PROJECT SUMMARY REPORT

RECIPPE: A SOFTWARE TOOL FOR MAXIMIZING EFFECTIVENESS OF INSPECTIONAND TESTING RESOURCES DURING CONSTRUCTION

The goal in any highway construction project is to produce a durable pavement that will perform satisfactorily throughout its expected design life. Even though a well-calibrated design algorithm is necessary to accurately predict the life-cycle performance, quality of construction also plays a significant role. In that context, quality of construction is defined as meeting a structural-related target variable with minimal variance.

The consensus among transportation agencies is that cost incentive / disincentive should be a part of the process to implement an effective performance-based construction quality management program. To properly account for the pay factors, relevant parameters that directly impact the remaining life should be identified and quantified. This process should carefully consider the fact that relevant parameters are obviously different for different types of pavements. What is not so obvious is that for the same type of pavement, the relevant parameters change with the relative structure of the pavement. Many parameters that are important for a thick pavement designed for an interstate highway may be of secondary significance to a secondary road. Simply put, defining one set of parameters that can be used in all projects is not appropriate because it may not be cost-effective.

What We Did …

We have developed a method which, for a given project, will guide TxDOT personnel to determine parameters that significantly impact pavement performance. The level of acceptable deviations from the target design value for
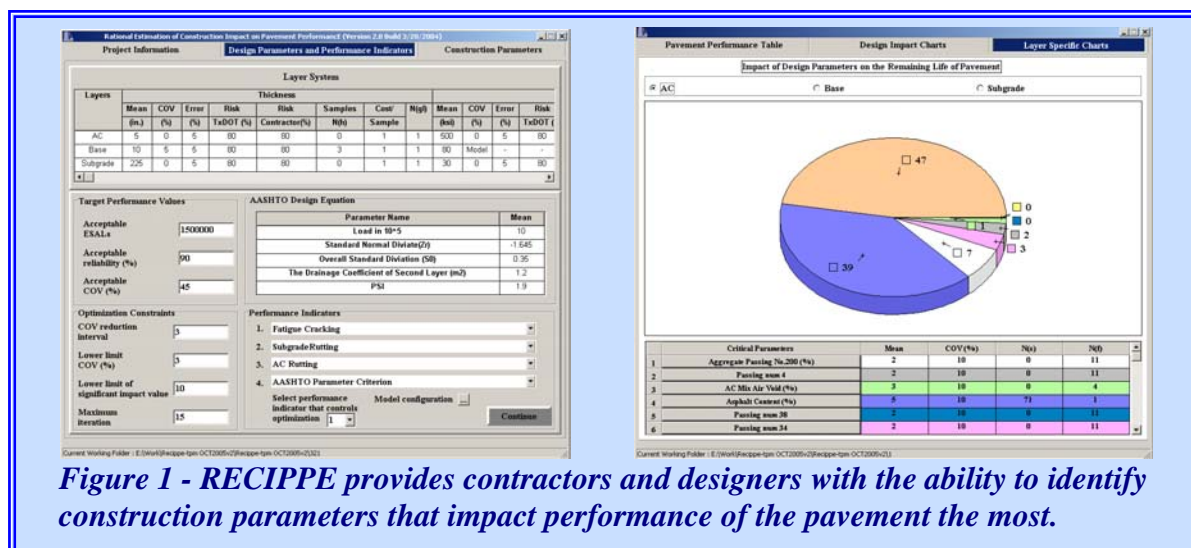

Figure 1 - RECIPPE provides contractors and designers with the ability to identify construction parameters that impact performance of the pavement the most.

each parameter is established based on quantification of the variability of the construction parameters introduced by: (a) the construction processes, (b) the material properties, (c) the models used to predict pavement performance and those used for data analysis, and (d) the resolution of the procedures used in the field for quality control.

This method is packaged into a program called Rational Estimation of Construction Impact on Pavement PerformancE (RECIPPE). RECIPPE carries out the analysis pre-construction mode, before the pavement is constructed. First, pavement information, such as layer properties and in-situ and laboratory tests performed to obtain statistical values, is provided as input into the program. Most of these measurements are typically made for QA/QC based on tests from the Texas Department of Transportation (TxDOT) guide schedule. The initial sampling rate, a required input, can also be adopted from the guide schedule. The algorithm in RECIPPE uses the probabilistic process to obtain the variability of performance values based on mechanistic analysis. RECIPPE produces an impact chart that identifies the construction parameters that impact the pavement performance variability. If the pavement performance variability is less than expected, construction parameters that most impact the performance variability are identified, and their variability is reduced. Several iterations are carried out until the expected performance variability is achieved. The optimization process is nonlinear, and different parameters can contribute to impact performance variability after each iteration. Significant parameters can be used during post-construction when inspectors focus resources.

In construction, a quality assurance process is performed. Project inspectors are advised to focus on parameters identified as significant. Sampling frequency for each significant parameter (the greater of either the frequency based on historical sampling determined from the parameter variability or that specified by the guide schedule) is initially performed. These frequencies are incorporated into quality control charts using the statistical mean and coefficient of variation (COV) of each material being inspected. Based on the control charts, an assessment is made of whether to reduce the sampling and cost by the recommendation determined from the program. If a parameter is in-control, suggesting that a good product is being constructed, less sampling is required. However, if results of the control chart are demonstrating a sub-quality product, then construction is halted until the problem is rectified. This process provides the inspector or project engineer with a tool to easily monitor the variability of each parameter impacting performance, thus maximizing effectiveness of inspection and testing resources during construction.
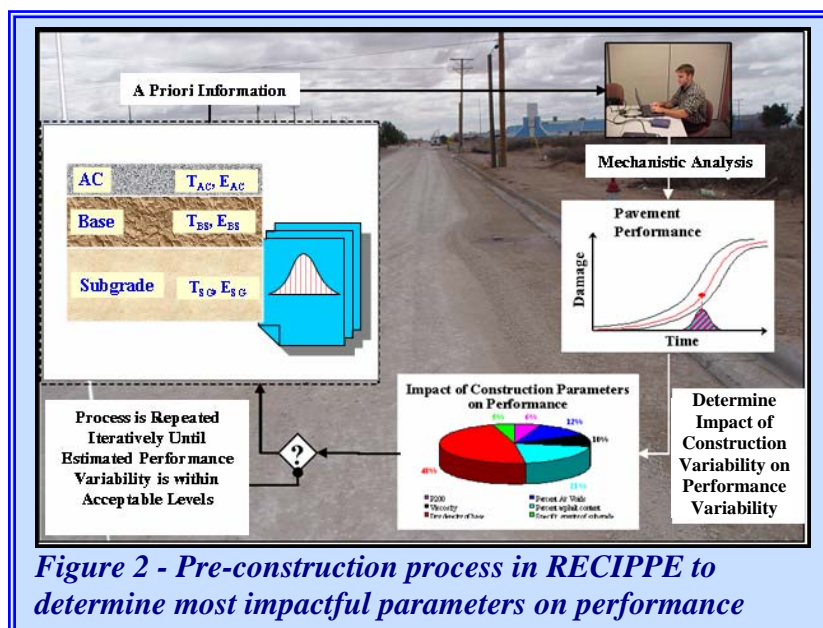
Figure 2 - Pre-construction process in RECIPPE to determine most impactful parameters on performance

What We Found …

Several critical aspects in the algorithm are: a) structural analysis, b) probabilistic algorithm, and c) material and performance models. A suitable analysis algorithm previously developed under TxDOT research that utilizes equivalent linear algorithm carried out the mechanistic analysis. The probabilistic algorithm developed, combined techniques of both Monte Carlo simulation and Two Point Mass simulation to accelerate the analysis process and adequately estimate statistical parameters necessary in this analysis.

In addition, performance models used in the state of practice that relate to fatigue cracking and rutting were incorporated into the mechanistic algorithm. The challenge was finding representative material models that reasonably estimate layer moduli from in-situ and laboratory test results. For the ACP layer, the suite of Witczak models was incorporated into the program. The parameters required for those models are typically measured by TxDOT. The simplest of these models was calibrated for Texas pavements using the LTPP database. For the lower layers, base and subgrade, the main model adopted was the constitutive model. This model is a function of k-parameters that can be estimated from field or laboratory testing on different material types using regression functions. Regression equations for granular and cohesive materials used in Georgia were initially used in the program. Since these equations were formulated for materials that are not representative of Texas materials, an attempt was made to develop and calibrate a new set of regression equations base on a limited database generated using several sites visited throughout the duration of this project. The results showed that the approach used to develop the material models needs to be explored further with a larger database of materials.

The development and calibration process sets a guideline for developing better models once a comprehensive database becomes available.
In this manner, RECIPPE was developed to accommodate models developed in the future. Users have the flexibility to make modifications to the current models by either 1) incorporating calibration factors to models, 2) applying new coefficient to models, or 3) adding new material models for any of the pavement layers with new construction parameters. Users are also able to deactivate material models for any of the pavement layers and input the layer moduli directly.

The Researchers Recommend …

This program has the potential to be used in several phases of a project as a quality control tool with the flexibility of selecting different levels of material models and performance models. With this flexibility, we recommend that this program, at the least, be used to shadow the day-to-day current QC process. This program could be used not only to optimize resources in a construction process, but also, when better models are developed, as a tool to assist in the development of effective performance-based specifications for construction of pavements.
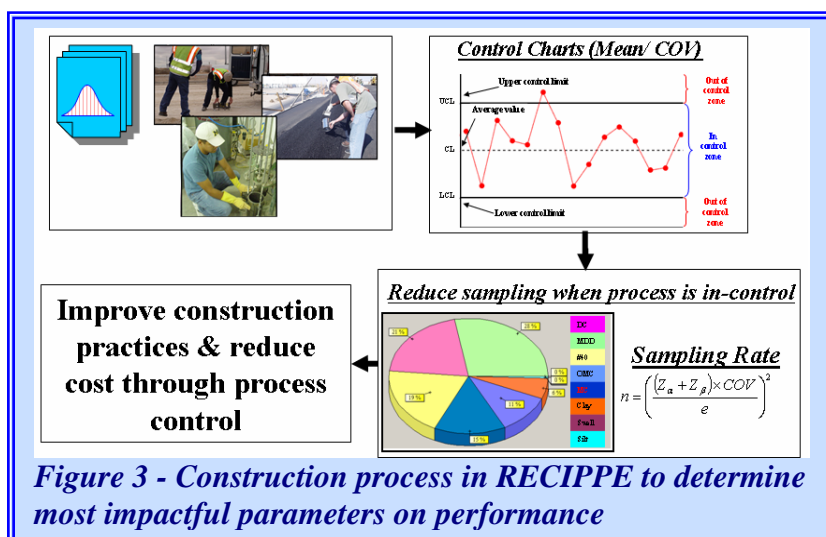
Figure 3 - Construction process in RECIPPE to determine most impactful parameters on performance

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