has the option to use CQC test results as part of the acceptance program. Because the Department elected to use the CQC option, additional requirements had to be developed. These include Department VT and a resolution system when QC and verification do not compare" (FDOT 2008c).

The Department must provide the Federal Highway Administration (FHWA) with a final project materials certification certifying that *"the results of the tests used in the acceptance program indicate that the materials incorporated in the construction work, and the construction operations controlled by sampling and testing, were in conformity with the approved plans and specifications."* It must also list any exceptions to the certification" (FDOT 2008c).

2.3 Differences between the Material and non-Material Models

To highlight the differences between the two models, it was essential to understand the process of work inspection and material testing in an FDOT project. After the submittal of the CQC plan and its approval by the district, the contractor starts executing the project. In the designated district at which the project is executed, there are a number of entities responsible for supervising the work done, and assuring its quality. These entities are: the District Construction Office, the District Materials Office, the consultant CEI, the project administrator, and the senior inspector.

The District Construction Office carries out the task of reviewing the contractor's proposed quality control plan. The construction office is concerned with field inspection of the work completed and the compliance of the contractor with the quality control plan. At a time, the construction office might hire a consultant CEI to undertake the inspection/testing of work. The consultant acts in accordance to a predefined procedures set by FDOT (FDOT 2008c).

The District Materials Office is concerned with the acceptance program. This program is designed to ensure that the materials used on FDOT projects meet the required specifications. The acceptance program is made of the following components: Laboratory Qualification Program (LQP), Personnel Qualification Program (PQP), Sampling Testing and Reporting Guide (STRG), Quality Control Program, and Final Project Materials Certification (FDOT 2008c).

The LQP qualifies the laboratories selected for testing the material, while the PQP qualifies the personnel involved in the material acceptance process. There are a set of courses offered by University of Florida for training and qualifying personnel on quality control testing. In addition, there is the Sampling Testing and Reporting Guide (STRG) that defines the responsibilities of personnel who are involved in the sampling and testing of materials that are incorporated into construction. It provides the frequency for sampling and testing, identification of the specific location in the construction or production operation at which sampling and testing is to be accomplished, and identification of the specific attributes to be inspected which reflect the quality of the finished product as required to satisfy the acceptance program (FDOT 2008c).

The consultant CEI is responsible for all testing as required by the job guide schedule. On the other hand, the project administrator is responsible for ensuring that the contractor builds the project in accordance with the plans and specifications. Senior Inspector is responsible for ensuring that the contractor builds the project in accordance with the plans and specifications and that all testing requirements are adhered to in the field. Moreover, the senior inspector should monitor lower level technicians to ensure that they are following the required test methods and testing in accordance with the job guide schedule and specifications (FDOT 2008c).

As such, the basic difference between the Material and non-Material Models relies mainly in the verification of contactor's QC testing. In the Material Model, the verification of the contractor's QC testing is conducted by DMO consultant qualified VT technicians, while in the non-Material Model the CEI team verifies the contractor's QC testing. The Turnpike Enterprise conducted a pilot study to compare between the Material and non-Material Models. The pilot project was the Western Beltway (SR 429). The study concluded that the projected cost for sampling and testing under the Material Model would be 2% less than that under the non-Material Model (See Appendix H).

2.4 Recent CQC and VT Studies

Several studies were conducted to investigate the characteristics of CQC and VT procedures. In a recent advisory memorandum, issued by the inspector general, concerns were raised about the results of a survey that intended to review the appropriateness and effectiveness of using the new CQC program (FDOT 2008j). The survey was performed on a population of FDOT personnel and consultants; and the main concerns raised were: (1) the negative responses from several entities about the effectiveness of the CQC program; (2) the controlling influence contractors have over quality control managers' decisions; (3) the inexperience of quality control managers and technicians; (4) the additional responsibility placed on the Department and consultants to provide training; and (5) the need for tougher consequences for non-compliant contractors (see Appendix I). The survey showed that more than 59 % of the FDOT personnel and 69% of the consultants did not observe an improvement in quality since the CQC program was implemented. The survey also showed that 55% of FDOT personnel and 67% of the consultants do not recommend expanding the CQC program to other materials mainly due to the unresolved problems of the current CQC system

(FDOT 2008j). The new CQC specifications has lead to a significant drop in the frequency of material sampling and testing carried out by FDOT. This occurs because FDOT does verification testing of Contractor's QC testing.

Turochy and Parker conducted a study to compare between the results of QC tests performed by contractors, and the state DOTs in Florida, North Carolina, and California for hot-mix asphalt concrete. The study indicated that the differences in results between contractors and DOTs are significant, which proposes reconsidering and restructuring the QA programs of DOTs (Turochy and Parker 2007).

2.5 Other Literature

An important reference that was essential in understanding the QC/QA procedures for FDOT is the FDOT Standard Specifications for Road and Bridge Construction. This document covers a wide variety of materials, their description, testing procedures as well as the FDOT required procedures for work inspection (FDOT 2008d).

In addition, two other important references are the Florida Flexible Pavement Condition Survey Handbook and the Rigid Pavement Condition Survey Handbook (FDOT 2008e, 2008f). These two handbooks are issued by the FDOT State material Office and are used as references for visual, mechanical and automated condition evaluation of flexible and rigid pavements. Moreover, the FDOT publishes the Pavement Management Reports (FDOT 2008g) to report the quality of Florida roadways using various parameters such as cracking, rutting, ride, patching, and raveling. These parameters are used in this study as solid indicators of the quality and performance of contractors finished product.

Chapter Three: Research Methodology

The approach used in this study has three folds. These are (1) data collection, (2) data analysis, and (3) results interpretation and documentation.

3.1 Data Collection

The data collection phase involved several activities including conducting face-to-face and virtual meetings with construction and materials personnel in the field of CQC, surveying construction and materials personnel, collecting cost data, and collecting quality data. The research started with a video conference with FDOT Project Manager, District 2 Construction Engineer, and District 5 Construction Engineer. During this meeting, the research team received valuable input from FDOT regarding the project objectives and approach. The FDOT also clarified the definition of the research objectives. FDOT indicated that the objectives are to include (1) identifying the effect of sampling randomness on the level of risk of non-detecting failing materials in both models; (2) determining if there are any other risk factors involved in the two models; (3) determining if any of the two models is more accurate than the other (e.g. if testing indicates conforming material, what are the chances it might not be the case and vice versa); and (4) Comparing between the two models in terms of the expected costs of sampling and testing. In addition, the Project Manager referred the research team to some important references that were valuable in guiding the team to conduct this research. The references included the Standard Specifications for Road and Bridge Construction (FDOT 2008d), the Construction Project Administration Manual (FDOT 2008a), and the Construction Training Qualification Program Manual (FDOT 2008h).

The research team visited District 2, which represents the Material Model, on June 6, 2008 and met with the District Construction Engineer (DCE) and the District Materials Engineer (DME) to obtain their opinion about the advantages and disadvantages of both the Material and non-Material Models. A similar visit was paid to District 5, which represents the non-Materials Model, on June 9, 2008. During these visits, the research team collected data related to the types of Verification Testing done in the field and the cost breakdown of CEI activities for District 2.

Based on the input received from the initial visits to Districts 2 and 5, the research team captured the main concerns of both Districts and was able to design a survey questionnaire to pool the opinion of construction and materials personnel representing the 8 Districts of the FDOT. The survey was sent to the 8 FDOT Districts and the research team received 20 completed responses representing all the 8 Districts. Out of the received responses, 14 responses represented the non-Material Model districts and 6 responses represented the only Material Model district (District 2). A copy of the survey questionnaire is included in Appendix 1.

The research team also contacted the Turnpike to inquire about a previous pilot study conducted on Material Model implementation. The research team received a summary of the main outcomes of the study and some data related to the cost comparison between the two models.

In addition, the research team collected data on the main indicators of quality for districts 1, 2, 5, and 7. These data are the Maintenance Rating Program (MRP) ratings, the Laboratory Information Management System (LIMS) data, and the Pavement Management Reports, as shown in Figures 3.1 and 3.2.

092L Retaining Wall Material						
District:	**2**					
Total Number of Samples=		38	Total Failed Samples=	17		
Total Q Samples=		19	Failed Q Samples=	9	Percent Q Failed=	47.37
Total IV Samples=		0	Failed IV Samples=	0	Percent IV Failed=	0
Total V Samples=		19	Failed V Samples=	8	Percent V Failed=	42.11
District:	**5**					
Total Number of Samples=		97	Total Failed Samples=	26		
Total Q Samples=		34	Failed Q Samples=	6	Percent Q Failed=	17.65
Total IV Samples=		34	Failed IV Samples=	6	Percent IV Failed=	17.65
Total V Samples=		29	Failed V Samples=	14	Percent V Failed=	48.28
123L Asphalt Material						
District:	**2**					
Total Number of Samples=		2,827	Total Failed Samples=	151		
Total Q Samples=		1,577	Failed Q Samples=	50	Percent Q Failed=	3.17
Total IV Samples=		763	Failed IV Samples=	84	Percent IV Failed=	11.01
Total V Samples=		486	Failed V Samples=	17	Percent V Failed=	3.5
District:	**5**					
Total Number of Samples=		2,239	Total Failed Samples=	111		
Total Q Samples=		1,401	Failed Q Samples=	45	Percent Q Failed=	3.21
Total IV Samples=		432	Failed IV Samples=	57	Percent IV Failed=	13.19
Total V Samples=		406	Failed V Samples=	9	Percent V Failed=	2.22
145F Concrete Paving Material Field						
District:	**2**					
Total Number of Samples=		163	Total Failed Samples=	8		
Total Q Samples=		126	Failed Q Samples=	8	Percent Q Failed=	6.35
Total IV Samples=		0	Failed IV Samples=	0	Percent IV Failed=	0
Total V Samples=		37	Failed V Samples=	0	Percent V Failed=	0
District:	**5**					
Total Number of Samples=		31	Total Failed Samples=	0		
Total Q Samples=		25	Failed Q Samples=	0	Percent Q Failed=	0
Total IV Samples=		0	Failed IV Samples=	0	Percent IV Failed=	0
Total V Samples=		6	Failed V Samples=	0	Percent V Failed=	0

Figure 3.1 Sample of Collected LIMS Data

DISTRICT	COUNTY	RDWYID	SYSTEM	SYST	STHWYSYS	RDWY	TYPE	BMP	EMP	IRI	LANES	PATCH	RIDE	CRKRATE	RUTRATE	CRKTYPE	REMARKS	YR	PCR	DPUP	DFI
2	26	26260000	4	2	1	L	1	0	16.525	53	3	.	8.2	9.5	9	C		2007	8.2	.	.
2	26	26260000	4	2	1	R	1	0	16.525	50	3	.	8.2	10	9			2007	8.2	.	.
2	26	26260000	4	2	1	L	1	16.525	17.452	66	3	.	7.9	9.5	9	C		2007	7.9	.	.
2	26	26260000	4	2	1	R	1	16.525	17.452	75	3	.	7.7	9.5	9	C		2007	7.7	.	.
2	26	26260000	4	2	1	L	1	17.452	35.19	57	3	1	8	9.5	10	C	PT SPL	2007	8	.	.
2	26	26260000	4	2	1	R	1	17.452	35.19	56	3	.	8	10	10			2007	8	.	.
2	27	27090000	4	2	1	L	1	0	9.439	50	2	1	7.9	6.5	6	C	PT RAV BLD	2007	6	.	.
2	27	27090000	4	2	1	R	1	0	9.439	63	2	.	7.5	4.5	7	C	RAV	2007	4.5	.	.
2	27	27090000	4	2	1	L	1	9.439	25.462	45	2	.	8.3	4.5	8	C	RAV RIP BLD	2007	4.5	.	.
2	27	27090000	4	2	1	R	1	9.439	25.462	77	2	.	6.5	6.5	7	C	RAV DEP	2007	6.5	.	.
2	27	27090024	4	2	1	C	0	0	0.063	.	.	.	.	.	.		EXCEPT RAMP	2007	.	.	.
2	27	27090025	4	2	1	C	0	0	0.218	.	.	.	.	.	.		EXCEPT RAMP	2007	.	.	.
2	27	27090026	4	2	1	C	0	0	0.221	.	.	.	.	.	.		EXCEPT RAMP	2007	.	.	.
2	29	29170000	4	2	1	L	1	0	10.105	49	2	.	8.3	8.5	9	C		2007	8.3	.	.
2	29	29170000	4	2	1	R	1	0	6.145	51	2	.	8.3	8.5	9	C		2007	8.3	.	.
2	29	29170000	4	2	1	R	1	6.145	6.76	75	2	.	7.8	9	9	C	RAV	2007	7.8	.	.
2	29	29170000	4	2	1	R	1	6.76	10.105	52	2	.	8.4	8.5	9	C		2007	8.4	.	.
2	29	29170000	4	2	1	L	1	10.105	20.69	73	2	.	6.9	3.5	9	C	RAV	2007	3.5	.	.
2	29	29170000	4	2	1	R	2	10.105	20.69	69	2	1	7.4	8	9	C	PT RAV	2007	7.4	.	.
2	29	29180000	4	2	1	L	1	0	9.369	55	3	.	7.8	9	9	C	RAV	2007	7.8	.	.
2	29	29180000	4	2	1	R	1	0	3.416	53	3	.	7.5	9	9	C		2007	7.5	.	.
2	29	29180000	4	2	1	R	1	3.416	9.369	52	3	.	8.1	8	9	C		2007	8	.	.
2	29	29180000	4	2	1	L	1	9.369	19.032	68	3	.	7.8	7.5	7	C	RAV	2007	7	.	.
2	29	29180000	4	2	1	R	1	9.369	19.032	65	3	.	7.9	7	8	C	RAV	2007	7	.	.
2	29	29180000	4	2	1	L	1	19.032	27.445	54	3	.	8.3	10	9			2007	8.3	.	.
2	29	29180000	4	2	1	R	1	19.032	27.445	52	3	.	8.3	10	9			2007	8.3	.	.
2	29	29180000	4	2	1	L	1	27.445	30.447	57	3	.	8.1	8.5	8	C		2007	8	.	.
2	29	29180000	4	2	1	R	1	27.445	30.447	56	3	.	8.2	8.5	8	C		2007	8	.	.
2	32	32100000	4	2	1	L	1	0	8.874	41	3	1	8.6	9	8	C	PT	2007	8	.	.
2	32	32100000	4	2	1	R	1	0	8.874	43	3	.	8.5	9	9	C	RIP	2007	8.5	.	.
2	32	32100000	4	2	1	L	1	8.874	19.175	42	3	1	8.2	8	8	C	RAV PT	2007	8	.	.
2	32	32100000	4	2	1	R	1	8.874	19.175	39	3	.	8.4	8	9	C	RAV	2007	8	.	.
2	32	32100000	4	2	1	L	1	19.175	28.746	60	3	.	7.9	8	8	C	RAV	2007	7.9	.	.
2	32	32100000	4	2	1	R	1	19.175	28.746	54	3	1	8	9.5	8	C	PT	2007	8	.	.
2	32	32100030	4	2	1	C	4	0	0.775	93	1	.	7	7.3	.		WEIGH STA. STATIC	2007	7	0	1
2	32	32100031	4	2	1	C	4	0	0.779	120	1	.	5.9	4.8	.		WEIGH STA. STATIC	2007	4.8	0	0
2	35	35090000	4	2	1	L	1	0	11.333	41	2	.	8.4	9	9			2007	8.4	.	.
2	35	35090000	4	2	1	R	1	0	11.333	43	2	1	8.4	9	9	C	PT	2007	8.4	.	.
2	35	35090000	4	2	1	L	1	11.333	16.941	43	2	.	8.5	9.5	9			2007	8.5	.	.
2	35	35090000	4	2	1	R	1	11.333	16.941	45	2	.	8.4	10	9			2007	8.4	.	.
2	35	35090000	4	2	1	L	1	16.941	23.686	42	2	.	8.5	8.5	9			2007	8.5	.	.
2	35	35090000	4	2	1	R	1	16.941	23.686	45	2	.	8.4	8.5	9	C		2007	8.4	.	.
2	35	35090000	4	2	1	L	1	23.686	32.96	44	2	.	8.5	10	9			2007	8.5	.	.
2	35	35090000	4	2	1	R	1	23.686	32.96	45	2	.	8.4	9.5	9			2007	8.4	.	.
2	37	37120000	4	2	1	L	1	0	5.861	60	2	1	8.2	8.5	7	C	PT	2007	7	.	.
2	37	37120000	4	2	1	R	1	0	5.861	56	2	.	8.3	8.5	7	C	BLEEDING	2007	7	.	.
2	37	37120000	4	2	1	L	1	5.861	15.099	63	2	.	7.7	7.5	9	C		2007	7.5	.	.
2	37	37120000	4	2	1	R	1	5.861	15.099	57	2	.	8	7.5	9	C		2007	7.5	.	.
2	37	37120000	4	2	1	L	7	15.099	25.523	41	2	.	8.5	10	10		NEW PAVT	2007	8.5	.	.
2	37	37120000	4	2	1	R	7	15.099	25.523	44	2	.	8.4	10	10		NEW PAVT	2007	8.4	.	.
2	37	37130000	4	2	1	L	1	0	3.277	60	3	.	8.1	8.5	7	C		2007	7	.	.
2	37	37130000	4	2	1	R	1	0	3.277	59	3	.	7.9	8.5	8	C		2007	7.9	.	.
2	37	37130000	4	2	1	L	1	3.277	3.656	63	3	.	8.1	8.5	8	C		2007	8	.	.
2	37	37130000	4	2	1	R	1	3.277	3.656	63	3	.	7.9	8.5	8	C		2007	7.9	.	.
2	72	72001000	4	2	1	L	0	0	0.733	.	.	.	.	.	.		EXCEPTION	2007	.	.	.
2	72	72001000	4	2	1	R	0	0	0.733	.	.	.	.	.	.		EXCEPTION	2007	.	.	.
2	72	72001000	4	2	1	L	7	0.733	1.414	41	3	.	8.6	9.5	.		NEW PAVT	2007	8.6	0	0

Figure 3.2 Sample of Collected Pavement Management Reports

3.2 Data Analysis

After collecting the abovementioned data, the next research step was to analyze the collected data. The data analysis included comparing the two models in three main areas: quality, risk and cost.

3.2.1 Quality Analysis

The research depended on three main data sources. These are:

i. MRP Data
ii. Pavement Condition Reports
iii. LIMS Data

The FDOT website allowed the research team to collect and analyze MRP ratings. The MRP is a program that defines the guidelines for evaluating road conditions and maintenance needs. The MRP ratings are based on a scale from zero to 100, the higher the measurements the better the conditions of the road. MRP sampling is done three times per year. For the purpose of analyzing quality, the research team focused on the ratings of the roadway and roadside elements for districts 1, 2, 5 and 7 between 2000 and 2008. The comparison between the Material Model and non-Material Model ratings is discussed in the next chapter.

The FDOT provided the research team with pavement condition and ride reports (FDOT 2008i). These reports presented a number of quality indicators that were used to compare the quality of the Material Model to that of the non-Material Model. The analysis of the quality indicators included analyzing the ride numbers for the abovementioned four districts. The ride number is a number that ranges from zero to ten to indicate the level of ride quality, with ten representing the highest level. The minimal standard of ride quality a road can bear is 6.4. Any value below this threshold indicates the need for maintenance. Data representing the ride quality for districts 1, 2, 5 and 7 were gathered and organized into tables to facilitate the analysis. District 2 represented the Material Model system and districts 1, 5, and 7 represented the non-Material Model system. In addition to ride numbers, the research team collected and analyzed rutting ratings, cracking ratings and the overall pavement condition ratings.

The research team also analyzed LIMS data. Specifically, the research team investigated the percentage failures of each type of verification testing for three types of materials (Asphalt, Concrete, and Embankment). The analysis was done on the data for the period from 2004 to 2008. These are the years for which complete data sets are available through the LIMS. This indicator was used to compare between the two models and determine which one of them has a lower percentage of failures.

3.2.2 Risk Analysis

The analysis of risk factors involved in utilizing the Material Model and/or the non-Material Model projects followed the suggestions received from the FDOT during the first video conference. During that conference, the research team was tasked by: (1) identifying the effect of sampling randomness on the level of risk of non-detection of failing materials in both models; (2) determining if there are any other risk factors involved in the two models; and (3) determining if any of the two models is more accurate than the other (e.g. if testing indicates conforming material, what are the chances it might not be the case and vice versa)

3.2.2.1 Sampling Randomness

To examine the effect of sampling randomness on the level of risk of non-detection of failing materials, the research team (1) investigated how the generation of sampling is determined; and (2) solicited the opinion of construction and materials personnel on the randomness of the sampling generation process; and the qualification of personnel conducting the sampling process.

3.2.2.2 Identifying Risk Factors

Through the review of literature and the interviews with construction and materials personnel, the research team identified a number of possible risk factors that needed further studying and analysis to determine their effect on the cost, quality and time of constructing FDOT facilities. The initial list of identified risk factors included:

1. Unqualified person conducting sampling.
2. Inadequate number of samples collected.
3. Biased collection of good samples.
4. Change of original sample location if the tester fails to take it in time.
5. Specimen collected not meeting specifications.
6. Specimen damage during transportation.
7. Specimen stored in non-standard conditions.
8. Specimen damage during storage.
9. Specimen damage during handling and before testing.
10. Unqualified person conducting VT.
11. Faulty testing equipment used.
12. Inadequate maintenance of testing equipment.
13. Testing done not in accordance with standards.
14. Quality could be negatively affected if split sampling used.
15. Quality of inspection is sacrificed if inspectors are required to conduct both inspection and material testing.
16. Quality of material verification testing is sacrificed if inspectors are required to conduct both inspection and material testing.

3.2.2.3 Results Accuracy

To check if both the Material and non-Material Models would produce accurate test results, the research team utilized the risk factors identified in the previous section to investigate the whole process of testing the materials under both models. The analysis of the probability of occurrence for these factors, and hence the effect on results accuracy, is presented in the next chapter.

3.2.2.4 Steps of the Risk Analysis Study

The main steps of the risk analysis study are as follows:

1. Identify typical risk factors involved in both the Material and non-Material Model projects by performing a literature review, interviewing construction and materials personnel, and collecting survey questionnaire data.
2. Assess the probability of occurrence of each identified risk factor by surveying construction and materials personnel.
3. Assess the impact of each risk factor – in case of materialization – on cost, time, and quality of construction.
4. Calculate the risk score by multiplying the probability of occurrence by the impact.

3.2.3 Cost Analysis

The UCF team used Activity-Based Costing (ABC) as a method for analyzing cost and understanding the various activities involved in material sampling, and testing. ABC is an accounting methodology that assigns costs to activities rather than products or services. In order to correctly associate costs with products and services, ABC assigns costs based on the use of resources to accomplish an activity, then assigns costs to cost objects. The process of identifying the activities and their relevant costs is called value chain analysis. In the present case, the two main activities to be analyzed are sampling and testing. All other activities were found to be similar under the Material and non-Material Models. Another difference between the two models is in the overhead cost, which differs based on the district size, number of projects, number of employees and other factors that affect the overhead cost calculations. Due to the difficulty in estimating the overhead accurately from district accounting systems, the research team decided to analyze the expected costs of a hypothetical project under the Material and non-Material Models. To analyze these costs, the UCF team compared the different processes, equipment and personal used in the example project that involved adding two lanes for both ways of an existing four-lane road. The road was assumed to be 10 miles long. Five miles of the road are flexible pavement and the other five miles are rigid. Through this example, the team found that the only difference between the two models was in the verification testing part. The example was provided through the survey to the construction and materials personnel and the district construction and material offices to estimate the required resources for the project.

In addition, the survey included a question about the percentage of time a CEI inspector spends on testing, inspection and other responsibilities. The result analysis found that the average percentages of time were 30%, 62% and 8% respectively. The survey example also revealed that the 10-mile widening road construction project (under the assumption of 6 months total project duration) needs on average:

- 1.6 Lead Inspector whose expected average hourly rate is $24.57
- 3.5 CEI Inspector including the asphalt plant inspector and aide inspector with average hourly rate $19.05

Since CEIs need to travel from one site to another, vehicle operating and licensing costs had to be included in the analysis. The Material VT rates are usually charged at a constant hourly rate or based on the number of tests to be performed without accounting for the traveled distances. Using the abovementioned project characteristics, the estimated cost for the non-Material Model was calculated. To estimate the Material Model costs, we contacted consultants to provide us with quotes for all tests to be performed for the example project. The steps of cost analysis are discussed in chapter 4 in more details.

3.3 Interpretation and Documentation of the Research Results

The research team analyzed the collected data as described above. The details of the analysis, the interpretation of the results and the main research findings are detailed in the following chapter.

3.4 Limitations

The cost analysis comparison analysis done in this report between the two models is limited by the inherent limitations imposed by the method of breakdown of costs involved in the two methods of verification testing as implemented by the Districts and is explained below.

The original cost analysis methodology intended to compare the two models according to the breakdown of the cost for testing and sampling of materials from the two sampled Districts. This cost was to include personnel and overhead expenses for CEI and in-house personnel. As the research began, District-2 was able to provide a detailed breakdown of their expenses due to the availability of resident offices that were capable of distinguishing between the types of cost. On the other hand, District-5 was not able to provide a detailed breakdown of their cost due to their adoption of a different operations structure in which many of the district operation facilities were consolidated under the same budget entity. As such, it is impossible at this time for D-5 to distinguish the differences in cost and provide their data in a form similar to that provided by D-2. This lead to the adoption of a cost analysis methodology that depended on estimating testing and sampling costs for an example project under each of the two models. Due to the difference between the operations of the two Districts and the way they were structured, the analysis was not possible to obtain the same type of data from the two Districts and therefore cost study is inclusive.

Chapter Four: Findings

The following sections discuss the findings of the analysis of the collected data. The sections specifically discuss: (1) the results of the completed survey questionnaire, (2) the results of the quality analysis study, (3) the results of the risk analysis study, and (4) the results of the cost analysis and comparison.

4.1 Survey Questionnaire Analysis and Results

The conducted survey solicited the opinions of twenty construction and materials personnel construction and materials personnel from the eight FDOT districts. These construction and materials personnel people were first classified according to the quality control model being implemented at their district (i.e. Material Model construction and materials personnel or non-Material Model construction and materials personnel). The average for each category was then calculated to present the beliefs of the construction and materials personnel in each category.

The survey included three main sections covering the various aspects of both the Material and non-Material models. The first section included 5 questions addressing some concerns that were raised by FDOT. The second section focused on analyzing the cost elements and resources for the construction of an example road project. The third question addressed the various possible sources of risks, their probability of occurrence, and their impact on time, cost and quality of FDOT construction projects.

The first section addressed questions related to the randomness of sample locations, the efficiency of outsourcing verification testing, material testing as a core responsibility for inspectors, the impact of conducting material testing on the inspectors' skills, and an estimate of the time spent by inspector on various activities.

Table 4.1a presents the responses received on the first survey question. In that question, construction and materials personnel were asked whether samples are taken from their predetermined random locations. Ten responses were received from the districts representing the non-Material Model and five responses were received from District 2. Due to this difference in the no. of responses representing the two models and to avoid any biasness that may result from psychological influences, the research team decided to analyze the responses using weighted average analysis rather than merely calculating the arithmetic averages. The arithmetic average, as illustrated in Table 4.1a, shows that 73% of the surveyed construction and materials personnel believe that samples are always taken from their predetermined random locations, while 7% disagreed. Table 4.1b illustrates the analysis of the responses using the weighted average approach. Using this approach, the agreement rate is adjusted to 70% versus 5% disagreement. Similarly, the arithmetic average of the responses to the second question showed that 47% of the surveyed construction and materials personnel believe that it is more efficient to outsource field VT to outside consultant giving the inspector more time to focus on inspection while 47% disagreed, as shown in Table 4.2a. The weighted average rate based on the weighted average analysis is 52% versus 44% disagreement, as shown in Table 4.2b. In response to the third question, the arithmetic average of the responses shows that 29% of the surveyed construction and materials personnel agreed that material testing should be a core responsibility for the inspector while 53% disagreed, as shown in Table 4.3a. The weighted average rate based on the weighted average analysis is 27% versus 56% disagreement, as shown in Table 4.3b. In response to the fourth question, the arithmetic average of the responses shows that, 44% of the surveyed construction and materials personnel believed that it is essential for the CEI inspectors to perform testing in order to maintain their skills while 38% disagreed, as shown in Table 4.4a. The adjusted rates, based on the weighted average analysis, are 38% and 43%, respectively, as shown in Table 4.4b. In response to the fifth question, the arithmetic average of the responses shows that construction and materials personnel reported that CEI inspectors spend 33% of their work time on testing, 58% on inspection, and 10% on other activities, as shown in Table 4.5a. The adjusted rates based on the weighted average approach are 30%, 62% and 8%, respectively, as shown in Table 4.5b. The population sample for the first four questions varied from 15 to 17 responses.

Table 4.1a Random Location Response

		Non-Material Model Responses																	Material M Responses							
1. Are the samples always taken from the predetermined random locations?	RID / RES	1	3	4	5	6	7	8	9	9-1	9-2	9-3	9-4	9-5	11	12	12-1	13	2	10	10-1	10-2	14	15	Total	Arithmetic Average
	Yes		1	1		1	1					1	1	1				1		1	1	1			11	73%
	No										1								1					1	3	20%
	Other, Specify									1															1	7%

Table 4.1b Random Location Response Analysis

1. Are the samples always taken from the predetermined random locations?	RID / RES	Non-Material Model Results	Material Model Results	Weighted Average
	Yes	80.00%	60.00%	70%
	No	10.00%	40.00%	25%
	Other	10.00%	0.00%	5%

Table 4.2a CEI vs. VT Technician Efficiency Response

		Non-Material Model Responses																	Material M Responses							
2. It is more efficient to outsource field VT to a consultant while CEI team focuses only on inspection in the material model.	RID / RES	1	3	4	5	6	7	8	9	9-1	9-2	9-3	9-4	9-5	11	12	12-1	13	2	10	10-1	10-2	14	15	Total	Arithmetic Average
	Agree			1									1	1				1	1	1	1	1			8	47%
	Neutral											1													1	6%
	Disagree		1			1		1		1	1						1						1	1	8	47%

Table 4.2b CEI vs. VT Technician Efficiency Response Analysis

2. It is more efficient to outsource field VT to a consultant while CEI team focuses only on inspection in the material model.	RID / RES	Non-Material Model Results	Material Model Results	Weighted Average
	Agree	36.36%	66.67%	52%
	Neutral	9.09%	0.00%	5%
	Disagree	54.55%	33.33%	44%

Table 4.3a Material Testing as a Core Responsibility Response

		Non-Material Model Responses																	Material M Responses							
3. Material testing should be a core responsibility for CEI inspectors.	RES \ RID	1	3	4	5	6	7	8	9	9-1	9-2	9-3	9-4	9-5	11	12	12-1	13	2	10	10-1	10-2	14	15	Total	Arithmetic Average
	Agree		1			1		1			1												1		5	29%
	Neutral									1							1							1	3	18%
	Disagree			1								1	1	1				1	1	1	1	1			9	53%

Table 4.3b Material Testing as a Core Responsibility Response Analysis

3. Material testing should be a core responsibility for CEI inspectors.	RES \ RID	Non-Material Model Results	Material Model Results	Weighted Average
	Agree	36.36%	16.67%	27%
	Neutral	18.18%	16.67%	17%
	Disagree	45.45%	66.67%	56%

Table 4.4a Keeping CEI Skills Response

		Non-Material Model Responses																	Material M Responses							
4. Do you think that CEI inspectors need to perform verification testing so that they keep up their skills of testing?	RES \ RID	1	3	4	5	6	7	8	9	9-1	9-2	9-3	9-4	9-5	11	12	12-1	13	2	10	10-1	10-2	14	15	Total	Arithmetic Average
	Agree		1	1					1		1	1					1						1		7	44%
	Neutral					1				1														1	3	19%
	Disagree													1				1	1	1	1	1			6	38%

Table 4.4b Keeping CEI Skills Response Analysis

4. Do you think that CEI inspectors need to perform verification testing so that they keep up their skills of testing?	RES \ RID	Non-Material Model Results	Material Model Results	Weighted Average
	Agree	60.00%	16.67%	38%
	Neutral	20.00%	16.67%	18%
	Disagree	20.00%	66.67%	43%

Table 4.5a Time Breakdown Response

		Non-Material Model Responses																	Material M Responses						
5. If you are a CEI inspector can you estimate what percentage of time you spend on each of the following activities:	RES \ RID	1	3	4	5	6	7	8	9	9-1	9-2	9-3	9-4	9-5	11	12	12-1	13	2	10	10-1	10-2	14	15	Arithmetic Average
	Testing			25		5					50	50	30								30		15		33%
	Inspection			45		95					40	40									70		75		58%
	Other Activities			30							10	10									0		10		10%

Table 4.5b Time Breakdown Response Analysis

5. If you are a CEI inspector can you estimate what percentage of time you spend on each of the following activities:	RES \ RID	Non-Material Model Results	Material Model Results	Weighted Average
	Testing	37.21%	22.50%	30%
	Inspection	51.16%	72.50%	62%
	Other Activities	11.63%	5.00%	8%

The survey results and analysis indicate that the Material Model is slightly favored by construction and materials personnel of the 8 FDOT districts over the non-Material Model.

4.2 Quality Analysis and Results

The research team analyzed the quality data collected for District 2 (Material Model) and Districts 1, 5, and 7 (non-Material Model) using 13 quality indicators. These indicators are analyzed over the period between 2000 and 2008 except for two indicators that are analyzed over the period between 2004 and 2008 due to the unavailability of data prior to 2004. The timeframe is classified into three periods. The first is from 2000 to 2002, when the non-Material Model was the only model in use by all districts. The second is from 2002 to 2004, the transitional period for implementing the Material Model by District 2. The third is from 2004 to 2008, when the Material Model was the only model used by District 2. The following sections discuss the analysis and evaluation of the quality indicators over these periods.

4.2.1 IV/V Index

The IV/V index is a quality indicator that compares the percentage of samples passing independent verification (IV) testing to the percentage of samples passing the verification (V) testing. The higher the IV/V ration, the better the verification process is and the better the quality of the finished product is. Figures 4-1 to 4-8 illustrate the comparison of the two models using this indicator for eight material types. The LIMS data that were used to calculate IV/V indexes are presented in Appendix C. These data are available through the LIMS for the period from 2004 to 2008. The LIMS has no significant data before 2004 to analyze.

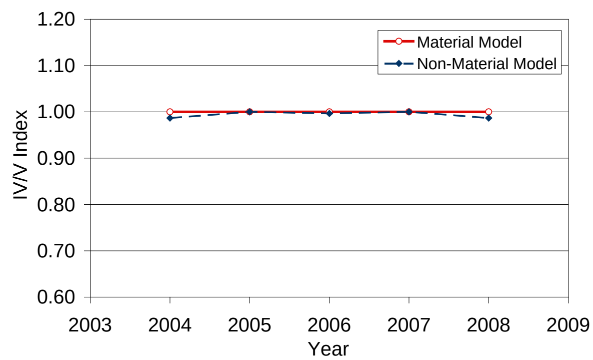

Figure 4.1 IV/V Index Comparison for Embankment Material

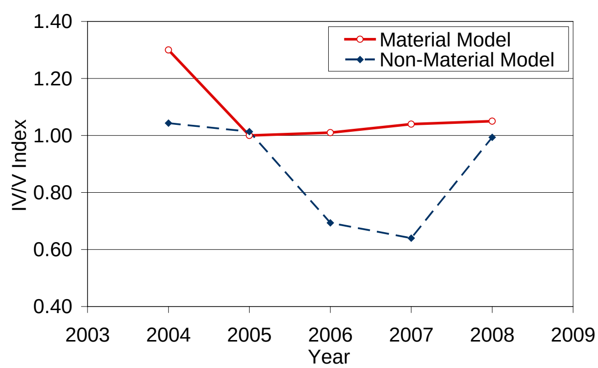

Figure 4.2 IV/V Index Comparison for Subgrade Material

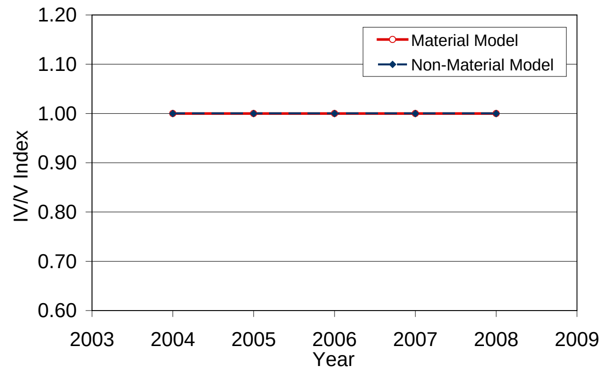

Figure 4.3 IV/V Index Comparison for Fill Material

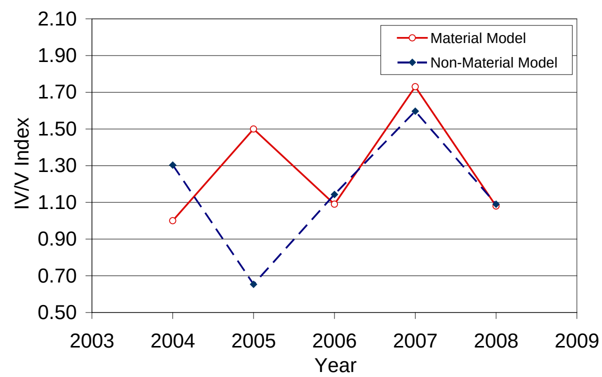

Figure 4.4 IV/V Index Comparison for Retaining Wall Material

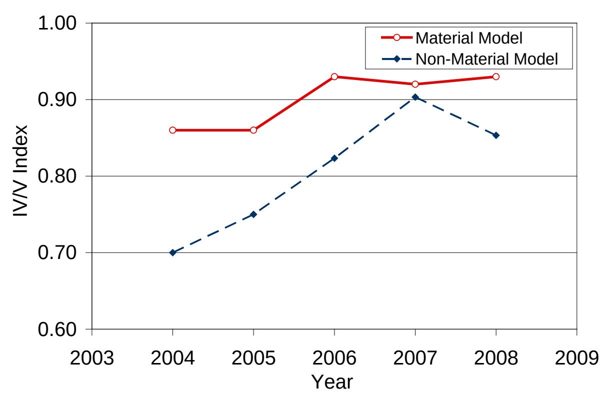

Figure 4.5 IV/V Index Comparison for Asphalt Material

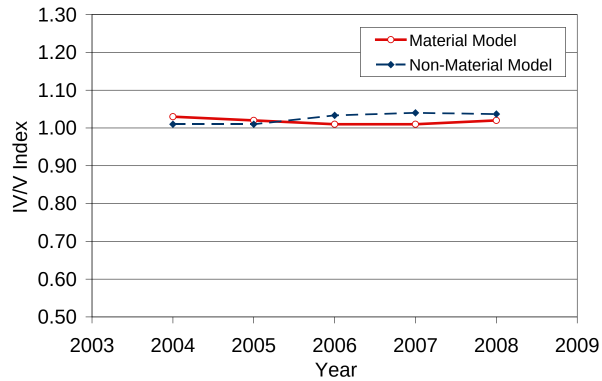

Figure 4.6 IV/V Index Comparison for Field Concrete Structural Material

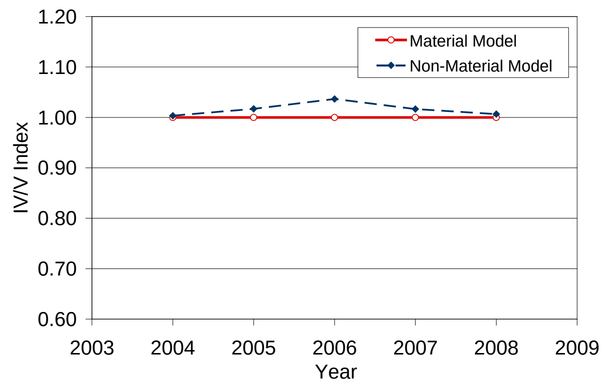

Figure 4.7 IV/V Index Comparison for Lab Concrete Structural Material

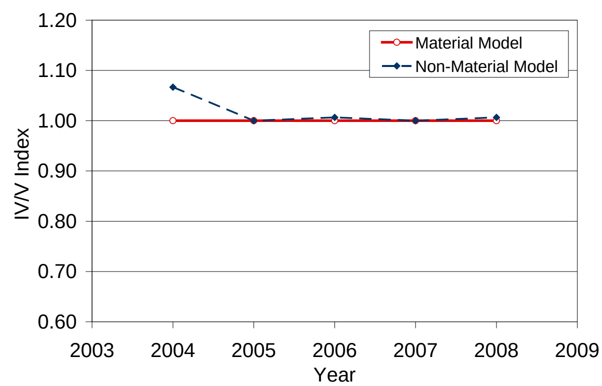

Figure 4.8 IV/V Index Comparison for Base Material

Statistical analysis was performed on the data. A paired t-test was conducted at a confidence interval of 95% to compare the means of the IV/V indexes of the Material

Model to those of the non-Material Model for the various types of materials through 2004 - 2008. The hypotheses were set as follows:

H0: No significant difference in means
H1: Significant difference in means

A summary of the paired t-test results are given in Table 4.6. The summary supports the abovementioned comparison between the two models. The complete details of the conducted statistical tests are presented in Appendix F. Based on the statistical analysis, two indicators showed higher quality for Material Model and one indicator showed higher quality for non-Material Model

Table 4.6 Summary of Testing the Statistical Difference in Means for IV/V Indexes for Material and non-Material Models 2004-2008

IV/V				
No.	**Material**	**P-Value**	**H0**	**Conclusion**
1	004L Embankment Material	0.061	Couldn't Reject	There is **no significant** difference in means
2	020LSubgrade Material	0.030	Reject	There **is significant** difference in means
3	054L Select Fill Material	0.187	Couldn't Reject	There is **no significant** difference in means
4	092L Retaining Wall Material	0.281	Couldn't Reject	There is **no significant** difference in means
5	123L Asphalt Material	0.008	Reject	There **is significant** difference in means
6	160F Concrete Structural Material Field	0.229	Couldn't Reject	There is **no significant** difference in means
7	160L Concrete Structural Material Lab	0.025	Reject	There **is significant** difference in means
8	405L Base Material	0.139	Couldn't Reject	There is **no significant** difference in means

4.2.2 QC/V Index

The QC/V index is a quality indicator that compares the percentage of samples passing contractor's quality control (QC) testing to the percentage of samples passing the verification (V) testing. The lower the ration, the better the quality control enforcement is and the better the quality of the finished product is. Figures 4-9 to 4-16 illustrate the comparison of the two models using this indicator for eight material types. The LIMS data used to calculate QC/V indexes is presented in Appendix C.

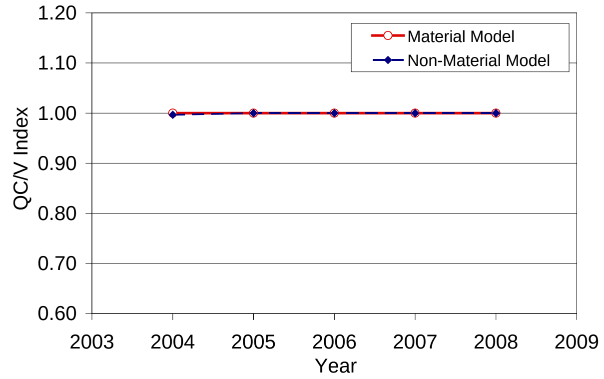

Figure 4.9 QC/V Index Comparison for Embankment Material

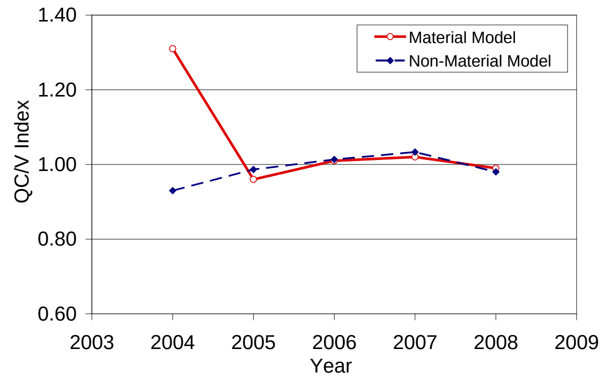

Figure 4.10 QC/V Index Comparison for Subgrade Material

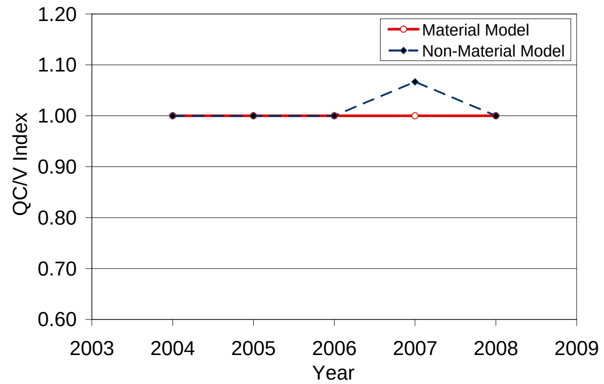

Figure 4.11 QC/V Index Comparison for Fill Material

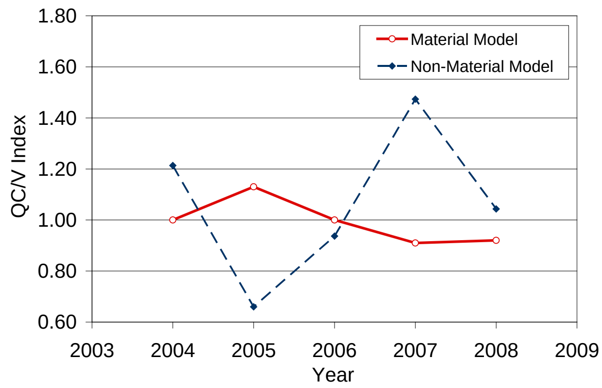

Figure 4.12 QC/V Index Comparison for Retaining Wall Material

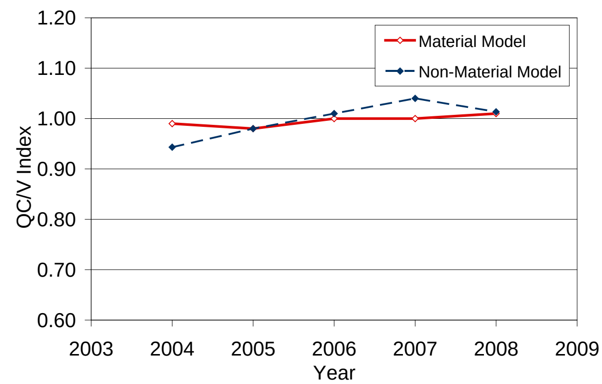

Figure 4.13 QC/V Index Comparison for Asphalt Material

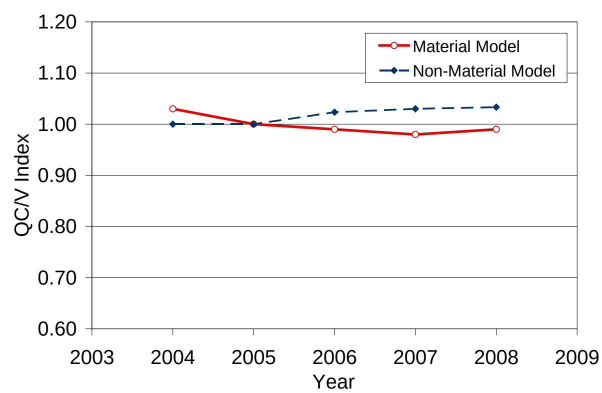

Figure 4.14 QC/V Index Comparison for Field Concrete Structural Material

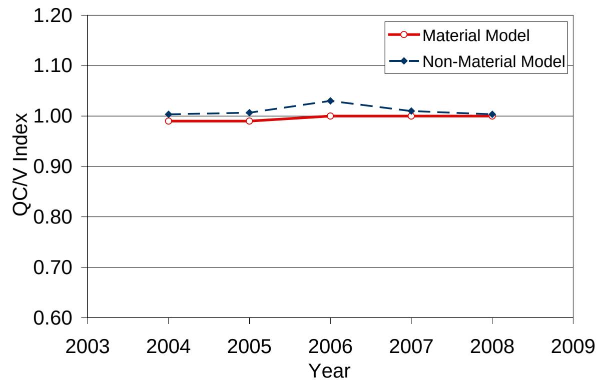

Figure 4.15 QC/V Index Comparison for Lab Concrete Structural Material

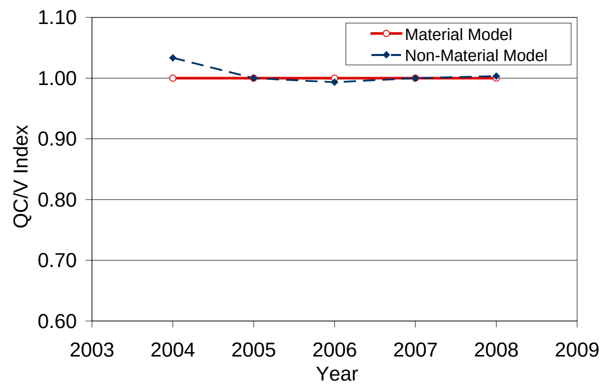

Figure 4.16 QC/V Index Comparison for Base Material

A paired t-test was conducted at a confidence interval of 95% to compare the means of the QC/V indexes of the Material Model to those of the non-Material Model for the various types of materials through 2004 - 2008. The hypotheses were set as follows:

H0: No significant difference in means
H1: Significant difference in means

A summary of the paired t-test results are given in Table 4.7. The statistical analysis results show that there is no significant difference between the means for QC/V for Material and non-Material models except for the concrete structural material lab tests in which the Material Model has an advantage. The complete details of the conducted statistical analysis tests are presented in Appendix F.

Table 4.7 Summary of Testing the Statistical Difference in Means for QC/V Indexes for Material and Anon-Material Models 2004-2008

QC/V				
No.	Material	P-Value	H0	Conclusion
1	004L Embankment Material	0.187	Couldn't Reject	There is **no significant** difference in means
2	020LSubgrade Material	0.212	Couldn't Reject	There is **no significant** difference in means
3	054L Select Fill Material	0.187	Couldn't Reject	There is **no significant** difference in means
4	092L Retaining Wall Material	0.344	Couldn't Reject	There is **no significant** difference in means
5	123L Asphalt Material	0.464	Couldn't Reject	There is **no significant** difference in means
6	160F Concrete Structural Material Field	0.134	Couldn't Reject	There is **no significant** difference in means
7	160L Concrete Structural Material Lab	0.015	Reject	There **is significant** difference in means
8	405L Base Material	0.221	Couldn't Reject	There is **no significant** difference in means

4.2.3 Average Crack Rating

The Crack Rating is a quality indicator that represents the presence of substantial cracking distresses on roadways. The higher the rating, the less the cracking is and the better the condition of the roadway is. The Average Crack Rating has been computed for FDOT projects that were completed in 2000 for the period from 2000 to 2003, as shown in Figure 4.17. During this period, all FDOT districts depended on the non-Material Model system for verifying CQC. In addition, the Average Crack Rating was computed for the projects that were completed in 2004 starting from 2004 to 2008, as shown in figure 4.17. This is the period when D2 started using the Material Model. As shown in the figure, both models appear to have comparable levels of cracking from 2004 to 2008.

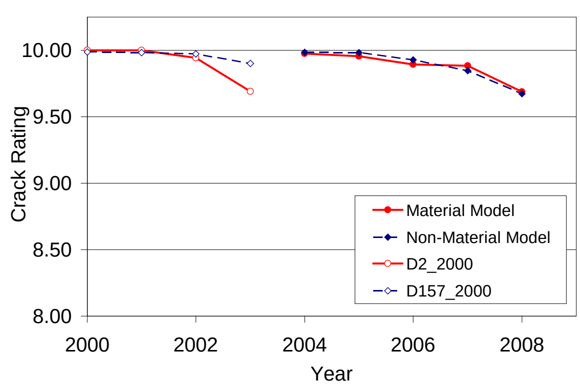

Figure 4.17 Average Cracking Rating Comparison

4.2.4 District 2 Crack Rating Deterioration

The research team also investigated the deterioration rate of Crack Ratings for District 2 to determine if there is any positive or negative effect for implementing the Material Model. For each project in District 2 that was completed between 2000 and 2003, the Crack Rating was computed for the periods (1) immediately after completion, (2) one year after completion, (3) two years after completion, and (4) three years after completion. The averages of these ratings are shown in Table 4.8. The same approach was utilized to determine the averages for the projects completed between 2004 and 2007. As shown in Table 4.8, the average annual deterioration rate was cut by 36 % after implementing the Material Model. This suggests that the Material Model has an advantage over the non-Material Model used in D2 between 2000 and 2003.

Table 4.8 District 2 Crack Rating Deterioration

Year Constructed	Years After Construction				Avg. Deter. / Year	Improv. %	p (2-tailed)	Result
	0	1	2	3				
2000-2003	9.99	9.97	9.94	9.81	0.06	36%	0.691925	No Sig. Diff.
2004-2007	9.99	9.98	9.91	9.88	0.04			

4.2.5 Average Ride Rating

The Ride Rating is a quality indicator that represents the smoothness of riding over a roadway. The higher the rating, the better the smoothness of riding is. The Average Ride Rating has been computed for FDOT projects that were completed in 2000 starting from 2000 to 2003, as shown in Figure 4.18. In addition, the Average Crack Rating was computed for the projects that were completed in 2004 starting from 2004 to 2008, as shown in Figure 4.18. As shown in the figure, both models appear to have comparable level of riding smoothness for the period from 2004 to 2008.

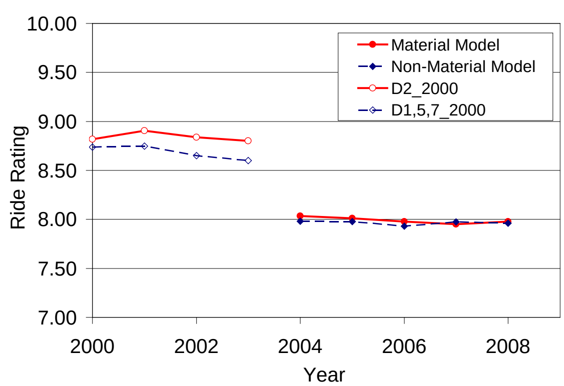

Figure 4.18 Average Ride Rating Comparison

4.2.6 District 2 Ride Rating Deterioration

Using the same approach presented in section 4.2.4, the research team investigated the deterioration rate of Ride Ratings for District 2 to determine if there is any positive or negative effect for implementing the Material Model. As shown in Table 4.9, the average annual deterioration rate was cut by 68%. This suggests that the Material Model has an advantage over the non-Material Model used in D2 between 2000 and 2003.

Table 4.9 District 2 Ride Rating Deterioration

Year Constructed	Years After Construction				Avg. Deter. / Year	Improv. %	p (2-tailed)	Result
	0	1	2	3				
2000-2003	8.68	8.57	8.46	8.33	0.118	68%	0.0029075	Sig. Diff.
2004-2007	8.11	8.03	7.98	8.00	0.038			

4.2.7 Average Rutting Rating

The Rutting Rating is a quality indicator that represents the rutting distresses in pavements. The higher the rating, the less the rutting is and the better the pavement condition is. The Average Rutting Rating has been computed for FDOT projects that were completed in 2000 starting from 2000 to 2003, as shown in Figure 4.19. In addition, the Average Rutting Rating was computed for the projects that were completed in 2004 starting from 2004 to 2008, as shown in Figure 4.19. Again, both models appeared to have comparable levels of rutting for the period between 2004 and 2008.

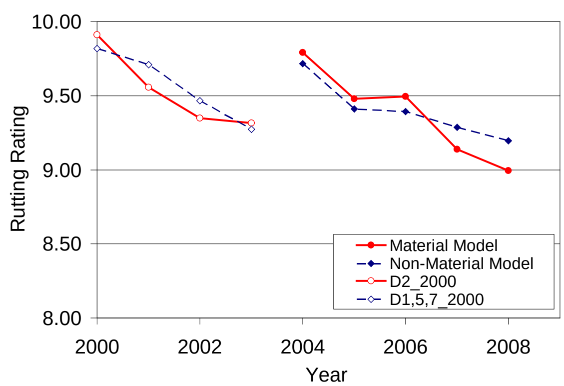

Figure 4.19 Average Rutting Rating Comparison

4.2.8 District 2 Rutting Rating Deterioration

Using the same approach presented in section 4.2.4, the research team investigated the deterioration rate of Rutting Ratings for District 2 to determine if there is any positive or negative effect for implementing the Material Model. As shown in Table 4.10, the average annual deterioration rate increased by 21%. This result favors the non-Material Model over the Material Model.

Table 4.10 District 2 Rutting Rating Deterioration

Year Constructed	Years After Construction				Avg. Deter. / Year	Improv. %	p (2-tailed)	Result
	0	1	2	3				
2000-2003	9.72	9.58	9.35	9.30	0.14	-21%	0.0125459	Sig. Diff.
2004-2007	9.54	9.41	9.25	9.04	0.17			

4.2.9 Average Pavement Condition Rating

The Pavement Condition Rating (PCR) is a quality indicator that represents the overall condition of a road pavement. The higher the rating, the better the overall condition of the road pavement is. The Average PCR has been computed for FDOT projects that were completed in 2000 starting from 2000 to 2003, as shown in Figure 4.20. In addition, the Average PCR was computed for the projects that were completed in 2004 starting from 2004 to 2008, as shown in figure 4.20. As shown in the figure, both models appeared to have the same level of PCR for the period between 2004 and 2008.

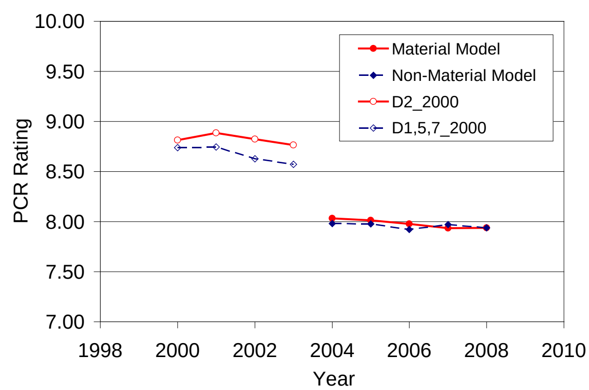

Figure 4.20 Average Pavement Condition Rating Comparison

4.2.10 District 2 Pavement Condition Rating Deterioration

The research team investigated the deterioration rate of Pavement Condition Ratings for District 2 to determine if there is any positive or negative effect for implementing the Material Model. As shown in Table 4.11, the average annual deterioration rate dropped from 0.13 to 0.05, a 60% improvement. This result suggests that the Material Model has an advantage over the non-Material Model system implemented by D2 between 2000 and 2003.

Table 4.11 District 2 Pavement Condition Rating Deterioration

Year Constructed	Years After Construction				Avg. Deter. / Year	Improv. %	p (2-tailed)	Result
	0	1	2	3				
2000-2003	8.68	8.57	8.45	8.30	0.13	60%	0.0022282	Sig. Diff.
2004-2007	8.11	8.03	7.95	7.96	0.05			

It is worth mentioning that the intervals of the laser profilers that are used to measure the Ride Ratings, Rutting Ratings, and PCR were changed from 12" to 6" in 2004. This generally resulted in lower Ride, Rutting, and PCR ratings, as shown in Figures 4.18, 4.19 and 4.20. The change did not affect the Crack Ratings, as they are determined manually. The data collected and analyzed from the pavement condition survey are presented in Appendix D.

A paired t-test was conducted at a confidence interval of 95% to compare the means of the Material Model (D2) to those of the non-Material Model (D1, D5 and D7) with respect to the ratings of crack, ride, rutting, and PCR through 2004-2008. The hypotheses were set as follows:

H0: No significant difference in means
H1: Significant difference in means

The summary of the paired t-test results is given in Table 4.12. The complete details of the conducted statistical analysis tests are given in Appendix F.

Table 4.12 Summary of Testing the Statistical Difference in Means for Pavement Condition Ratings for Material and non-Material Models 2004-2008

Rating	P-Value	H0	Conclusion
Crack	0.735	Fail to Reject	There is **no significant** difference in means
Ride	0.755	Fail to Reject	There is **no significant** difference in means
Rutting	0.132	Fail to Reject	There is **no significant** difference in means
PCR	0.304	Fail to Reject	There is **no significant** difference in means

4.2.11 MRP Roadway Rating

The MRP Roadway Rating is a quality indicator that represents the maintenance needs for roadways. The higher the rating, the less the needs are and the better the condition of roadway is. Figure 4.21 illustrates the MRP Roadway ratings for the Material and non-Material Models for the period from 2001 to 2008. The figure shows comparable levels of MRP Roadway Ratings for both models in between 2004 and 2008.

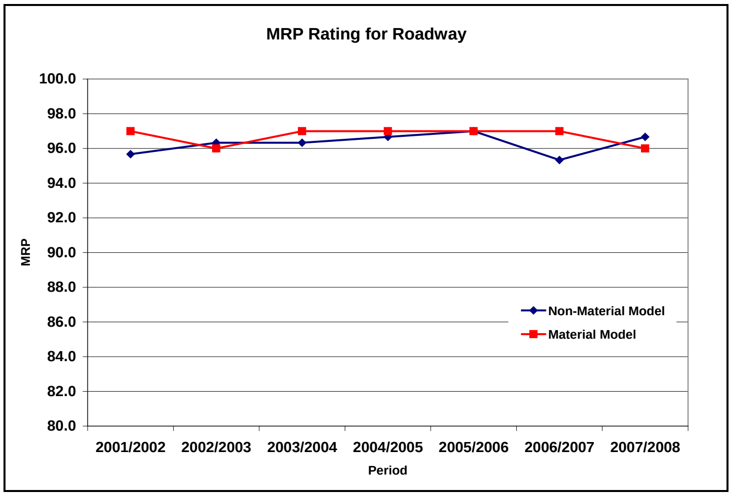

Figure 4.21 Average MRP Roadway Rating Comparison

4.2.12 MRP Roadside Rating

The MRP Roadside Rating is a quality indicator that represents the maintenance needs for pavement roadsides. The higher the rating, the less the needs and the better the conditions of the roadside. Figure 4.22 illustrates the MRP Roadside Rating for the Material and non-Material Models for the period from 2001 to 2008. Before 2004, the non-Material Model ratings were higher than those of the Material Model were and the gap between the two models was increasing in favor of the non-Material Model. In the period between 2004 and 2008, the application of the Material Model seemed to have affected this trend and lead to a positive slope for the Material Model. This new trend leaded the Material Model to be in a comparable level with the non-Material Model in the last two years. MRP data for roadway and roadside through 2001-2008 are presented in Appendix E.

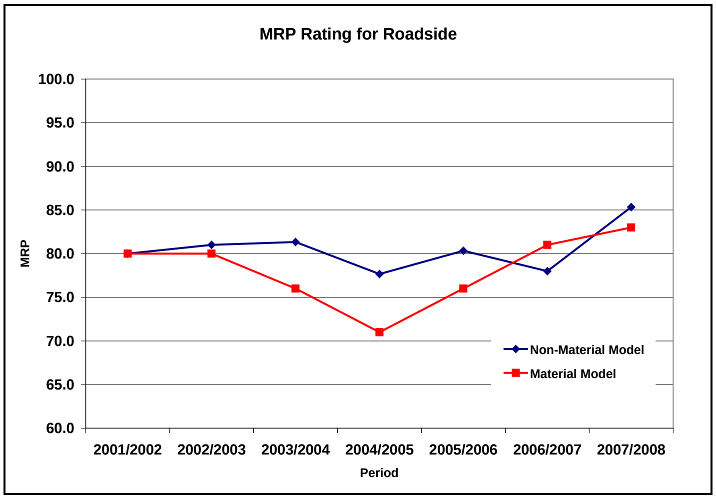

Figure 4.22 Average MRP Roadside Rating Comparison

A paired t-test was conducted at a confidence interval of 95% to compare the means of the Material and non-Material Models with respect to MRP ratings through 2001-2008. The hypotheses were set as follows:

H0: There is no difference in means
H1: There is difference in means

The results of the paired t-tests are summarized in Table 4.13. The complete details of the statistical analysis tests are given in Appendix F of this report.

Table 4.13 Summary of Testing the Statistical Difference in Means for MRP Indicators for Material and non-Material Models 2004-2008

MRP Category	P-Value	H0	Conclusion
Roadway	0.116	Couldn't Reject	There is **no significant** difference in means
Roadside	0.055	Couldn't Reject	There is **no significant** difference in means

4.2.13 CEI vs. VT Technician Efficiency

As has been discussed in section 4.1, there is 47% arithmetic average rate for accepting the statement that it is more efficient to have a VT technician performing the testing while CEI focus on inspection vs. 47% disagreement. The weighted average rates based on weighted average analysis are 52% vs. 44% disagreement, respectively. As such, the Material Model is slightly favored by the surveyed construction and materials personnel over the non-Material Model, as shown in Table 4.2b.

4.2.14 Quality Indicators Summary

In summary, 13 quality indicators with 27 different parameters were analyzed to compare the quality of both models. Tables 4.14a and 4.14b summarize the parameters showing statistically significant difference between the two models. Table 4.14c summarizes the parameters that showed no significant difference between the two models.

Table 4.14a Summary of the Parameters Reflecting Significant Differences in Means for Material and Non-Material Models (D2 vs. D1, 5 and 7)

Indicator	Parameter	Basis of Analysis	Statistically Higher Quality
IV/V	020LSubgrade Material	D2 to D1, D5, D7 *	Material
	123L Asphalt Material	D2 to D1, D5, D7 *	Material
	160L Concrete Structural Material Lab	D2 to D1, D5, D7 *	non-Material
QC/V	160L Concrete Structural Material Lab	D2 to D1, D5, D7 *	Material

* compared for the period from 2004 through 2008

Table 4.14b Summary of the Parameters Reflecting Significant Differences in Means for Material and Non-Material Models (D2 before and after 2004)

Indicator	Parameter	Basis of Analysis	Statistically Higher Quality
Ride Det.	Deterioration in Ride Quality	D2 before and after 2004	Material
Rutting Det.	Rutting Rating Deterioration	D2 before and after 2004	non-Material
PCR Det.	Deterioration in Pavement Condition	D2 before and after 2004	Material

Table 4.14c Summary of the Parameters Reflecting No Significant Differences in Means for Material and Non-Material Models (D2 vs. D1, 5 and 7)

Indicator	Parameter	Basis of Analysis	Result
IV/V	004L Embankment Material	D2 to D1, D5, D7 *	No Difference
	054L Select Fill Material	D2 to D1, D5, D7 *	No Difference
	092L Retaining Wall Material	D2 to D1, D5, D7 *	No Difference
	160F Concrete Structural Material Field	D2 to D1, D5, D7 *	No Difference
	405L Base Material	D2 to D1, D5, D7 *	No Difference
QC/V	004L Embankment Material	D2 to D1, D5, D7 *	No Difference
	020 L Subgrade Material	D2 to D1, D5, D7 *	No Difference
	054L Select Fill Material	D2 to D1, D5, D7 *	No Difference
	092L Retaining Wall Material	D2 to D1, D5, D7 *	No Difference
	123L Asphalt Material	D2 to D1, D5, D7 *	No Difference
	160F Concrete Structural Material Field	D2 to D1, D5, D7 *	No Difference
	405L Base Material	D2 to D1, D5, D7 *	No Difference
MRP Roadway	MRP Roadway Rating	D2 to D1, D5, D7 *	No Difference
MRP Roadside	MRP Roadside Rating	D2 to D1, D5, D7 *	No Difference
Avg. Crack	Average Crack Rating	D2 to D1, D5, D7 *	No Difference
Avg. Ride	Average Ride Rating	D2 to D1, D5, D7 *	No Difference
Avg. Rutt.	Average Rutting Rating	D2 to D1, D5, D7 *	No Difference
Avg. PCR	Average Pavement Condition Rating	D2 to D1, D5, D7 *	No Difference

* compared for the period from 2004 through 2008

Table 4.14d Summary of the Parameters Reflecting No Significant Differences in Means for Material and Non-Material Models (D2 before and after 2004)

Indicator	Parameter	Basis of Analysis	Result
Crack Det.	D2 Crack Rating Deterioration	D2 before & after 2004	No Difference

4.3 Risk Analysis and Results

The risk analysis study followed the recommendations of the Project Management Institute's Body of Knowledge (BOK). According to these recommendations, a matrix is designed to define the levels of impact of risk on time, cost, and quality of completing FDOT projects, as shown in Table 4.15. The matrix is included with the survey to insure that all the construction and materials personnel have the same level of understanding the impact scores. Also according to the BOK recommendations, a risk severity score matrix is designed as shown in Table 4.16. This matrix represents the combined outcome of the probabilities of occurrence of risk factors and their expected impact. This matrix is also used to score construction and materials personnel responses to the survey questionnaire and identify the risk severity score, as shown in Table 4.17. As shown in this table, the majority of risk factors are of a low score except for 5 factors (see Table 4.17). A summary of the collected survey data on the risk factors and their severity is presented in Appendix B.

Table 4.15 Levels of Impact of Risk on Time, Cost, and Quality

Impact / Objective	Very Low 0.05	Low 0.1	Moderate 0.2	High 0.4	Very High 0.8
Time	Insignificant Time Slippage	<5% Time Slippage	5-10% Time Slippage	10-20% Time Slippage	>20% Time Slippage
Cost	Insignificant Cost Increase	<5% cost increase	5-10% cost increase	10-20% cost increase	>40% cost increase
Quality	Insignificant Decrease in Quality	<5% Decrease in Quality	5-10% Decrease in Quality	10-20% Decrease in Quality	>20% Decrease in Quality

Table 4.16 Risk Severity Score Matrix

Risk Score For a Specific Risk					
Probability	**Risk Score = P x I**				
0.9	0.05	0.09	0.18	0.36	0.72
0.7	0.04	0.07	0.14	0.28	0.56
0.5	0.03	0.05	0.10	0.20	0.40
0.3	0.02	0.03	0.06	0.12	0.24
0.1	0.01	0.01	0.02	0.04	0.08
Impact	0.05	0.10	0.20	0.40	0.80
	Impact on Objective (Cost or Time)				

Table 4.17 Expert Response Summary

Source of Risk	Parameter	Impact	Probability	Risk	Severity
Unqualified person conducting sampling.	Time	0.03	0.28	0.01	Low
	Cost	0.03		0.01	Low
	Quality	0.08		0.02	Low
Inadequate number of samples collected.	Time	0.04	0.31	0.01	Low
	Cost	0.04		0.01	Low
	Quality	0.07		0.02	Low
Biased collection of good samples.	Time	0.02	0.31	0.00	Low
	Cost	0.02		0.01	Low
	Quality	0.13		0.04	Medium
Change of original sample location if the tester fails to take it in time.	Time	0.02	0.40	0.01	Low
	Cost	0.02		0.01	Low
	Quality	0.03		0.01	Low
Specimen collected not meeting specifications.	Time	0.08	0.31	0.03	Low
	Cost	0.08		0.02	Low
	Quality	0.14		0.04	Medium
Specimen damage during transportation.	Time	0.08	0.31	0.03	Low
	Cost	0.08		0.03	Low
	Quality	0.07		0.02	Low
Specimen stored in non-standard conditions.	Time	0.08	0.35	0.03	Low
	Cost	0.08		0.03	Low
	Quality	0.06		0.02	Low
Specimen damage during storage.	Time	0.08	0.31	0.02	Low
	Cost	0.08		0.03	Low
	Quality	0.06		0.02	Low
Specimen damage during handling and before testing.	Time	0.08	0.24	0.02	Low
	Cost	0.08		0.02	Low
	Quality	0.06		0.01	Low
Unqualified person conducting VT.	Time	0.03	0.24	0.01	Low
	Cost	0.06		0.02	Low
	Quality	0.10		0.02	Low
Faulty testing equipment used.	Time	0.07	0.28	0.02	Low
	Cost	0.04		0.01	Low
	Quality	0.16		0.04	Medium
Inadequate maintenance of testing equipment.	Time	0.07	0.39	0.03	Low
	Cost	0.03		0.01	Low
	Quality	0.13		0.05	Medium
Testing done not in accordance with standards.	Time	0.08	0.35	0.03	Low
	Cost	0.08		0.03	Low
	Quality	0.13		0.05	Medium
Quality could be negatively affected if split sampling used.	Time	0.01	0.24	0.00	Low
	Cost	0.02		0.00	Low
	Quality	0.03		0.01	Low
Quality of inspection is sacrificed if inspectors are required to conduct both inspection and material testing.	Time	0.05	0.35	0.02	Low
	Cost	0.06		0.02	Low
	Quality	0.10		0.04	Low
Quality of material verification testing is sacrificed if inspectors are required to conduct both inspection and material testing.	Time	0.05	0.35	0.02	Low
	Cost	0.05		0.02	Low
	Quality	0.11		0.04	Low

4.4 Cost Analysis and Results

An example project was presented through the survey questionnaire to solicit expert estimates of the required human resource hours and verification testing costs to complete the project. The project involved adding two lanes to a four-lane, two-way urban arterial roadway. The length of the example roadway is 10 miles (5 miles flexible pavement + 5 miles rigid pavement).The allowed duration to complete the project was 6 months. The estimates received from the construction and materials personnel (see Appendix E) were averaged in order to be used in the analysis as shown in Table 4.18.

Table 4.18 Summary of Survey Questionnaire on the Example Roadway Project

	Type of Resource		Non-Material Model Results	Material Model Results	Average	Standard Deviation
	Lead Inspector	No. of Resources	1.33	2.00	1.67	0.55
		Avge Hourly Rate	$24.54	$24.61	$24.57	2.14
		Overhead %age	175%	108%	141%	0.75
	CEI Inspector	No. of Resources	2.17	3.00	2.58	0.87
		Avge Hourly Rate	$22.30	$19.59	$20.95	3.83
		Overhead %age	175%	102%	139%	0.79
	Materials Model VT Technician	No. of Resources	1.00	2.00	1.50	0.71
		Avge Hourly Rate	$20.00	$14.00	$17.00	4.24
		Overhead %age		151%	151%	
Others	Aide Inspector	No. of Resources	1.00	1.00	1.00	0.00
		Avge Hourly Rate	$12.00	$14.00	$13.00	1.41
		Overhead %age	110%	151%	131%	0.29
	Asphalt plant inspector	No. of Resources	1.00		1.00	
		Avge Hourly Rate	$20.34		$20.34	
		Overhead %age	110%		110%	
	PA (half time)	No. of Resources		0.50	0.50	
		Avge Hourly Rate		$39.70	$39.70	
		Overhead %age		92%	92%	
	Office Engineer	No. of Resources		0.33	0.33	
		Avge Hourly Rate		$24.61	$24.61	
		Overhead %age		65%	65%	

4.4.1 VT-Related Costs for the Non-Material Model

Construction and materials personnel estimated that a team composed of approximately 2.5 CEI Inspectors and 1 CEI Inspector's Aide is needed for the example project, as shown in Table 4.18. Construction and materials personnel estimated the average percentage of CEI time spent on VT to be around 30% (see Table 4.5b). In addition, construction and materials personnel estimated that the average hourly rate for CEI Inspectors in the State of Florida is approximately $20.95 (see Table 4.18). This figure is very close to the $20.61 negotiated average hourly rate for CEI Inspectors reported by FDOT Procurement Office, as shown in Appendix G (FDOT 2009). Construction and materials personnel also estimated the hourly rate for CEI Inspector's Aide to be around $13.0. This rate is also close to the $15.0 FDOT Procurement Office estimate of the average negotiated hourly rate for CEI Inspector's Aide (see Appendix G). For the purpose of the cost analysis, the research team decided to use the FDOT Procurement Office rates as they are based on more substantial amount of data. The home and field office mean overhead rates could be estimated from the FDOT Negotiation Handbook at 167% and 121% respectively (FDOT 2008k). As such, the loaded monthly VT-related costs for the CEI team can be calculated using the following formula:

CEI team monthly VT-related cost = Σ [(1+ Overhead) x No. of resources x Hourly rate x No. of hours per month x Percent time spent on testing] = (1+1.67 + 1.21) x 2.5 x 20.61 x 167 x 0.3 + (1+1.67 + 1.21) x 1.0 x 15.0 x 167 x 0.3 = $12,932.

In addition to the CEI team costs, the cost related to utilizing FDOT vehicles in VT should be estimated. Vehicle costs are traditionally classified into (i) ownership and (ii) operation costs.

As a conservative estimate, the research team assumed that an economy class pickup will be used for the duration of the project. The monthly ownership cost of this economy pickup could be estimated as $294 according to the FDOT Negotiation Handbook (FDOT 2008k). This average ownership monthly cost is based on a straight-line depreciation of the new vehicle cost, less 20% trade in value, over a 4-year period (FDOT 2008k). As such, the monthly VT-related vehicle ownership costs could be estimated using the following formula:

Monthly VT-related vehicle ownership costs = Monthly ownership cost x Percent time used for VT = 294 x 0.3 = $88.2.

The operation costs for the economy pickup truck consists of licensing cost, insurance cost, and maintenance and utilization cost. The average monthly licensing cost is estimated at $4 (FDOT 2008k). The average monthly insurance cost is estimated at $120 (FDOT 2008k). The average monthly maintenance and utilization cost is $192 (FDOT 2008k). As such, the monthly VT-related vehicle operation costs could be estimated using the following formula:

Monthly VT-related vehicle operation costs = Monthly operation cost x Percent time used for VT = (4+120+192) x 0.3 = $94.8.

In addition, the average operating and maintenance costs for VT testing equipment are around $100.00 (material consultant quote). As such, the total VT-related monthly cost for the non-Material Model is $13,215, as shown in Table 4.19.

Table 4.19 Non-Material Model Cost Summary

Non-Material Model Cost Per Month		
Cost Item	**Actual Cost**	**Data Source**
Unloaded CEI Team Cost	$12,932	Survey + FDOT 2009
Vehicle Ownership Cost	$88.2	FDOT 2008k
Vehicle Operation Cost	$94.8	FDOT 2008k
VT Equipment Maintenance Cost	$100.00	Quote
Total Monthly VT Cost	**$13,215**	

4.4.2 VT-Related Costs for the Material Model

To estimate the VT-related costs for the Material Model, it was necessary to identify the type and number of verification tests required for the example project. The estimated quantities of material and required verification tests for the example project are as follows:

1. Flexible Pavement

For adding 12’ wide, 4” thick flexible pavement lanes, it is estimated that 21,370 tons of asphalt are required (FDOT 2008m). The number of tons of asphalt needed to pave 5 miles has been calculated as follows:

Volume = Length x Width x thickness = (5 x 1760 x 3) x 2 (12+6) X (4/12) = 316,800 cu ft.

Mass = Volume X Asphalt Density = 316,800 x 135 = 42,678,000 lb = 21,384 tons

With a lot size of 4000 ton, the project will consist of 6 lots of asphalt. The required verification tests for the flexible pavement are:

- Bulk Spec. Grav. Rdwy: 1 VT per lot for every 5 QC core cylinders
- Temperature: 1 VT per lot for every 3 QC tests
- Mix design: 1 VT for all lots
- Sieve analysis: 1 VT per lot

2. Rigid Pavement

For adding five miles of rigid pavement, it is estimated that 35200 cu yd of concrete will be needed. This volume has been estimated as follows:

Volume = Length x Width x thickness = (5 x1760) X 2 (12+6)/3 X 1/3 = 35,200 cu yd

With a lot size of 150 cu yd, the project will consist of approximately 235 lots. The required verification tests for the rigid pavement are:

- Slump ASTM143 test: 1 per 4 lots
- Temperature: 1 per 4 lots
- Compressive strength ASTMc39: 3 Cyl/Set (Discretion of Engr.)

3. Earthwork

For an estimated 234,667 square yards of earthwork and a standard 10,000 sq yd lot size, the project will consist of 24 lots. This estimate is based on the following formula:

Area = Length X Width = (10 x 1760) x 2 (12+6+2) /3 = 17,600 X 40/3 = 234,667 sq yd

The verification tests required for earthwork are:

- Embankment:
  - Standard Proctor (1 per soil type)
  - Plastic limits (1 per Lft5Ln)
  - Permeability (1 per Lft5Ln)
- Stab Subgrade & Shoulders:
  - Lime rock Bearing Ratio (1 per 8 lots)
  - Modified Proctor (1 per 8 lots)
- Density (1 per lot)

4. Base Material

For the estimated 211,200 square yards of base material and the standard 10,000 square yard lot size, the project will consist of 22 lots. This estimate is based on the following formula:

Area = Length x Width = (10 x 1760) X 2 (12+6)/3 = 17600 X 12 = 211,200

The verification tests required for base material are:

- Density (1 per 4 lots)
- Liquid Limit (3 per mile)
- Plastic Limits (3 per mile)
- Modified Proctor (1 test)
- % Carbonate in Lime rock (1 per SrcPrj)
- Gradation (1 per lot)

To calculate the total VT cost for the project, the following formula could be used:

$$\text{Total Cost} = \Sigma \text{ (No. of performed tests x Cost per test)}$$

Tables 4.20 - 4.24 summarize the calculation of the VT costs using the above formula. As shown in the tables, the average cost of verification tests were obtained from a variety of resources including FDOT Materials Office, the Cost Estimation Guide (CEG

2008) and actual material consultant quotes. It is worth mentioning that the costs reported through the CEG are national averages. These costs were adjusted to reflect the conditions of the State of Florida by using a cost multiplier of 0.98. The total VT-related cost under a Material Model system is presented in Table 4.24.

Table 4.20 Material Model Asphalt Testing Cost

Asphalt						
Test	**Frequency**	**No. of Lots**	**No. of Tests**	**Cost /Test**	**Total Cost**	**Data Source**
Bulk Spec. Grav. Rdwy	1 per lot	6	6	$ 28	$168	FDOT 2008m & CEG 2008
Temperature	1 per lot	6	6	$ 28	$168	FDOT 2008m & CEG 2008
Mix Design (one batch mix)	1 for all	6	1	$178	$178	FDOT 2008m & CEG 2008
Sieve Analysis	1 per lot	6	6	$ 53.90	$323.4	FDOT 2008m & CEG 2008
Total Cost	**$728**					

Table 4.21 Material Model Concrete Testing Cost

Concrete						
Test	**Frequency**	**No. of Lots**	**No. of tests**	**Cost/Test**	**Total Cost**	**Data Source**
Slump & Temperature	1 per 4 lots	235 lots	59	$22	$ 1298	FDOT 2008m & CEG 2008
Compressive Strength ASTM c39	3 Cyl/Set (Descr.)	N/A	30	$11.76	$ 353	FDOT 2008m & CEG 2008
Total Cost	**$ 1,651**					

Table 4.22 Material Model Earthwork Testing Cost

Earthwork						
Test	**Frequency**	**No. of Lots**	**No. of tests**	**Cost/Test**	**Total Cost**	**Data Source**
Embankment S. Proctor	1 per soil type	N/A	1	$122.5	$122.5	FDOT 2008m & CEG 2008
Embankment Plastic Limits	1 per Lft5Ln	N/A	6	$37.10	$222.6	FDOT*
Embankment Permeability	1 per Lft5Ln	N/A	6	$231.30	$1388	FDOT*
Stab Subgrade & Shoulders LBR	1 per 8 lots	24	3	$325	$975	FDOT*
Stab Subgrade & Shoulders Mod. Proctor	1 per 8 lots	24	3	$101	$303	FDOT*
Density	1 per 4 lots	24	6	$120.54	$723	FDOT 2008m & CEG 2008
Total Cost	**$3,734**					

* Average Cost/Test provided by FDOT Materials Office

Table 4.23 Material Model Base Testing Cost

Base						
Test	**Frequency**	**No. of Lots**	**No. of tests**	**Cost/Tes t**	**Total Cost**	**Data Source**
Density	1 per 4 lots	22 lots	6	$120.54	$723	FDOT 2008m & CEG 2008
Liquid Limit	3 per mile	N/A	30	$39.95	$1,199	FDOT*
Plastic Limits	3 per mile	N/A	30	$37.10	$1,113	FDOT*
Modified Proctor	1 test	N/A	1	$101	$101	FDOT*
Carbonate in Lime rock	1 per SrcPrj	N/A	1	$3.24	$3.24	FDOT*
Gradation	1 per lot	22 lots	22	$45.44	$1,000	FDOT*
Total Cost	**$4,139**					

* Average Cost/Test provided by FDOT Materials Office

Table 4.24 Material Model Cost Summary

Total VT Cost for the Material Model	**$10,252**
Cost Per Month	**$1,709**

As shown in Table 4.24, the total VT-related cost for the 6-month project under a Material Model system is approximately $10,252. As such, the average monthly cost will be around $1,709. Comparing this to the VT-related cost under a non-Material Model assumption ($13,215), an estimated monthly saving of $11,506 is expected if a Material Model system is employed.

As a method of verifying the estimated Material Model costs, the research team used the average overall estimate provided through Cost Estimate Guide 2008. The guide projects that the overall cost for sampling and testing should range between $500/week for relatively simple projects and $1,400/week for more complex projects, if only one technician is required. For each additional technician required, the guide estimates that an additional $1,000/week is needed. Using the guide projection and an estimate of two technicians (see Table 4.18), it is expected that the Material Model VT-related cost will range from $1,500 to $2,400 per month with an average of $1,950 per month. This average is very close to the above estimated $1,709 monthly cost.

In conclusion, the cost analysis comparison showed that the adoption of the Material Model system should not result in any increase in VT-related costs. The cost savings are considered insignificant on this project scale. On the large scale of the State and on the long term, the cost savings for either of the model have to be analyzed with the understanding that the cost analysis comparison between the two models is limited by the inherent limitations imposed by the method of breakdown of costs involved in the two methods of verification testing as implemented by the Districts. This is explained in 3.4.

Chapter Five: Conclusions and Recommendations

5.1 Conclusions:

The main outcomes of the study are summarized in the following points:

1. The Material and non-Material Models systems offer quality levels that are comparable. No definitive conclusion as to the preference of model based on quality can be drawn.
2. The two models have comparable levels of low risk.
3. The study concludes that the application of the Material Model should have no negative effects on the quality of construction and should not increase the level of risk involved in FDOT projects. The Material Model holds these characteristics as long as CEIs are able to interpret test results, VT technicians continue to obtain certification, and there is no conflict of interest between material consultants and the verified contractor.

5.2 Recommendations:

Based on these conclusions, the research team recommends the following:

1. The Department should continuously monitor the aforementioned five risk factors. This is necessary in order to allow for effective intervention in case any of these factors materialize during testing and verification.
2. Maintain data on the comparison of the Quality Indicators between both models.
3. Develop tools to obtain actual cost of testing during construction for the Non-Material Model testing. As this tool becomes available and with more data on the Quality Indicators in hand, the Department can judge the preference of one model to another.

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Appendices

Appendix A: Expert Questionnaire

UNIVERSITY OF CENTRAL FLORIDA
FDOT STATE CONSTRUCTION OFFICE

COST AND QUALITY EFFECTIVENESS OF MATERIAL AND NON-MATERIAL MODELS IN CONTRACTOR QUALITY CONTROL (CQC) SYSTEM

FDOT#: BD550 -13

EXPERT'S OPINION QUESTIONNAIRE
ON
MATERIAL AND NON-MATERIAL MODELS

Thank you for your cooperation, please provide your contact information:

Name (optional): ______________________________
Position: ______________________________
District: ______________________________
Department/ Office: ______________________________
Phone (optional): ______________________________
e-mail (optional): ______________________________

This questionnaire could be returned via:

Email to: FDOT-CQC@cecs.ucf.edu
Fax to: 407-823-3315; or
Mail to: Ahmed Khalafallah
Department of Civil & Environmental Engineering,
University of Central Florida
223 Engineering Building II
Orlando, FL 32816-2450

Dear Madam/Sir

State Construction Office initiated a research project with a goal to quantify and compare the Material and non-Material models of testing in the contractor's quality control (CQC) program.

The Material Model is a Verification Testing (VT) procedure that was introduced by District 2 in which the district assigns a material technician (VT technician) to perform the required material tests. This process is believed to relieve the Construction Engineering Inspection (CEI) team to perform verification tasks. The non-Material Model is a verification procedure in which the CEI team is responsible for field verification testing of the contractor's quality control of construction testing.

The research will address if and how the Material Model, minimizes the total number of required CEI man-hours leading to a reduction in the total cost of verification testing for a project (i.e. a VT technician is dispatched to the construction site as needed). It will also investigate any possible savings to the department in terms of equipment ownership, operation, and maintenance.

The main differences between the two models are summarized in the following table:

non-Material Model	**Material Model**
CEI verify Contractor's Quality Control	Material Model VT technician verifies Contractor's Quality Control

Adopting any of the two models is expected to influence the cost incurred by districts, the quality of constructed facilities, and the level of risk to which FDOT is exposed. As such, researchers from the University of Central Florida (UCF) are tasked by State Construction Office with measuring the effectiveness of both models in terms of:

1. The quality of sampling procedures and the reliability of material test results.
2. The costs associated with each model.
3. The risks involved in utilizing each model.

In this essence, the questionnaire has been organized into three major sections with each one addressing questions about one of the above three objectives. You are kindly requested to answer all of these questions to the best of your knowledge.

In case you have any questions or comments to the research team, please use the address below or call us at (407) 823-4826. You may also contact us by fax at (407) 823-3315 or via email at FDOT-CQC@cecs.ucf.edu.

Thank you,

Dr. Ahmed Khalafallah
Department of Civil & Environmental Engineering,
University of Central Florida
223 Engineering Building II
Orlando, FL 32816-2450

I – Sampling and Material Testing

Please circle your response

1. Are the samples always taken from the predetermined random locations?
    a) Yes
    b) No, there is a flexibility to change the location if the tester fails to show in time.
    c) Other:……………………………………………………. (Please specify)

2. It is more efficient to outsource field VT to a consultant while CEI team focuses only on inspection in the Material Model.
    a) Agree
    b) Neutral
    c) Disagree

3. Material testing should be a core responsibility for CEI inspectors.
    a) Agree
    b) Neutral
    c) Disagree

4. Do you think that CEI inspectors need to perform verification testing so that they keep up their skills of testing?
    a) Agree
    b) Neutral
    c) Disagree

5. If you are a CEI inspector can you estimate what percentage of time you spend on each of the following activities:
    a) testing:
    b) inspection:
    c) other activities:

II – Cost

a) Consider the following scenario of a road-widening project:

- The road is originally four-lane 2-way traffic.
- The length of the road is 10 miles (5 miles flexible pavement + 5 miles rigid pavement).
- A lane is to be added on each side.
- Type of road: Urban Arterial.
- The duration of this project is 6 months.

Use the following table to estimate **All** the resources needed by FDOT for **Construction Inspection and Material Verification Testing <u>ONLY</u>:-**

Type of Resource	**Number of Resources**	**Average Hourly Rate**	**Overhead %age**
Lead Inspector			
CEI Inspector			
Materials Model VT Technician			
Others:			

III – RISK

This section aims to measure the impacts of various sources testing-related risks on project time, cost and quality. Please complete the following the table.

Source of Risk	Probability of Occurrence	Impact on*		
		Time	Cost	Quality
Unqualified person conducting sampling.	Low– Medium - High			
Inadequate number of samples collected.	Low – Medium - High			
Biased collection of good samples.	Low – Medium - High			
Change of original sample location if the tester fails to take it in time.	Low – Medium - High			
Specimen collected not meeting specifications.	Low – Medium - High			
Specimen damage during transportation.	Low – Medium - High			
Specimen stored in non-standard conditions.	Low – Medium - High			
Specimen damage during storage.	Low – Medium - High			
Specimen damage during handling and before testing.	Low – Medium - High			
Unqualified person conducting VT.	Low – Medium - High			
Faulty testing equipment used.	Low – Medium - High			
Inadequate maintenance of testing equipment.	Low – Medium - High			
Testing done not in accordance with standards.	Low – Medium - High			
Quality could be negatively affected if split sampling used.	Low – Medium - High			
Quality of inspection is sacrificed if inspectors are required to conduct both inspection and material testing.	Low – Medium - High			
Quality of material verification testing is sacrificed if inspectors are required to conduct both inspection and material testing.	Low – Medium - High			
Others:				
	Low – Medium - High			
	Low – Medium - High			

* The impact could be estimated as follows:

Time:
- 0 = Not Applicable
- 1 = Very Low (Insignificant Time Slippage)
- 2 = Low (<5% Time Slippage)
- 3 = Moderate (5-10% Time Slippage)
- 4 = High (10-20% Time Slippage)
- 5 = Very High (>20% Time Slippage)

Cost:
- 0 = Not Applicable
- 1 = Very Low (Insignificant Cost Increase)
- 2 = Low (<5% Cost Increase)
- 3 = Moderate (5-10% Cost Increase)
- 4 = High (10-20% Cost Increase)
- 5 = Very High (>20%Cost Increase)

Quality:
- 0 = Not Applicable
- 1 = Very Low (Insignificant Decrease in Quality)
- 2 = Low (<5% Decrease in Quality)
- 3 = Moderate (5-10% Decrease in Quality)
- 4 = High (10-20% Decrease in Quality)
- 5 = Very High (>20% Decrease in Quality)

Appendix B: Data Collected from Survey

II – Cost

	Type of Resource		Non-Material Model 3	Non-Material Model 4	Non-Material Model 6	Material M 2	Material M 14
	Lead Inspector	No. of Resources	1	1	2	2	2
		Avge Hourly Rate	22.63	23	28	24.2	25
		Overhead %age	110%		240%	64%	151%
	CEI Inspector	No. of Resources	2	2.5	2	2	4
		Avge Hourly Rate	19.9	19	28	20.2	19
		Overhead %age	110%		240%	53%	151%
	Materials Model VT Technician	No. of Resources		1			2
		Avge Hourly Rate		20			14
		Overhead %age					151%
Others	Aide Inspector	No. of Resources	1				1
		Avge Hourly Rate	12				14
		Overhead %age	110%				151%
	Asphalt plant inspector	No. of Resources	1				
		Avge Hourly Rate	20.34				
		Overhead %age	110%				
	PA (half time)	No. of Resources				0.5	
		Avge Hourly Rate				39.7	
		Overhead %age				92%	
	Office Engineer	No. of Resources				0.33	
		Avge Hourly Rate				24.6	
		Overhead %age				65%	

III – RISK

Source of Risk		1	2	3	4	5	6	7	8	9	9-1	9-2	9-3	10	10-1	11	12	12-1	13	14	Average	Probabilit	Risk
Unqualified person conducting sampling.	Time	0	0.1	0	0.05	0	0.05	0	0	0	0	0	0	0	0.2	0	0	0.1	0.05	0	0.03		0.01
	Cost	0	2.5	0	2.5	0	0	0	0	0	0	0	0	0	7.5	0	0	0	0	0	0.66	0.28	0.18
	Quality	0	7.5	0	7.5	0	0	0	0	0	0	0	15	0	7.5	0	0	15	0	0	2.76		0.76
Inadequate number of samples collected.	Time	0	7.5	0	7.5	0	0	0	0	0	0	0	0	0	7.5	0	0	2.5	0	0	1.32		0.41
	Cost	0	7.5	0	7.5	0	0	0	0	0	0	0	0	0	7.5	0	0	2.5	0	0	1.32	0.31	0.41
	Quality	0	2.5	0	7.5	0	0	0	0	0	0	0	15	0	15	0	0	7.5	0	0	2.50		0.78
Biased collection of good samples.	Time	0	2.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.13		0.04
	Cost	0	7.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.39	0.31	0.12
	Quality	0	2.5	0	2.5	0	0	0	0	0	0	0	15	0	25	0	0	25	0	7.5	4.08		1.27
Change of original sample location if the tester fails to take it in time.	Time	0	0	0	7.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.39		0.16
	Cost	0	0	0	7.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.39	0.40	0.16
	Quality	0	0	0	7.5	0	0	0	0	0	0	0	0	0	7.5	0	0	0	0	0	0.79		0.32
Specimen collected not meeting specifications.	Time	0	15	0	7.5	0	0	0	0	0	0	0	7.5	0	15	0	0	7.5	0	2.5	2.89		0.90
	Cost	0	15	0	7.5	0	0	0	0	0	0	0	7.5	0	15	0	0	7.5	0	0	2.76	0.31	0.86
	Quality	0	7.5	0	7.5	0	0	0	0	0	0	0	25	0	25	0	0	15	2.5	2.5	4.47		1.40
Specimen damage during transportation.	Time	0	15	0	15	0	0	0	0	0	0	0	15	0	7.5	0	0	0	0	0	2.76		0.86
	Cost	0	15	0	15	0	0	0	0	0	0	0	15	0	7.5	0	0	0	0	0	2.76	0.31	0.86
	Quality	0	7.5	0	15	0	0	0	0	0	0	0	7.5	0	0	0	0	2.5	0	15	2.50		0.78
Specimen stored in non-standard conditions.	Time	0	15	0	15	0	0	0	0	0	0	0	15	0	2.5	0	0	0	0	0	2.50		0.88
	Cost	0	15	0	15	0	0	0	0	0	0	0	15	0	7.5	0	0	0	0	0	2.76	0.35	0.97
	Quality	0	7.5	0	15	0	0	0	0	0	0	0	2.5	0	0	0	0	7.5	0	7.5	2.11		0.74
Specimen damage during storage.	Time	0	15	0	15	0	0	0	0	0	0	0	15	0	2.5	0	0	0	0	0	2.50		0.78
	Cost	0	15	0	15	0	0	0	0	0	0	0	15	0	7.5	0	0	0	0	0	2.76	0.31	0.86
	Quality	0	7.5	0	15	0	0	0	0	0	0	0	2.5	0	0	0	0	7.5	0	7.5	2.11		0.66
Specimen damage during handling and before testing.	Time	0	15	0	15	0	0	0	0	0	0	0	15	0	2.5	0	0	0	0	0	2.50		0.59
	Cost	0	15	0	15	0	0	0	0	0	0	0	15	0	7.5	0	0	0	0	0	2.76	0.24	0.66
	Quality	0	7.5	0	15	0	0	0	0	0	0	0	2.5	0	0	0	0	7.5	0	0	1.71		0.41
Unqualified person conducting VT.	Time	0	2.5	0	0	0	0	0	0	0	0	0	0	0	7.5	0	0	0	0	0	0.53		0.13
	Cost	0	7.5	0	2.5	0	0	0	0	0	0	0	0	0	25	0	0	0	0	0	1.84	0.24	0.44
	Quality	0	2.5	0	2.5	0	0	0	0	0	0	0	15	0	25	0	0	15	0	0	3.16		0.75
Faulty testing equipment used.	Time	0	7.5	0	25	0	0	0	0	0	0	0	0	0	7.5	0	0	0	0	2.5	2.24		0.62
	Cost	0	7.5	0	7.5	0	0	0	0	0	0	0	0	0	15	0	0	0	0	0	1.58	0.28	0.43
	Quality	0	15	0	25	0	0	0	0	0	0	0	15	0	25	0	0	15	0	2.5	5.13		1.41
Inadequate maintenance of testing equipment.	Time	0	7.5	0	25	0	0	0	0	0	0	0	0	0	7.5	0	0	0	0	0	2.11		0.82
	Cost	0	7.5	0	7.5	0	0	0	0	0	0	0	0	0	7.5	0	0	0	0	0	1.18	0.39	0.46
	Quality	0	15	0	25	0	0	0	0	0	0	0	15	0	7.5	0	0	15	0	7.5	4.47		1.73
Testing done not in accordance with standards.	Time	0	7.5	0	15	0	0	0	0	0	0	0	0	0	25	0	0	0	0	0	2.50		0.88
	Cost	0	7.5	0	15	0	0	0	0	0	0	0	0	0	25	0	0	0	0	0	2.50	0.35	0.88
	Quality	0	15	0	15	0	0	0	0	0	0	0	15	0	25	0	0	7.5	0	7.5	4.47		1.57
Quality could be negatively affected if split sampling used.	Time	0	2.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.13		0.03
	Cost	0	2.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2.5	0.26	0.24	0.06
	Quality	0	2.5	0	0	0	0	0	0	0	0	0	15	0	0	0	0	0	0	0	0.92		0.22
Quality of inspection is sacrificed if inspectors are required to conduct both inspection and material testing.	Time	0	2.5	0	15	0	0	0	0	0	0	0	0	0	15	0	0	0	0	0	1.71		0.60
	Cost	0	2.5	0	2.5	0	0	0	0	0	0	0	7.5	0	7.5	0	0	0	7.5	7.5	1.84	0.35	0.64
	Quality	0	7.5	0	25	0	0	0	0	0	0	0	0	0	25	0	0	0	2.5	0	3.16		1.11
Quality of material verification testing is sacrificed if inspectors are required to conduct both inspection and material testing.	Time	0	0	0	15	0	0	0	0	0	0	0	0	0	15	0	0	0	0	0	1.58		0.55
	Cost	0	2.5	0	7.5	0	0	0	0	0	0	0	7.5	0	7.5	0	0	0	7.5	0	1.71	0.35	0.60
	Quality	0	7.5	0	25	0	0	0	0	0	0	0	0	0	25	0	0	0	2.5	0	3.16		1.11

Appendix C: Data Collected from LIMS

			2004		2005		2006		2007		2008	
			Q/V	IV/V	Q/V	IV/V	Q/V	IV/V	Q/V	IV/V	Q/V	IV/V
1	004L Embankment Material	D1	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
		D2	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
		D5	0.99	0.96	1.00	1.00	1.00	0.99	1.00	1.00	1.00	0.96
		D7	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
2	020LSubgrade Material	D1	0.91	1.07	0.96	1.00	1.04	1.05	1.04	1.04	0.99	0.91
		D2	1.31	1.30	0.96	1.00	1.01	1.01	1.02	1.04	0.99	1.05
		D5	1.00	1.06	0.98	1.00	1.00	1.03	1.01	0.88	1.00	1.01
		D7	0.88	1.00	1.02	1.04	1.00	0.00	1.05	0.00	0.95	1.06
3	054L Select Fill Material	D1	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
		D2	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
		D5	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
		D7	1.00	1.00	1.00	1.00	1.00	1.00			1.00	1.00
4	092L Retaining Wall Material	D1	1.00	1.00	1.00	1.00	0.50	1.00	1.20	1.20	1.22	1.22
		D2	1.00	1.00	1.13	1.50	1.00	1.09	0.91	1.73	0.92	1.08
		D5	0.94	1.05	0.98	0.96	1.02	1.14	1.59	1.59	0.93	0.73
		D7	1.70	1.86	0.00	0.00	1.29	1.29	1.63	2.00	0.98	1.32
5	123L Asphalt Material	D1	0.97	0.65	0.97	0.67	1.03	0.77	1.11	0.90	1.02	0.85
		D2	0.99	0.86	0.98	0.86	1.00	0.93	1.00	0.92	1.01	0.93
		D5	0.91	0.72	0.98	0.79	0.99	0.82	0.99	0.89	1.00	0.90
		D7	0.95	0.73	0.99	0.79	1.01	0.88	1.02	0.92	1.02	0.81
6	145F Concrete Paving Material Field	D1			1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
		D2					0.98	1.00	0.94	1.00	0.98	1.00
		D5	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
		D7			1.00	1.00	1.00	1.00	1.00	1.00	0.99	1.00

			2004		2005		2006		2007		2008	
			Q/V	IV/V	Q/V	IV/V	Q/V	IV/V	Q/V	IV/V	Q/V	IV/V
7	145L Concrete Paving Material Lab	D1			1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
		D2					1.00	1.00	1.00	1.00	1.00	1.00
		D5	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
		D7			1.00	1.00	1.02	1.02	1.00	1.00	1.00	1.00
8	146F Concrete Paving Material Field	D1	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00		
		D2					1.00	1.00	0.92	1.00	0.98	1.00
		D5								1.00	1.00	1.00
		D7	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
9	146L Concrete Paving Material Lab	D1	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00		
		D2					1.00	1.00	1.00	1.00	1.00	1.00
		D5									1.00	1.00
		D7	1.00	1.00	0.99	1.00	0.99	1.00	1.02	1.02	1.00	1.00
10	160F Concrete Structural Material Field	D1	1.00	1.02	1.00	0.01	1.05	1.06	1.03	1.05	1.08	1.09
		D2	1.03	1.03	1.00	1.20	0.99	1.01	0.98	1.01	0.99	1.02
		D5	1.01	1.01	1.01	0.00	1.02	1.03	1.05	1.06	1.01	1.01
		D7	0.99	1.00	0.99	1.00	1.00	1.01	1.01	1.01	1.00	1.01
11	160L Concrete Structural Material Lab	D1	1.00	1.00	1.02	1.04	1.08	1.09	1.02	1.03	1.00	1.00
		D2	0.99	1.00	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00
		D5	1.01	1.01	0.99	1.01	1.00	1.00	1.00	1.01	1.01	1.01
		D7	1.00	1.00	1.01	1.01	1.01	1.02	1.01	1.01	1.00	1.01
12	405L Base Material	D1	0.96	1.00	1.00	1.00	0.96	1.00	1.00	1.00	1.00	1.00
		D2	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
		D5	0.94	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
		D7	1.20	1.20	1.00	1.00	1.02	1.02	1.00	1.00	1.01	1.02

Appendix D: Data Collected from FDOT Pavement Condition Surveys

Category	Year	D1	D2	D5	D7	Material Model	Non-Material Model
Cracking	2002	5.67	5.72	5.88	5.29	5.72	5.61
	2003	5.95	6.91	6.46	6.51	6.91	6.31
	2004	6.36	7.18	6.26	7.02	7.18	6.55
	2005	7.36	7.66	6.78	7.56	7.66	7.23
	2006	8.52	8.60	8.34	8.42	8.60	8.43
	2007	9.87	9.88	9.68	9.71	9.88	9.75
	2008	9.76	9.71	9.43	9.59	9.71	9.59
Rutting	2002	7.83	7.64	7.66	6.77	7.64	7.42
	2003	7.88	8.42	8.19	7.55	8.42	7.87
	2004	7.67	8.18	7.62	7.63	8.18	7.64
	2005	7.83	7.88	7.69	7.84	7.88	7.79
	2006	8.24	8.40	8.42	8.30	8.40	8.32
	2007	9.32	9.13	9.20	8.96	9.13	9.16
	2008	9.31	9.15	9.07	8.92	9.15	9.10
Ride	2002	7.48	7.13	7.17	6.64	7.13	7.10
	2003	7.44	7.77	7.48	7.32	7.77	7.41
	2004	6.61	6.93	6.39	6.63	6.93	6.54
	2005	6.74	6.85	6.48	6.84	6.85	6.69
	2006	7.10	7.26	6.95	7.25	7.26	7.10
	2007	8.06	8.11	7.92	7.97	8.11	7.98
	2008	8.04	8.00	7.75	7.94	8.00	7.91
PCR	2002	5.36	5.25	5.54	4.89	5.25	5.26
	2003	5.50	6.19	5.91	5.87	6.19	5.76
	2004	5.53	6.16	5.38	5.98	6.16	5.63
	2005	6.16	6.43	5.63	6.30	6.43	6.03
	2006	6.95	7.05	6.75	6.87	7.05	6.86
	2007	8.05	8.08	7.89	7.95	8.08	7.96
	2008	7.99	7.97	7.71	7.90	7.97	7.87

Appendix E: Data Collected From the Maintenance Rating Program

Roadway				
Year	D2	D5	D3	D7
2001/2002	97	97	92	98
2002/2003	96	96	95	98
2003/2004	97	97	95	97
2004/2005	97	97	95	98
2005/2006	97	96	98	97
2006/2007	97	95	96	95
2007/2008	96	96	98	96

Roadside				
Year	D2	D5	D3	D7
2001/2002	80	82	83	75
2002/2003	80	80	84	79
2003/2004	76	82	85	77
2004/2005	71	80	77	76
2005/2006	76	83	78	80
2006/2007	81	77	77	80
2007/2008	83	79	90	87

Appendix F: Statistical Analysis of the Difference in Quality Indicator Means

IV/V[t-Test: Paired Two Sample for Means]

Statistical Parameters	004L Embankment Material		020LSubgrade Material		054L Select Fill Material		092L Retaining Wall Material	
Variable	*Variable 1*	*Variable 2*	*Variable 1*	*Variable 2*	*Variable 1*	*Variable 2*	*Variable 1*	*Variable 2*
Mean	1	0.994	1.08	0.87666667	1	0.99933333	1.28	1.15733333
Variance	0	4.6667E-05	0.01555	0.03742222	0	2.2222E-06	0.10135	0.11826889
Observations	5	5	5	5	5	5	5	5
Pearson Correlation			0.461525				0.14172658	
Hypothesized Mean Difference	0		0		0		0	
df	4		4		4		4	
t Stat	1.96396101		2.59468776		1		0.63162215	
P(T<=t) one-tail	0.06050196		0.03019246		0.18695048		0.28096536	
t Critical one-tail	2.13184678		2.13184678		2.13184678		2.13184678	
P(T<=t) two-tail	0.12100392		0.06038492		0.37390097		0.56193071	
t Critical two-tail	2.77644511		2.77644511		2.77644511		2.77644511	

IV/V[t-Test: Paired Two Sample for Means]

Statistical Parameters	123L Asphalt Material		160F Concrete Structural Material Field		160L Concrete Structural Material Lab		405L Base Material	
Variable	*Variable 1*	*Variable 2*	*Variable 1*	*Variable 2*	*Variable 1*	*Variable 2*	*Variable 1*	*Variable 2*
Mean	0.9	0.806	1.018	1.026	1	1.01606667	1	1.016
Variance	0.00135	0.00659667	7E-05	0.00021889	0	0.00016902	0	0.00081333
Observations	5	5	5	5	5	5	5	5
Pearson Correlation	0.86846034		-0.7540079					
Hypothesized Mean Difference	0		0		0		0	
df	4		4		4		4	
t Stat	3.99849187		-0.8203031		-2.763369		-1.2545001	
P(T<=t) one-tail	0.00807517		0.22905605		0.02533711		0.1389817	
t Critical one-tail	2.13184678		2.13184678		2.13184678		2.13184678	
P(T<=t) two-tail	0.01615034		0.4581121		0.05067421		0.27796339	
t Critical two-tail	2.77644511		2.77644511		2.77644511		2.77644511	

QC/V [t-Test: Paired Two Sample for Means]								
Statistical Parameters	004L Embankment Material		020LSubgrade Material		054L Select Fill Material		092L Retaining Wall Material	
Variable	*Variable 1*	*Variable 2*	*Variable 1*	*Variable 2*	*Variable 1*	*Variable 2*	*Variable 1*	*Variable 2*
Mean	1	0.99933333	1.058	0.98866667	1	1.01333333	0.992	1.06533333
Variance	0	2.2222E-06	0.02037	0.00153111	0	0.00088889	0.00777	0.09242556
Observations	5	5	5	5	5	5	5	5
Pearson Correlation			-0.7556376				-0.8177149	
Hypothesized Mean Difference	0		0		0		0	
df	4		4		4		4	
t Stat	1		0.89004372		-1		-0.4320875	
P(T<=t) one-tail	0.18695048		0.21186832		0.18695048		0.34397543	
t Critical one-tail	2.13184678		2.13184678		2.13184678		2.13184678	
P(T<=t) two-tail	0.37390097		0.42373665		0.37390097		0.68795085	
t Critical two-tail	2.77644511		2.77644511		2.77644511		2.77644511	

QC/V [t-Test: Paired Two Sample for Means]								
Statistical Parameters	123L Asphalt Material		160F Concrete Structural Material Field		160L Concrete Structural Material Lab		405L Base Material	
Variable	*Variable 1*	*Variable 2*	*Variable 1*	*Variable 2*	*Variable 1*	*Variable 2*	*Variable 1*	*Variable 2*
Mean	0.996	0.99733333	0.998	1.01733333	0.996	1.01066667	1	1.006
Variance	0.00013	0.00136333	0.00037	0.00026333	3E-05	0.00012444	0	0.00024667
Observations	5	5	5	5	5	5	5	5
Pearson Correlation	0.62154947		-0.7955752		0.46371302			
Hypothesized Mean Difference	0		0		0		0	
df	4		4		4		4	
t Stat	-0.0957278		-1.2860342		-3.3166248		-0.8542422	
P(T<=t) one-tail	0.46417046		0.13391321		0.01473566		0.2205564	
t Critical one-tail	2.13184678		2.13184678		2.13184678		2.13184678	

P(T<=t) two-tail	0.92834092		0.26782642		0.02947132		0.44111281	
t Critical two-tail	2.77644511		2.77644511		2.77644511		2.77644511	

Pavement Condition Ratings [t-Test: Paired Two Sample for Means]								
Statistical Parameters	Crack		Ride		Rutting		PCR	
Variable	*Variable 1*	*Variable 2*	*Variable 1*	*Variable 2*	*Variable 1*	*Variable 2*	*Variable 1*	*Variable 2*
Mean	9.878944	9.883729	9.37966	9.400999	7.990274	7.965136	7.978759	7.957807
Variance	0.012961	0.016901	0.099965	0.038681	0.001064	0.000404	0.00198	0.00073
Observations	5	5	5	5	5	5	5	5
Pearson Correlation	0.97935		0.950443		0.442558		0.470599	
Hypothesized Mean Difference	0		0		0		0	
df	4		4		4		4	
t Stat	-0.3623		-0.33371		1.886332		1.179296	
P(T<=t) one-tail	0.367729		0.377678		0.066155		0.151816	
t Critical one-tail	2.131847		2.131847		2.131847		2.131847	
P(T<=t) two-tail	0.735459		0.755356		0.13231		0.303633	
t Critical two-tail	2.776445		2.776445		2.776445		2.776445	

Maintenance Rating Program [t-Test: Paired Two Sample for Means]				
Statistical Parameters	**Roadway**		**Roadside**	
Variable	*Variable 1*	*Variable 2*	*Variable 1*	*Variable 2*
Mean	96.71428571	96.28571429	78.14285714	80.52380952
Variance	0.238095238	0.349206349	16.47619048	6.476190476
Observations	7	7	7	7
Pearson Correlation	-0.247716847		0.567018995	
Hypothesized Mean Difference	0		0	
df	6		6	
t Stat	1.326977605		-1.87911507	
P(T<=t) one-tail	0.116389286		0.054644508	
t Critical one-tail	1.943180274		1.943180274	
P(T<=t) two-tail	0.232778572		0.109289016	
t Critical two-tail	2.446911846		2.446911846	

Appendix G: FDOT Procurement Office Average Hourly Rates

Florida Department of Transportation
Professional Services Information System

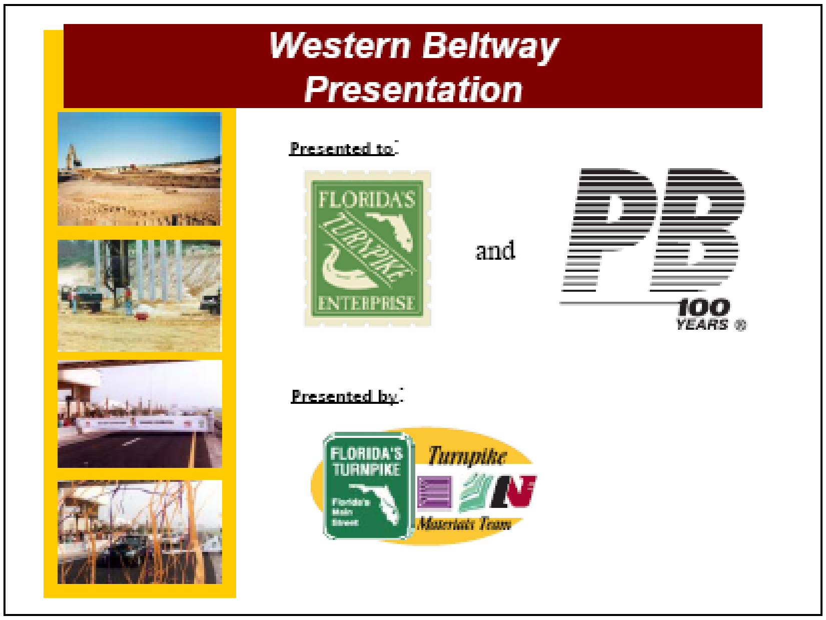
Consultant Wage Rate Averages Report
by Job Classification
For Job Class Wage Rates Uploaded from
Automated Fee Proposal(AFP) Spreadsheets
For the time period from 25SEP2008 to 27MAR2009

STATEWIDE Average Salary Rates							
	Proposed Unloaded Rate Statistics			Negotiated Unloaded Rate Statistics			
Jobclass	25% Quartile	Mean/Avg.	75% Quartile	25% Quartile	Mean/Avg.	75% Quartile	Unit
Acquisition Agent	$36.88	$37.72	$38.56	$36.88	$37.72	$38.56	Hr.
Appraiser	$33.65	$37.32	$39.74	$33.65	$37.32	$39.74	Hr.
Archaeologist	$14.50	$15.95	$14.53	$14.50	$15.95	$14.53	Hour
Architect	$12.00	$16.84	$27.23	$12.00	$17.98	$27.23	Hr.
Architect Intern	$36.80	$36.80	$36.80	$36.80	$36.80	$36.80	Hr.
Certified Bridge Inspector	$27.00	$29.50	$32.04	$27.00	$29.50	$32.04	Hr.
Chief Archaeologist	$34.00	$32.18	$34.00	$31.50	$31.76	$34.00	Hr.
Chief Engineer	$59.00	$66.61	$72.05	$58.89	$65.04	$70.40	Hr.
Chief Scientist	$49.04	$62.79	$56.01	$49.04	$62.79	$56.01	Hour
Chief Utility Coordinator	$45.74	$48.90	$54.27	$45.74	$48.06	$50.09	Hour
Computer Programmer	$27.85	$30.00	$31.08	$27.85	$30.00	$31.08	Hour
Contract Coordinator	$19.92	$21.41	$23.01	$19.92	$20.92	$23.01	Hr.
CADD/ Computer Technician	$18.50	$21.46	$24.42	$18.50	$21.46	$24.42	Hr.
CADD/Computer Technician	$20.66	$23.85	$26.47	$20.66	$23.57	$26.04	Hr.
CEI Asphalt Plant Inspector	$17.51	$20.62	$23.74	$17.51	$20.78	$24.05	Hour
CEI Assist Project Administrator	$26.07	$32.04	$38.00	$26.07	$29.78	$33.50	Hr.
CEI Assoc Contract Support Spec	$19.87	$22.25	$24.63	$19.87	$21.33	$22.80	Hr.
CEI Contract Support Specialist	$28.71	$31.17	$32.98	$28.17	$31.09	$33.17	Hr.
CEI Environmental Specialist							Hour
CEI Inspector/Engineer Intern	$19.64	$20.79	$21.85	$19.19	$20.61	$21.93	Hr.
CEI Inspector's Aide	$13.31	$15.45	$17.00	$13.00	$15.03	$16.48	Hr.
CEI Instrument-Man	$16.33	$16.33	$16.33	$16.33	$16.33	$16.33	Hr.
CEI ITS Inspector	$23.11	$36.33	$49.54	$23.11	$35.08	$47.04	Hr.
CEI Project Administrator/CEI Project Engineer	$38.37	$40.88	$43.77	$38.37	$40.75	$43.77	Hr.

	Proposed Unloaded Rate Statistics			Negotiated Unloaded Rate Statistics			
Jobclass	**25% Quartile**	**Mean/Avg.**	**75% Quartile**	**25% Quartile**	**Mean/Avg.**	**75% Quartile**	**Unit**
CEI Public Information Officer	$26.86	$32.82	$38.78	$26.86	$31.57	$36.28	Hr.
CEI Res Compliance Specialist	$16.50	$18.18	$20.24	$16.50	$18.02	$20.15	Hr.
CEI Resident Compliance Specialist							Hour
CEI Secretary/Clerical Typist	$15.09	$16.52	$18.81	$14.00	$16.32	$18.45	Hr.
CEI Senior Inspector/Senior Engineer Intern	$25.50	$27.24	$28.67	$25.10	$27.16	$28.83	Hr.
CEI Senior ITS Inspector	$23.19	$32.06	$27.04	$23.19	$30.53	$27.04	Hr.
CEI Senior Project Engineer	$51.93	$58.03	$63.57	$51.79	$55.07	$61.90	Hr.
CEI Survey Party Chief	$22.78	$22.78	$22.78	$22.78	$22.78	$22.78	Hr.
CEI Utility Coordinator	$26.15	$31.83	$37.50	$26.15	$31.83	$37.50	Hr.
Designer	$28.50	$31.79	$34.83	$28.50	$31.58	$34.50	Hr.
Engineer	$30.39	$33.36	$36.06	$30.39	$33.26	$36.00	Hr.
Engineering Intern	$26.05	$27.58	$29.00	$26.03	$27.45	$29.00	Hr.
Engineering Technician	$17.10	$20.16	$22.86	$16.88	$20.00	$21.39	Hr.
Environmental Specialist	$24.00	$27.31	$31.21	$24.00	$27.00	$30.15	Hr.
Field Crew Supervisor	$25.70	$28.51	$31.32	$25.70	$28.51	$31.32	Hr.
Geotechnical Engineer	$43.34	$48.34	$53.35	$43.34	$48.34	$53.35	Hour
Geotechnical Technician	$16.90	$18.12	$18.18	$16.90	$18.12	$18.18	Hour
GIS Specialist	$22.42	$24.87	$26.93	$22.42	$24.87	$27.10	Hour
Inspector	$14.98	$20.72	$24.50	$14.98	$20.72	$24.50	Hr.
Instrument Man	$13.32	$14.51	$15.67	$13.32	$14.39	$15.00	Hr.
Land Planner	$37.24	$37.24	$37.24	$37.24	$37.24	$37.24	Hr.
Landscape Architect	$32.07	$33.44	$35.28	$32.07	$33.44	$35.28	Hr.
Landscape Architect Intern	$24.01	$25.47	$26.92	$24.01	$25.47	$26.92	Hr.
Landscape Designer	$22.31	$24.83	$27.35	$22.31	$24.83	$27.35	Hr.
Office Manager/EEO/RCS	$14.00	$15.29	$16.58	$14.00	$15.29	$16.58	Hr.
Party Chief	$19.55	$21.17	$22.85	$19.55	$20.95	$22.13	Hr.
Planner	$26.24	$29.15	$30.45	$26.24	$29.18	$31.55	Hr.
Project Engineer	$35.50	$38.99	$42.90	$35.55	$38.64	$42.00	Hr.
Project Manager	$46.02	$55.24	$61.50	$46.02	$53.73	$60.00	Hr.
Project Planner	$32.21	$35.41	$35.53	$32.21	$35.27	$35.53	Hr.
Public Information Officer	$25.22	$34.91	$42.35	$25.71	$35.03	$42.35	Hr.
Rod Man/Chain Man	$10.67	$11.47	$11.86	$10.75	$11.44	$11.81	Hr.
Scientist	$25.53	$28.39	$32.75	$25.53	$28.39	$32.75	Hour
Secretary/Clerical	$16.22	$18.54	$20.35	$16.39	$18.34	$20.00	Hr.
Senior Accountant	$25.25	$26.46	$27.09	$25.25	$26.46	$27.09	Hr.
Senior Archaeologist	$28.00	$27.03	$28.00	$25.00	$26.53	$28.00	Hour
Senior Architect	$35.50	$41.65	$48.86	$35.50	$41.65	$48.86	Hr.
Senior Engineer	$48.08	$53.44	$56.86	$48.08	$52.93	$56.65	Hr.
Senior Engineer Technician	$15.23	$18.33	$19.88	$15.23	$18.33	$19.88	Hr.
Senior Engineering Technician	$23.64	$26.76	$30.32	$23.68	$26.44	$28.73	Hour
Senior Inspector	$20.58	$24.34	$28.10	$20.58	$24.34	$28.10	Hr.
Senior Landscape Architect	$41.88	$48.94	$52.88	$41.88	$48.94	$52.88	Hr.
Senior Planner	$42.88	$46.19	$52.10	$42.88	$45.92	$51.01	Hr.
Senior Project Engineer	$43.10	$49.49	$53.56	$40.00	$48.41	$53.56	Hr.
Senior Scientist	$38.72	$42.69	$45.76	$38.46	$42.18	$44.98	Hr.
Senior Surveyor & Mapper	$41.75	$46.91	$52.36	$41.75	$46.52	$52.03	Hr.
Senior Utility Coordinator	$34.73	$38.74	$43.27	$34.73	$38.53	$42.45	Hr.
Survey Technician	$21.62	$25.01	$29.71	$21.62	$24.81	$29.71	Hr.
Surveying Intern	$31.00	$32.68	$31.00	$30.25	$32.47	$31.00	Hr.
Surveyor & Mapper	$34.32	$38.77	$39.63	$34.32	$37.52	$39.50	Hr.

	Proposed Unloaded Rate Statistics			Negotiated Unloaded Rate Statistics			
Jobclass	**25% Quartile**	**Mean/Avg.**	**75% Quartile**	**25% Quartile**	**Mean/Avg.**	**75% Quartile**	**Unit**
Technician Aid	$13.25	$16.38	$19.25	$13.25	$16.38	$19.25	Hr.
Utility Coordinator	$25.49	$28.03	$29.87	$25.49	$28.03	$29.87	Hr.
Utility Locator	$19.67	$22.83	$23.51	$21.00	$22.53	$23.51	Hr.
Utility Technician	$11.83	$13.63	$15.39	$11.83	$13.63	$15.39	Hour

Appendix H: Turnpike Study



MATERIALS MODEL

Materials Model is a Construction Inspection Concept Developed to Enhance the Inspection Services Provided to the Client by Aiding in the Contractor Quality Control Process.

Inspection Services Used to Include Sampling/Testing of the Materials for Quality/Pay

On-Site Testing/Less Time for Inspections

QC 2000 (CQC)

Contractors Responsible/Quality

Verify Results/More Inspection Time

QC 2000 / CQC

Non-Materials Model
(CEI Verifies Contractor)

- Inspections (CEI)
- On-Site Materials Testing
  - (CEI)
    - Sampling
    - Concrete
    - Embankment
    - Base
    - Pipe Backfill
    - Wall Backfill
    - Topsoil
    - Asphalt Paving
    - Log Books
    - Data Entry – LIMS/CQR
    - Coordinate Asphalt Plant
  - (Materials Consultant)
    - Asphalt Plant Testing
    - Lab Testing/Materials

Materials Model
(Materials Consultant Verifies Contractor)

- Inspections (CEI)
- On-Site Materials Testing
  - (Materials Consultants)
    - Sampling
    - Concrete
    - Embankment
    - Base
    - Pipe Backfill
    - Wall Backfill
    - Topsoil
    - Asphalt Paving
    - Log Books
    - Data Entry – LIMS/CQR
    - Asphalt Plant Testing
    - Lab Testing/Materials
    - Coordinate Asphalt Plant

WHY THE WESTERN BELTWAY?

Location

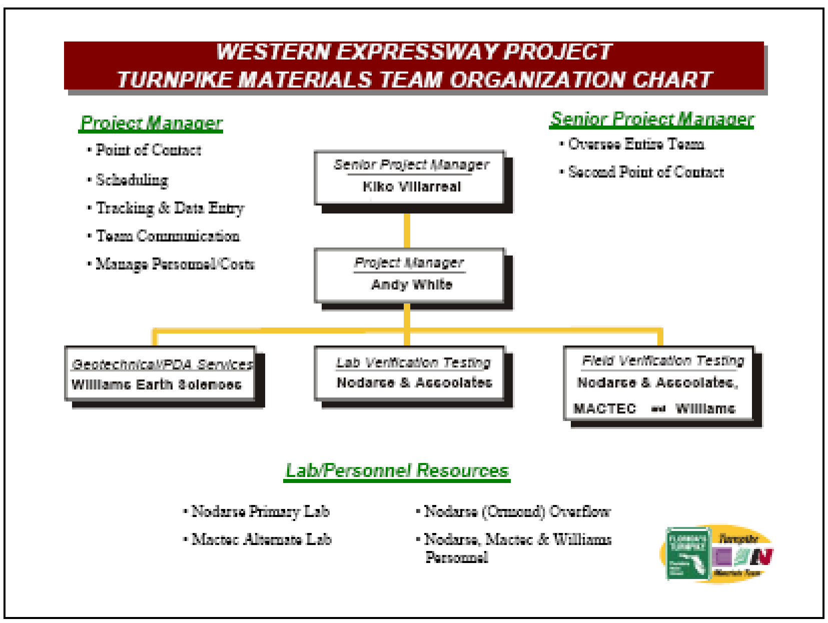
- Convenient/Turkey Lake Office
- Laboratory Resources
- Personnel

Size of Project

- $115,000,000.00
- New Construction/Materials

Timing

WESTERN BELTWAY MATERIALS MODEL OVERVIEW



IN THE BEGINNING CHALLENGES

Pre-Construction

- Confidence from CEI
- Confidence from Contractor
- Change in Responsibilities

Construction Begins

- Plotting Log Books
- Roles and Responsibilities
- What is Testing, What is Inspection
- Time Management

Progress

Changes

Pre-Construction

✓ Plotting logbooks Materials/Contractor
✓Define roles and responsibilities

During Construction

✓Materials point of contact
✓Monthly (as needed) Materials Model meeting

•*Benefits of the Materials Model*

Enhanced Quality

- CEI Focuses on Inspection
- Materials Team Focuses on Testing
- Everyone is in the Loop and Working Together
- Quicker Response Times
- Quicker Lab Turn Around
- Added Level Inspection
- Experienced Cross Trained Personnel

CEI Comments & Responses

- "As with our work, I feel that the success really depends on the staff. Having personnel who take there job seriously is the reason things have gone well on the project. Because of the closeness of both our teams, we have been able to correct, adjust and resolve issues. I have been pleased with the results and expect to complete this project with the quality that the owner expects."

  R. Karl Trewick, P.E.
  Senior Project Engineer
  Western Beltway Part C

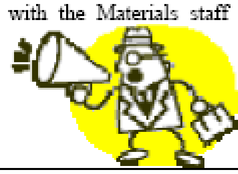
- "We think that the Materials Model allows the material and inspection personnel to perform in their area of specialty which facilitates improved quality; i.e. material staff can concentrate on material issues and inspection personnel can concentrate on inspection issues."

  Rhett L. Leary, P.E.
  Florida Construction Services
  Director, HNTB Corporation
  Western Beltway Part C

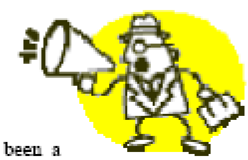
CEI Comments & Responses

- "1) One of the most favorable aspects is the extra set of eyes in the field. On several occasions throughout the embankment placement, the pace in which the fill material is being received, requires testing at such a rate that the materials testers are required to stay with those operations. While materials are performing the actual testing, that time we would be spending is utilized in the inspection of other issues.
  2) Another major help is no longer are we utilizing our staff to deliver samples to off-site locations (for lab testing). Again this allows more inspection time on-site.
  3) The handling of site manager (LIMS), most time consuming, data entry, again frees our staff to continue site inspection. Our office administrations can devote all there time to product issues.
  4) Bridge deck, concrete placement, in past placements the CEI handled the testing with most of these pours taking place at night, on most cases, the staff performing the testing would also be required to perform their day-time operations. This always caused strains on the staff and safety issues. That no longer applies with the Materials staff handling the testing."

  Rob Pollock, P.E.
  Senior Project Engineer
  Western Beltway Part C



CEI Comments & Responses



- It is my opinion that the Materials Model has been a benefit to the Western Beltway project. It allows key individuals with the necessary field experience to coordinate with the contractor's personnel to ensure that the product desired by the Department is achieved, while allowing our roadway and building inspectors to perform their daily inspection responsibilities."

Tracey Keenan, P.E.
Senior Project Engineer
Greenhorne & O'Mara, Inc.
Western Beltway Part C

Contractor Comments & Responses

- "there is more of a comfort level knowing that the watchers are being watched. It feels good to know that the verification personnel (materials team) are being inspected along with the contractors personnel."

Jack Bowles
QC Manager
Granite Construction

How much is it costing?

Progress

- Section 1 and 2A, Gilbert - 234/780 days - 30%
- Section 2B and 3A, Granite - 404/681 days - 59%
- Tolls, Gilbert Southern - 345/820 days - 42%

Construction costs 5/01/05

• Section 1& 2A, Gilbert	$17,453,000.00	
• Section 2B &3, Granite	$28,118,000.00	
• Tolls, Gilbert Southern	$4,390,000.00	
• Total Construction Costs to Date	$49,474,000.00	44%
• Awarded Construction Amount	$114,917,000.00	
• Materials Team Proposed Costs to Date	$853,000.00	.75%
• Materials Team Actual Costs to Date	$736,000.00	.64%
• Difference to Date (Savings)=	$117,185.07	

Materials Testing Costs
Non-Materials Model

Typical construction job 1% to 1.5%

+ Additional Geotechnical (PDA, Vib. Monitoring)

✓Materials Lab Testing

✓Asphalt Plant Inspections

New Construction Costs 1.5% to 2.0%

+ Additional Geotechnical (PDA, Vib. Monitoring)

✓Materials Lab Testing

✓Asphalt Plant Inspections

Proposed Costs

Projected 2% of construction costs
Western Beltway-Materials Team

✓Materials Lab Testing

✓Asphalt Plant Inspections

✓Asphalt Paving Inspections *

✓Field Testing *

✓Materials Sampling and Recording *

✓PDA

✓Vibratory Monitoring

✓Misc. GEO Services

* Indicates services typically done by CEI

Materials Testing Costs

Western Beltway materials totals

- 10 Miles of New Construction
- Embankment 4,909,575 cy
- Subgrade 1,034,951 cy
- Base 744,099 sy
- Concrete 12,976 cy
- Bridges 13 total

Typical CEI Costs

- CEI (typically) 12% to 15%
- Materials (typically) 1.5% to 2%
- CEI Awarded <10%
- Materials Proposed 2%
- Total 12% of Construction Costs
- Difference from Typical 1.5% to 5%

Actual CEI Costs

- CEI Percent of Construction 7.29% 4/1/05
- Materials Team Percent of Const. 1.49% 5/1/05
- Total Percent of Construction 8.77%
- Range of Percent Difference 4.73% to 8.23%

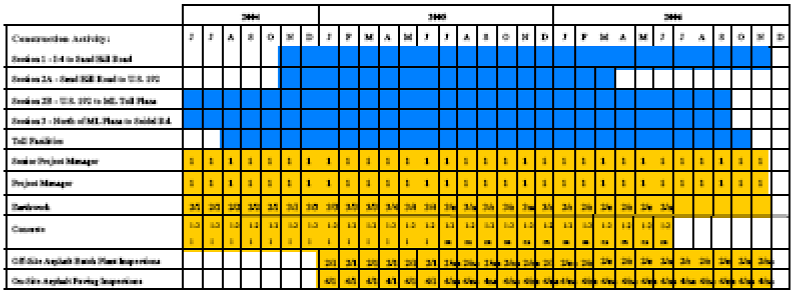
Construction Costs to Date

- Section 1 & 2A, Gilbert $17,453,000.00
- Section 2B & 3, Granite $28,118,000.00
- Tolls, Gilbert Southern $ 4,390,000.00
- Total Construction Costs $49,474,000.00
- CEI/Materials % of Construction 8.77%
- % Range Difference 4.73% to 8.23%
- Inspection/Testing Savings to Date…..

$2,340,121.99 to $4,071,713.32


Bottom Line
• Structured Project
• Accurate and Detailed Testing Results
• Tighter Communication
• Quick Response Time
• Higher Quality Construction
• Lower Costs
It just makes cents…..

WESTERN EXPRESSWAY PART C PROJECTS MANPOWER SCHEDULE

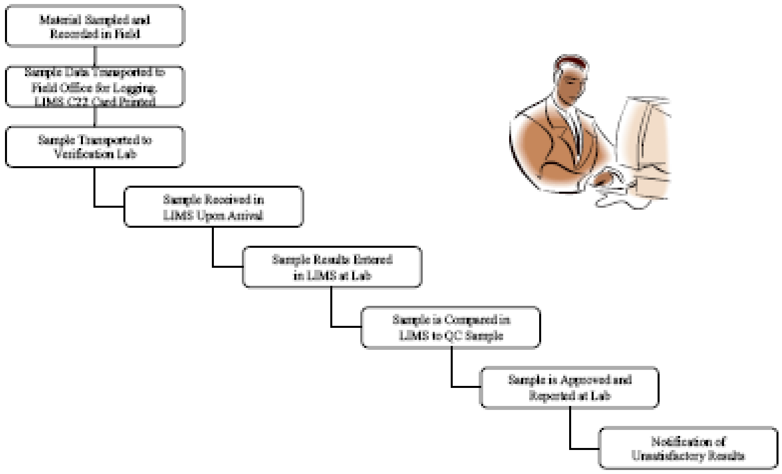


Notes: Blue shading denotes project construction activities.
Yellow shading denotes Turnpike Materials Team staff providing testing/inspection services during the course of construction activities.
Top numbers in boxes denote number of staff anticipated to complete task(s).
Bottom numbers in boxes denote actual number of staff

LIMS PRACTICES

- INVOLVEMENT FROM DEVELOPMENT TO IMPLEMENTATION
- INVOLVEMENT WITH PILOT PROJECTS

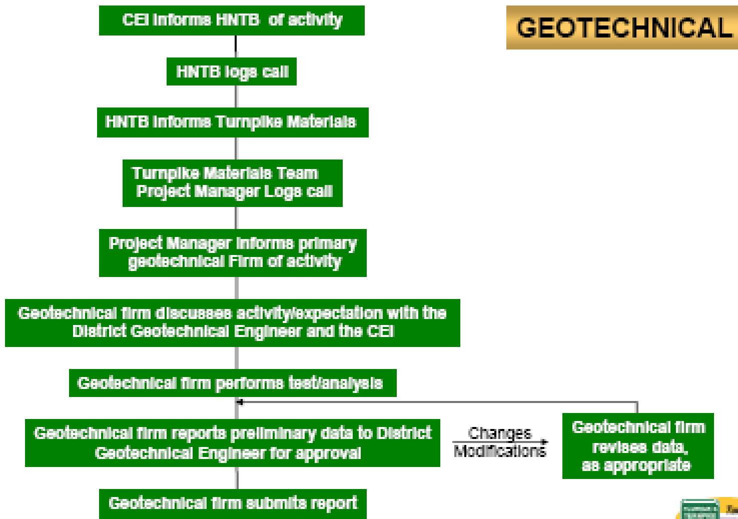
LIMS DATA ENTRY PROCESS



LEADERSHIP MATERIALS TESTING GUIDANCE

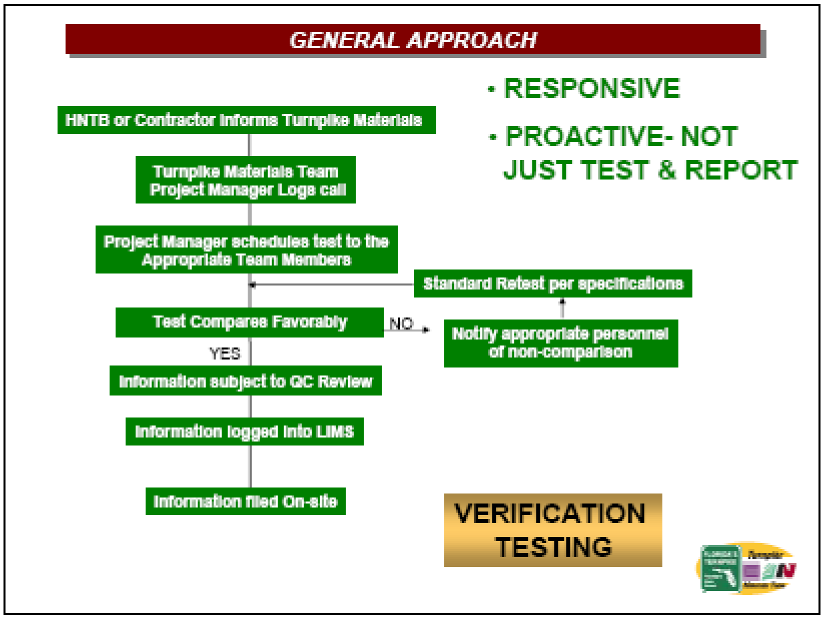
- CROSS TRAINING IS KEY
- QUALIFICATION, EXPERIENCE, MOTIVATION
- AVAILABLE RESOURCES = ESTUARY

GENERAL APPROACH



AVAILABLE SPECIALIZED EQUIPMENT

Location	Drill Rigs						PDA/Pile	Vibration Monitoring
	Truck	ATV	Track	Amphibious	Barge	Other		
Jacksonville	1	1			1	1	1	1
Largo	8	2	1	1		2	2	2
Miami	1						2	2
Orlando/Winter Park	2	3	1	1	1	3		
Panama City	1					1	1	
Pompano Beach	1					1	1	1
Tampa	1	1					1	2
West Palm Beach		1						
TOTALS	15	8	2	2	2	8	8	8


GENERAL APPROACH
• RESPONSIVE
• PROACTIVE- NOT JUST TEST & REPORT
HNTB or Contractor Informs Turnpike Materials
Turnpike Materials Team Project Manager Logs call
Project Manager schedules test to the Appropriate Team Members
Standard Retest per specifications
Test Compares Favorably
NO
Notify appropriate personnel of non-comparison
YES
Information subject to QC Review
Information logged into LIMS
Information filed On-site
VERIFICATION TESTING


SERVICE ADVANTAGES OF YOUR TEAM
LOCATION
Primary Lab Facility
Field Technicians
Nodarse in Winter Park
Alternate Lab Facility
Field Technicians
MACTEC in Orlando
Alternate Lab Facility
Nodarse in Ormond Beach
Geotechnical/PDA Services
WES in Largo
Additional Field Technicians
MACTEC and Nodarse in Tampa
WESTERN EXPRESSWAY - PART C
TURNPIKE SYSTEM EXPANSION
PROJECT
I-4
Volusia
Seminole
Lake
Orange
I-4
Osceola
Polk
Hillsborough

SERVICE ADVANTAGES OF YOUR TEAM

RESOURCES

PERSONNEL	Asphalt Paving Level 1	Asphalt Paving Level 2	Asphalt Plant Level 1	Asphalt Plant Level 2	Earthwork Const. Level 1	Earthwork Const. Level 2	Aggregate Field	Aggregate Laboratory	LBR	ACI Level I	Concrete Level 1 Field	Concrete Level 1 Laboratory	Prestressed Conc. Insp.	Pile Driving Insp.	Drilled Shaft Insp.	QC Manager
Resource of Local Personnel	19	10	19	16	26	16	8	3	6	33	13	6	4	7	4	3

SERVICE ADVANTAGES OF YOUR TEAM

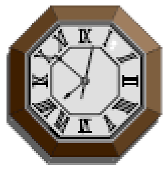
EXPERIENCE

- S.R. 429 (Western Expressway) Part A Materials Testing, Inspection and PDA
  Orange County, Florida
- S.R. 570 (Polk Parkway) Materials Testing, Inspection and PDA
  Polk County, Florida
- S.R. 417 (Seminole II Expressway) Materials Testing, Inspection and PDA
  Orange County, Florida
- S.R. 589 (Veterans Expressway) Independent Assurance and PDA
  Hillsborough and Pasco Counties, Florida
- S.R. 589 (Suncoast Parkway) Independent Assurance Testing and Inspection
  Pasco and Hernando Counties, Florida

SHARED RESOURCES

APPROACH TO MITIGATION OF RISK AREAS

- Short notification of need at project
- Detection of work fluctuations



- ONSITE – FULL-TIME
- COMMUNICATION
- WEEKLY PROGRESS MEETING
- WEEKLY VERIFICATION STAFF MEETING
- PROJECT STATUS MEETING

APPROACH TO MITIGATION OF RISK AREAS

- Disposition of missing QC tests

- PROACTIVE
- AVAILABLE TOOLS
  - -EXPERIENCE FULL-TIME PERSONNEL
    - - SITE VISITS BY SEN. PROJECT MANAGER
  - - DENSITY LOG BOOK
  - - QC/CEI QUANTITY TRACKING SHEETS
  - - LIMS
- TIMELINESS

APPROACH TO MITIGATION OF RISK AREAS

❑ **Cost Controls**

- *PROJECT MANAGER- ANDREW WHITE*
- *STATUS MEETING*
  - *GOAL- BALANCE OF MANPOWER/EQUIPMENT & PROJECT NEEDS*
  - *MINIMIZING OVERTIME*
  - *OTHER COST CONSIDERATIONS*
- *QUARTERLY QUANITY/COST MEETING*

TEAM IDENTIFIED RISKS & MITIGATION PLANS

A TEAM

Communicates
Plans
Executes

As

ONE

❑ ***COMMUNICATION***

- *EVERYONE IN THE LOOP*
- *EMAIL OF ACTIVITY*
- *IMMEDIATE NOTIFICATION REQUIRING ACTION ITEMS (NEXTEL)*

❑ ***OBTAINING CONFIDENCE***

- *MATERIALS MODEL*
- *LIMS*
- *CHANGE IN RESPONSIBILITY*
- *EXPERIENCE*

SUMMATION

EXPERIENCE

RESOURCES

EXPERTISE

LOCATIONS

+ COMMITTMENT

IT JUST ADDS UP!!!

SUCCESS

PERSONNEL

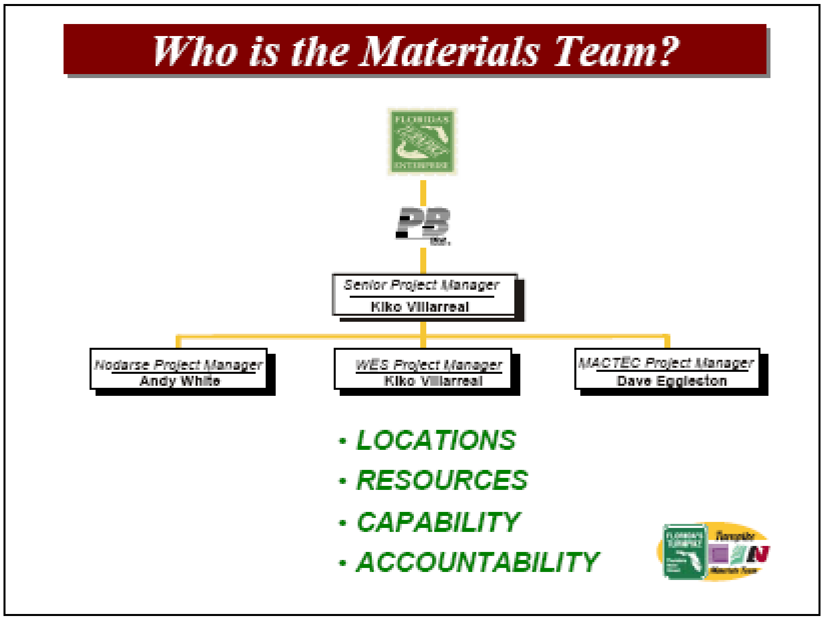
EXPERIENCED

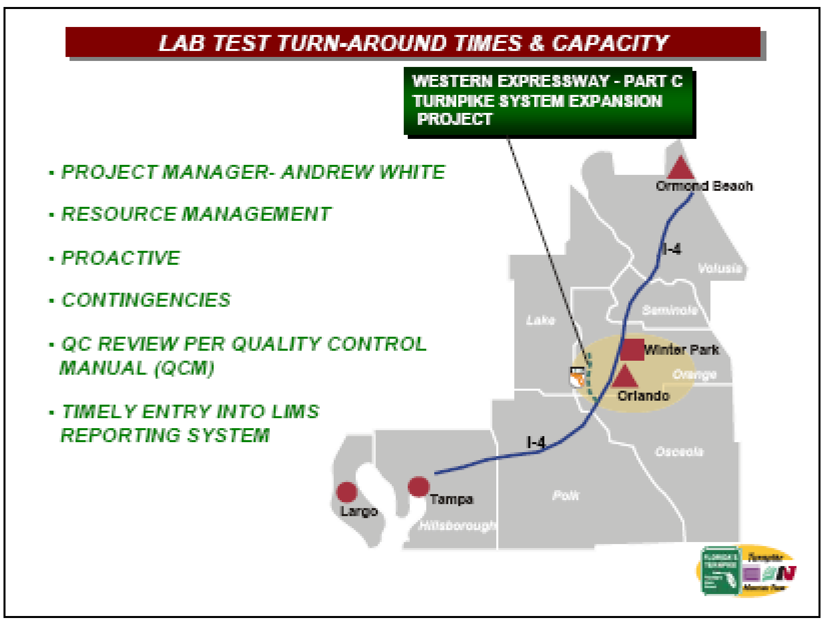
- CTQP & Other Qualifications
- Cross Trained

DIVERSIFIED

- Ability to Handle Other Projects
- Proposed Staffing Plan

LAB TEST TURN-AROUND TIMES & CAPACITY


Who is the Materials Team?
Senior Project Manager
Kiko Villarreal
Nodarse Project Manager
Andy White
WES Project Manager
Kiko Villarreal
MACTEC Project Manager
Dave Eggleston
• LOCATIONS
• RESOURCES
• CAPABILITY
• ACCOUNTABILITY


LAB TEST TURN-AROUND TIMES & CAPACITY
WESTERN EXPRESSWAY - PART C
TURNPIKE SYSTEM EXPANSION
PROJECT
• PROJECT MANAGER- ANDREW WHITE
• RESOURCE MANAGEMENT
• PROACTIVE
• CONTINGENCIES
• QC REVIEW PER QUALITY CONTROL MANUAL (QCM)
• TIMELY ENTRY INTO LIMS REPORTING SYSTEM
Ormond Beach
I-4
Volusia
Seminole
Lake
Winter Park
Orange
Orlando
I-4
Osceola
Polk
Tampa
Largo
Hillsborough

Appendix I: Inspector General Memorandum

May 24, 2007

Advisory Memorandum 06P-0014
Contractor Quality Control Survey

For the Inspector General

EXECUTIVE SUMMARY

This advisory memorandum provides the results of the Contractor Quality Control (CQC) survey. At the request of the Assistant Secretary for Engineering and Operations, we conducted a survey of the CQC process to obtain the opinions of Department personnel and Construction Engineering and Inspection Consultants (Consultants) on the effectiveness of the CQC process. The survey included questions about the quality of the work, verification testing, Laboratory Information Management System (LIMS), and the Quality Control (QC) Plan. The CQC Survey was sent to 130 Department personnel and 200 Consultants with a response rate of 22% and 42%, respectively.

Based on the responses received from the survey, we observed that Consultants provided more feedback than DOT personnel, expressed stronger opinions, and generally had more negative responses on the effectiveness of the CQC program. One of the most notable concerns is the controlling influence contractors have over the Quality Control Managers' decisions. Another issue is the inexperience of Quality Control Managers and technicians and the additional responsibility placed on the Department and Consultants to provide training. Also of concern to respondents is the need to improve LIMS and the need for tougher consequences for non-compliant contractors. Our memorandum provides the survey results for each question, a judgmental sample of comments, and insightful suggestions for improvements offered by Department personnel and Consultants. We appreciate the opportunity to provide this service. An official response to this memorandum is not required. If you have any questions, please contact Marnie Parry at 410-5844.

For the Inspector General

BACKGROUND AND INTRODUCTION

At the request of the Assistant Secretary for Engineering and Operations, we performed preliminary work to determine whether the Department was receiving value for the funds spent on CQC. After a discussion with Central Office and District 2 personnel, we concluded that the costs associated with CQC were not segregated from other project costs and, therefore, could not be accurately evaluated. In addition, the Department did not track quality control costs prior to QC2000 to allow a comparison study. As an alternative, and at the request of the Assistant Secretary for Engineering and Operations, we prepared a web-based survey to obtain information about the CQC program.

A web-based survey was distributed to 130 Department personnel (including project, material, geotechnical, construction, and bituminous engineers and project administrators) and 200 Consultants. The survey listed the following eight statements and provided an opportunity to comment:

1. There has been an improvement in quality since CQC was implemented.
2. Verification testing is effective in assuring contractor quality control testing results are accurate.
3. Verification testing is performed randomly, without prior knowledge by contractor personnel.
4. Contractor quality control testing data is entered into the Department's database within 24 hours of testing.
5. I trust that contractor personnel are performing their sampling and testing duties as required.
6. The contractors' Quality Control Managers are resolving specification compliance issues timely as part of their duties and responsibilities.
7. The Department regularly monitors contractor compliance with the CQC Plan.
8. CQC should be expanded to include other materials of work in addition to materials currently tested.

The following chart provides information about the number of responses received.

	Department	%	Consultants	%	Total
Responses					
Number sent	130		200		330
Number returned	29	22%	84	42%	113
Comments					
Responses	29		84		113
Responses with comments	20	69%	72	86%	92
Number of comments made	46		178		224

SURVEY RESULTS

Over 50 percent of respondents agree that the Department regularly monitors contract compliance with the CQC Plan, verification testing is performed randomly, and the results are accurate.

Results also show that over 50 percent of respondents do not see improvement in quality since CQC was implemented and are concerned about the lack of timeliness of both LIMS data entry and resolving Specification compliance issues.

In addition, our analysis of survey comments showed the following five areas were most often mentioned as a concern by respondents:

- Controlling influence contractors have over the Quality Control Managers' decisions;
- Lack of Quality Control Manager experience and the need for training;
- LIMS input and processing problems;
- Need for tougher consequences for non-compliant contractors; and
- Quality of work issues - requests to return quality control to the Department.

The eight survey questions and the responses are listed below:

	Department Personnel			Consultants		
	Agree	Disagree	Neutral	Agree	Disagree	Neutral
1) There has been an improvement in quality since CQC was implemented.	23%	54%	23%	23%	69%	8%
2) Verification testing is effective in assuring contractor quality control testing results are accurate.	64%	22%	14%	52%	34%	14%
3) Verification testing is performed randomly, without prior knowledge by Contract personnel.	54%	28%	18%	75%	15%	10%
4) Contractor quality control testing data is entered into the Department's database within 24 hours of testing.	32%	61%	7%	16%	70%	14%
5) I trust that contractor personnel are performing their sampling and testing duties as required.	32%	36%	32%	38%	46%	16%
6) The contractors' Quality Control Managers are resolving specification compliance issues timely as part of their duties and responsibilities.	25%	54%	21%	13%	67%	20%
7) The Department regularly monitors contractor compliance with the CQC plan.	68%	18%	14%	72%	8%	20%

8) CQC should be expanded to include other materials of work in addition to materials currently tested.	18%	55%	27%	14%	67%	19%

A summary of the survey and a sample of respondents' comments are presented in the remainder of the memorandum. In addition, suggestions for improvement by Department personnel and Consultants, at the end of the memorandum, offer valuable insight and ideas for increasing the effectiveness of the CQC program.

STATEMENT 1	Department Personnel			Consultants		
	Agree	Disagree	Neutral	Agree	Disagree	Neutral
There has been an improvement in quality since CQC was implemented.	23%	54%	23%	23%	69%	8%

Survey comments include:

Department Personnel

- Overall, the Quality Control Manager is not as involved in the quality aspects as they could be or should be. There are some excellent Quality Control Managers but they are few. I would like to see Industry more actively (or really proactively) involve the Quality Control Manager and have that person report to someone outside of the Production demands. There are some isolated instances when the Quality Control Manager is overruled by the person in charge of production for the contractor. If we could refine in this area, then we would almost have a "perfect" system.

Consultants

- There has been an increase in quality since the inception of CQC. At first the quality went down as some contractors tried to circumvent CQC, but most of the contractors now realize the system is here to stay and have adapted to it;
- CQC provides the necessary paperwork, but not the quality control required to insure a quality project.
- I have seen very little problems with the product based on material failures, but I have seen issues with the quality of workmanship of the product being used;
- Quality in the CQC program can only be achieved when all testing is performed by persons not associated with the contractor.
- Quality Control Managers are generally not given the authority to make changes on site and are usually subordinate to the superintendent.
- The contractor's Quality Control Manager is being constantly overruled by the

contractor's superintendent and/or project manager because they are more interested in production (profit) rather than quality. If the quality control does not have complete control of the quality of work on the Project than the CQC system does not work as intended.

- The process does not improve quality as much as it helps coordination during the project. It does make the contractor responsible for coordination of tests for which he cannot say he is being held up by someone else. The contractor having knowledgeable people who are not afraid to speak up when a deficiency occurs would help the situation.
- The contractor's quality control personnel have little if any construction experience and cannot fill out daily reports properly, let alone resolve issues regarding the quality of the finished product.
- CQC does not increase the job quality as compared to non-CQC projects because the first line of inspection (quality control) as a whole does not have the experience of FDOT or CEI personnel.
- Quality issues are being handled after the fact and many times a balance has to be attained between questionable quality and other goals such as timely completion and cost control. These are the pressures being placed upon the CEI industry due to CQC.
- Overall the system appears to be working well but needs a little tweaking. The Department/CCEI should have more "tools" to deal with uncooperative/

noncompliant contractors.

- Monitoring the CQC Plan has not resulted in quality work. It more often results in project stop work and delays.
- Production and Quality Control have always battled to achieve a quality product and still maintain profitability. With quality control placed in control of production, it certainly becomes an unleveled playing field with quality control always facing an uphill battle.

STATEMENT 2	Department Personnel			Consultants		
	Agree	Disagree	Neutral	Agree	Disagree	Neutral
Verification Testing is effective in assuring contractor quality control testing results are accurate.	64%	22%	14%	52%	34%	14%

Survey comments include[1]:

Department Personnel

- We have several missed quality control tests particularly in Earthwork and Concrete. Since this is contractor quality control, pay penalties or non-payment for lots not tested should be considered in the specifications.

Consultants

- When the contractor is not observed 100% of the time he has the tendency to take shortcuts during the sampling and testing process that will never be caught.
- The quality control technician and Verification technician have to keep separate log books, both of which are identical.

Logging verification tests into the same log books would eliminate errors between books and would make it easier to ensure all verification tests are taken as required.
• Entry of results into LIMS is inconsistent and has, on multiple occasions, resulted in the inability to properly test resolution samples.

1 The only comments in the survey associated with Statement 2 were those in disagreement with the statement.

STATEMENT 3	Department Personnel			Consultants		
	Agree	Disagree	Neutral	Agree	Disagree	Neutral
Verification Testing is performed randomly, without prior knowledge by contractor personnel.	54%	28%	18%	75%	15%	10%

Survey comments include:

Consultants

• Asphalt and Concrete verification testing is random, but verification on Earthwork lots are controlled by the contractor.
• In the field, it is nearly impossible to keep verification tests completely random and effective such as in earthworks. If CQC is the way to go, then the verification testing (VT) has to be random, not per lots, but completely random. Or else, do away with VT's and rely on a contractor's certification and a warranty period for all work after developing criteria to measure failure.

STATEMENT 4	Department Personnel			Consultants		
	Agree	Disagree	Neutral	Agree	Disagree	Neutral
Contractor quality control testing data is entered into the Department's database within 24 hours of testing.	32%	61%	7%	16%	70%	14%

Survey comments include:

Department Personnel

• Quality control is not being entered on time. That causes the delay in the verification and the comparison and the approval of samples in LIMS.

Consultants

• Quality control personnel in general do not input results within 24 hrs.

• There needs to be a better way to control the VT labs. Whether its asphalt or soils there's a problem with getting test results and LIMS entry in a timely manner.

• One issue is LIMS. Simple mistakes such as “typo's” turn into a long process such as roll back samples, e-mails to change and re-enter/validate/approve etc. I would make changing information easier and allow the project administrator to approve all samples that they have to review which are missed by the labs.

• LIMS seems to make the process drag on. Every time we have a problem, it goes back to LIMS. This includes password problems.

• LIMS is a major problem. The responsibility for improper LIMS entry always falls on the CEI company associated with the project. Results should be sent to one entity and all results should be entered by one source.

STATEMENT 5	Department Personnel			Consultants		
	Agree	Disagree	Neutral	Agree	Disagree	Neutral
I trust that contractor personnel are performing their sampling and testing duties as required.	32%	36%	32%	38%	46%	16%

Survey comments include:

Consultants

• It is not a matter of trust, but it is necessary for us (Consultants) to constantly monitor and remind CQC personnel of their responsibility.

• Quality Control managers still do not step in when there is deficient work. The CEI has to do it. Contractors tell the Quality Control Manager that they work for the contractor not the Department.

• "Trust but verify" approach leaves the door open to what some QC consider "minor" variances from procedure, but in fact lead them down the road of cutting corners.

• The contractor's quality control people on site are often the least knowledgeable about the material and how to test it properly. They have received the minimum training. This is to be expected as they are generally the lowest paid certified people in the industry.

• There's still a concern with the Quality Control holding resolution samples. There should be a "neutral" place to store these so as to eliminate any "tampering" concerns.

STATEMENT 6	Department Personnel			Consultants		
	Agree	Disagree	Neutral	Agree	Disagree	Neutral
The contractors' Quality Control Managers are resolving specification compliance issues timely as part of their duties and responsibilities.	25%	54%	21%	13%	67%	20%

Survey comments include:

Consultants

- Many quality control technicians do not hold the contractor to contract specifications due to "not wanting to upset the client they work for".
- There's a real problem with ensuring that specs are being met. This puts the burden on the VT / CEI. It should be more clear what the quality control responsibilities are besides showing up to perform sampling/ testing.
- Even though we partner with the contractor to ensure the job gets built in accordance with the specs, it takes a lot of communication and effort to get the "paperwork" done. Also the contractor's quality control should be limited to a number of jobs because they tend to forget some jobs and only react upon our calling them to remind them.
- As a Project Administrator I have spent hours arguing with Quality Control Managers about why the specifications should be enforced.
- Contractor quality control personnel do not seem to have a sense of urgency in resolving paperwork issues during the construction. They only want to continue the construction until the end of the project, then go back to resolve the outstanding testing paperwork.
- The contractor's personnel do not seem to have a handle on completing the required reports (asphalt, concrete, earthwork) to provide FDOT/CEI personnel the information required to certify material or compile the final estimate.
- Very few contractors accurately measure and record field items, and are

clueless when filling out FDOT required forms.

- Testing and sampling are being performed, but the inspection is either not being done at all or being done very poorly. The CEI in most cases is doing the

Inspection.

- Typically, the quality control function is assigned to someone who also has numerous

other duties and responsibilities and quality control is not high on their priority list.
• Some contractors just ignore the issues until their quality control plan is pulled.

STATEMENT 7	Department Personnel			Consultants		
	Agree	Disagree	Neutral	Agree	Disagree	Neutral
The Department regularly monitors contractor compliance with the CQC plan.	68%	18%	14%	72%	8%	20%

Survey comments include:

Department Personnel

• District Construction and Materials work collaboratively to monitor the contractor’s compliance with the quality control plan.
• The Department looks for a quality product from the contractor. Therefore, they regularly monitor contractor compliance with the CQC plan.
• On some projects, there are too many revisions to the original quality control plan to retain effective oversight by the Consultant.
• The Quality Control Managers submit incomplete monthly compliance reports to the project engineers and that makes it difficult to monitor the activities by the project engineers.
• It is the duty of the project engineer and the Quality Control Managers to make sure that contractors comply with the CQC plan guideline. So far I don't see any control by the Department in this manner.

Consultants

• FDOT only gets involved when the entries for concrete and asphalt are late and during the final estimate acceptance period; otherwise, they are hands off for the most part.
• Some Districts choose to take on the role as owner of the CQC Plan and do not expect the contractor to take responsibility for the plan.
• The Department and the CEI both review compliance with the plans, but the specifications need to make the contractors more liable.

STATEMENT 8	Department Personnel			Consultants		
	Agree	Disagree	Neutral	Agree	Disagree	Neutral
CQC should be expanded to include other materials of work in addition to materials currently tested.	18%	55%	27%	14%	67%	19%

Survey comments include:

Department Personnel

• Adding the materials that currently are accepted by their certification might be a good idea, for example, the materials listed in Qualified Products List, auger cast piles, steel, deck thickness.

Consultants

• Contractors have yet to master quality control of the materials currently included in the CQC program.
• Contractor personnel have difficulty in properly documenting their current material responsibilities.
• CQC is working for asphalt; other materials, not so much;
• Asphalt and concrete are logical areas for CQC. Soils still have concerns with both the contractors and Consultants.
• It is already hard enough to get the contractors to address problems with LIMS for the pay items, proper sample coding and testing. The contractors do not spend enough time training their personnel or review the work. Additional materials would require additional time reviewing and additional corrections (by the Department).
• If "other materials" are needed to be further scrutinized, then simply have the manufacturer or contractor certify it.

Additional concerns mentioned by Consultants

Survey comments include:

- Consultants have taken on the role of mitigating problems after the fact, rather than focusing on early prevention of problems.
- There is not an appreciable reduction in Consultant man-hours because project personnel must be present to conduct verification (VT) samples. In many instances, additional man-hours are expended to:

-Follow up on unresolved problems or differences between the contractor's quality control samples and VT samples;
-Train technicians on the job;
-Correct quality control errors before a completed project can be certified;
-Enforce asphalt specifications and check asphalt paperwork that is too complicated for contractor personnel.

- Consultants (not contractors) receive the majority of complaints from the Department concerning LIMS errors, mistakes in contractor reports (asphalt), and erroneous log books (densities). It takes more time to find someone else's mistake and correct it, than to correct your own mistake.
- Although quality control inspectors have the requisite CTQP certifications, in many instances they lack practical experience on FDOT projects. Consequently, project personnel will spend time training these individuals that could otherwise be spent inspecting the work.
- After training the Quality Control Managers to have a good understanding of your project, he/she quits to go work for a Consultant. Also, the contractor will send a different quality control technician for the same job and each one does not have a set of plans or understands the project. The verification people (including the Department) find themselves doing the "training" all over again. The one thing I know has made the quality control program possible is the continuous support I get from the Department Materials personnel (D4, D6, Gainesville). If it was not for them we would be in bad shape. They are a blessing in disguise.
- The CQC program does not provide the quality of work once achieved when the CEI performed this role. It also requires more effort from the CEI to assure that the contractor is performing his required testing responsibilities.
- Quality Control Managers need to be more involved in projects. Some Quality Control Managers who are hired from a test lab rarely set foot on the project and have little knowledge of problems or issues associated with the project.
- The main criteria for dealing with significant CQC compliance issues are timeline and budget. The producers know this and utilize it to their advantage. Until the Department allows their representatives the freedom to deal with compliance issues without concern for how it affects timeline and budget, the contractors know they have the upper hand. This also lessens the FDOT's image

with the contractor's and industries.

SUGGESTIONS FOR IMPROVEMENT
BY DEPARTMENT PERSONNEL AND CONSULTANTS

- Provide better training of quality control technicians including Department forms and log reports, accurate measurements, coordinating with VT technicians, and entering information into LIMS.

- Return to Consultant inspectors who are selected based on experience and proven performance - (i.e. a technical qualification selection as opposed to the contractor's bid based selection).

- Use the contractor rating system to award contracts. The bid should go to the lowest test bidder with the highest Contractor's Past Performance Rating.

- Require a separate company to bid for the CQC contract. The contractor should not hire personnel to perform testing and the Quality Control Manager should not report to the contractor's project manager.

- Improve LIMS to allow deletion and modification of information and improve

storage and retrieval mechanisms.

- Require contractors and independent labs to submit test results to the Consultant for entry into LIMS.

- Impose tougher consequences for failing to comply with Specifications or

quality control plan requirements.

- Provide the Department/Consultant with more tools to contend with

uncooperative or noncompliant contractors.

- Allow contractors the option to use the Department for testing the final product.

This would allow small contractors to compete with larger firms.

- Eliminate dual copies of density log books. With one density log book for the contractor only, the verification density would be input along side of the quality control entry. You could simply have a place for VT to sign off on any quality control tests.

- Reduce the verification testing when CQC plans indicate materials to be acceptable.

Reduce numbers (of testing) after certain number of favorable comparisons. Remove the resolution testing when concrete cylinders are both over design.

• Provide a copy of the CQC plan to the Project Engineers and their agents on the field, so they can have more control over the operation, and monitor the mix designs and qualified personnel in the field.
• Minimize the number of quality control plan revisions by providing as much accurate information as possible in the original quality control plan.

• Encourage more leniency in pulling the quality control plan to stop operations, if there has been a good quality control test history.

- The CQC process is a good step, but the paperwork needs to be simplified, especially for asphalt.

PURPOSE, SCOPE AND METHODOLOGY

The purpose of this engagement was to solicit the opinions of Department personnel and Consultants on the effectiveness of the CQC process and provide a summary of the results.

We developed a web-based survey which was distributed to 130 Department personnel (including project, material, geotechnical, construction, and bituminous engineers and project administrators) and 200 Consultants.

The responses, ranging from Strongly Agree to Strongly Disagree, were tabulated and comments were analyzed. Survey comments were grouped by topic as they related to one of the eight statements. A judgmental sample of comments was selected to show the variety of viewpoints received and to expand on the survey results for each statement.

ATTACHMENT 1 – Engagement Team and Statement of Accordance

Engagement Team

Monica Taina, Auditor
Margaret S. Parry, CPA, Performance Audit Manager
Joseph K. Maleszewski, CIA, CISA, CIG, Audit Director

Statement of Accordance

This advisory service was conducted in accordance with applicable International Standards for the Professional Practice of Internal Auditing published by the Institute of Internal Auditors and Principles and Standards for Inspectors General published by the Association of Inspectors General.

ATTACHMENT 2 – Addressee and Distribution List

Kevin Thibault, P.E., Assistant Secretary for Engineering and Operations

Copies distributed to:

Ananth Prasad, P.E., State Highway Engineer
Brian Blanchard, P.E., Director, Office of Construction
David Sadler, P.E., State Construction Engineer