Center for Transportation Research
The University of Texas at Austin

PROJECT SUMMARY REPORT

Project Summary Report 1781-S
Project 0-1781: Development of Appropriate Testing Frequencies for the Guide to Minimum Testing for Construction and Maintenance
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Summary of Findings from Development of a Methodology to Determine the Appropriate Minimum Testing Frequencies for the Construction and Maintenance of Highway Infrastructure

What We Did...

The quality of highway materials has always been a major concern to highway engineers and contractors. It is undeniable that the overall performance of a highway structure will be greatly influenced by the quality of the materials used during its construction, maintenance, and rehabilitation. Sample size/testing frequency directly affects the reliability of a test program in characterizing the properties of the materials. The use of a large sample produces a more reliable decision (i.e., lower failure rate). However, an increase in sample size is also more costly. In reality, economic constraints generally force engineers to keep the sample size as small as possible. Figure 1 illustrates the trade-off between material testing costs and failure rate. The main

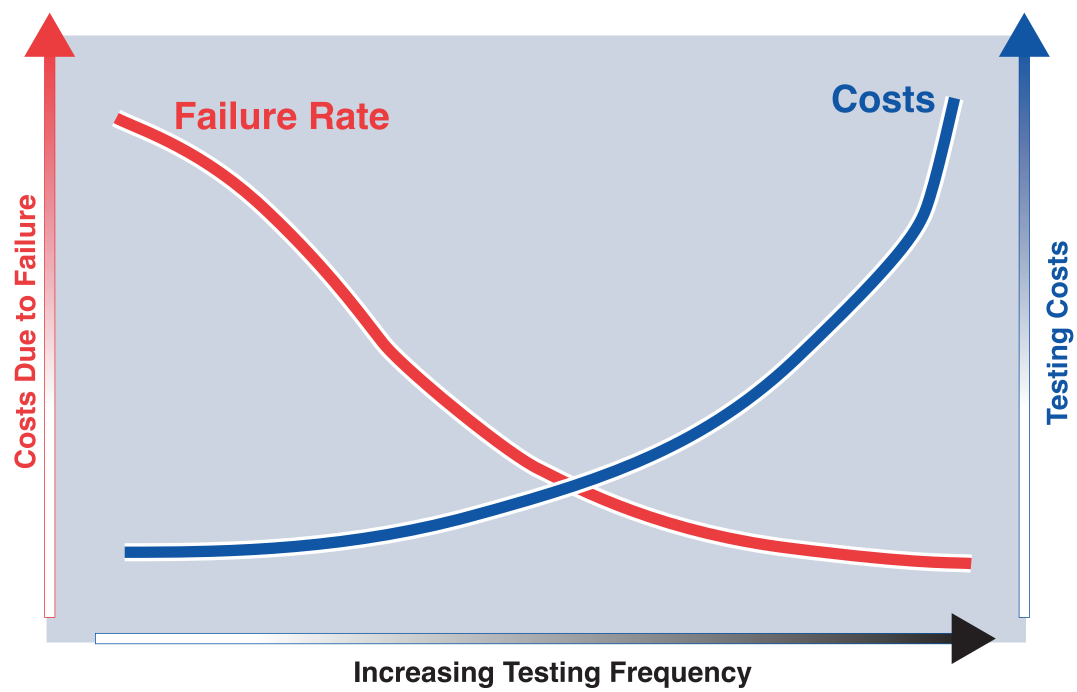

Figure 1: The trade-off between material testing costs and failure rate

objective of this research was to develop a methodology to determine the optimal sample size and appropriate minimum testing frequencies for the materials used in the construction and maintenance of highway infrastructure.

Testing frequencies currently used by the Texas Department of Transportation (TxDOT) and other departments of transportation (DOTs) are generally based on experience. Based on a statistically sound approach, the methodology developed under this project takes into account the relationships among sample size, material variability, tolerable error, agency risk (type II error), and contractor risk (type I error). Using the data collected from TxDOT districts and the methodology developed under the project, the frequencies for certain TxDOT tests were obtained and compared to the current TxDOT Testing Schedule. Such a methodology will help TxDOT optimize testing frequencies and improve the effectiveness and efficiency of construction quality control. The implementation of this methodology will in turn increase the service life of highway infrastructure in Texas by minimizing the occurrence of accepting defective materials.

What We Found...

The major research efforts and key findings from this project are summarized as follows:

1. A survey was conducted during the early stages of this research to collect information on current QC/QA practices among state DOTs and other agencies. It shows that most state DOTs use historical or experience-based methods to determine testing frequencies of materials.

2. A literature review was undertaken to identify, collect, and synthesize studies on the state-of-the-art of QC/QA practices. Different methods are used by different agencies in determining testing frequency. These methodologies can be grouped into three categories:
   1) experience-based methods,
   2) statistics-based methods, and
   3) economics-based methods.

   Statistics-based methods have long been the accepted standards in the process of acceptance sampling in other areas where QC/QA practices are essential. In particular, the risk-based statistical method that controls both type I error and type II error proves to be the most promising approach for determining appropriate testing frequencies.

3. A methodology was developed to estimate required sample size and testing frequency based on statistical theory, reliability concepts, and economic principles.

4. Statistically appropriate testing frequencies or required sample sizes are based primarily on four factors: the variability of the quality characteristic being measured, the risks that a state DOT or contractor is willing to take, the tolerable errors each is willing to accept, and the cost of the testing to be performed. Once the required sample size is estimated, the testing frequency (TF) can be determined by using the following calculations:
   1) Time-based testing frequency:
      TF = daily production / sample size
   2) Quantity-based testing frequency:
      TF = batch quantity / sample size

5. Type I errors and type II errors are critical to the determination of sample sizes. The producer's risk, type I error affects the contractor, since it is probable that the agency may reject what is in fact an acceptable work. The customer's risk, type II error affects the agency, since it is probable that the agency may accept what is in fact an unacceptable work. The true meaning of risk is how much one is willing to lose in terms of dollars if an action is taken. The goal of developing statistically based methodology for determining the appropriate testing fre-

quencies is to minimize (within practical limits) and/or balance the risks of both parties.

6. According to the model, the sample size is proportional to the variability (square of standard deviation). In other words, for materials with larger variability, a larger sample size will be required in order to achieve the same reliability of material testing for a test with a smaller variability. The required sample size is inversely proportional to the square of the tolerable error. The larger the tolerable error, the smaller the required sample size. As for the confidence level, the contractor's risk and the agency's risk will decrease if the sample size increases.

7. For the materials and testing examined as part of this research, an analysis was conducted to compare the current testing frequencies specified in the TxDOT Guide Schedule of Sampling and Testing with the testing frequencies produced from the statistics-based method.

The Researchers Recommend...

Potential areas of implementation of the research are briefly discussed in the following sections:

1. The statistics-based methodology developed in this research can be used not only for evaluating current QC/QA practice used at TxDOT, but also for determining appropriate testing frequencies for QC/QA programs.

2. Collection of project-level data to continue accumulating the data for variability analysis will increase the reliability of the methodology. Furthermore, gathering data from the beginning of construction activities on new projects allows the rates of production to be taken into consideration in order to enhance the developed methodology.

3. As a continuation of this research, it is recommended that a computer program be developed to speed up the calculation of the required sample size and ensure higher accuracy. The computer program can also be used to conduct "What-if" analyses.

4. Implementation of trial testing frequencies for selected materials in a pilot project or projects is a good and effective method. It is extremely useful because with pilot projects, the results of the new methodology can be proven to the interested parties. Modifications to the methodology could also be made with minimum level of risk to the success of the project and minimal economic consequences.

5. The results of this research could also be used in the pavement design process to better control the reliability of the design. In particular, with the known testing frequencies of the materials used in the design and the corresponding risk level, the as-designed values of the design parameters can be well related to the expected as-built values. This would help reduce the overall costs of a project without compromising the quality of the project.

For More Details...

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The research is documented in the following reports:

1781-1 *Development of a Methodology to Determine the Appropriate Minimum Testing Frequencies for the Construciton and Maintenance of Highway Infrastructure,* October 2001

To obtain copies of a report: CTR Library, Center for Transportation Research, (512) 232-3138, email: ctrlib@uts.cc.utexas.edu

TxDOT Implementation Status
November 2003

Implementation of the findings of this project has been included in the new testing schedules developed by the Materials and Pavement Section of the Construction Division. The data generated by this project is also being used in research project 0-4046 "The Impacts of Construction Quality on the Life-cycle Performance of Pavements Using Mechanistic Analysis". The Materials and Pavements Section may do further implementation of the findings of this project.

For more information contact; Dr. German Claros P.E. Research and Technology Implementation Office (512) 467-3881, gclaros@dot.state.tx.us

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