For Pooled Fund Proposal

Study Description

Background:

In late 2009, the Transportation Research Board (NCHRP IDEA Program) awarded a contract (NCHRP 150) to the firm of Chesner Engineering, P.C. and New Mexico State University to investigate the feasibility of using Laser Induced Breakdown Spectroscopy (LIBS) as a quality control screening tool for characterizing aggregate materials used in highway construction. The final report on this study was released in April 2012 and is attached in the documents section of this proposal listed as document (1).

LIBS technology is based on a process called laser ablation. A high powered pulsed laser is focused onto a very tiny spot on a target material breaking the chemical bonds. The material is fractured into energetic fragments releasing energy across a broad spectral range, most importantly for LIBS between 200 to 980 nanometers. The spectral image can then be visually and mathematically recorded in a computer. Once the emission spectra are recorded and stored it is possible to make use of multivariate statistical techniques to generate models to define the properties of the target material. The models are used as a means to fingerprint or profile the spectral signal generated during the laser ablation process. An in depth explanation of the laser ablation process can be found in the attached document (1).

The primary advantage of the subject technology over conventional aggregate testing and screening methods is its potential to identify the aggregate source in real-time in the field without sample preparation. This provides a means to identify pre-approved materials and to ensure that only such materials are being introduced into the production process. It also provides a means to calibrate the fingerprint against known engineering properties to determine whether the aggregate can be expected to pass or fail designated in lab test criteria.

Three State DOTs participated in the NCHRP 150 research effort: Kansas (KSDOT), New York State (NYSDOT) and Texas (TXDOT). Each State DOT supplied specific aggregates for laser calibration testing to determine if laser screening could identify the specific engineering property of interest to that state and whether the laser could be used as a means to differentiate between good and poor aggregates as defined by each state's criteria.

Aggregates from Kansas were examined to see if selected beds within a number of quarries, some of which were approved for use in portland cement concrete plus others not approved, could be identified by the technology. In addition D-cracking susceptible aggregates were tested to determine whether the test results used by KSDOT could be calibrated and duplicated by laser output modeling. Aggregates from New York were studied to see if the acid insoluble residue (AIR) content of limestones (a test criteria used by NYSDOT to determine friction course acceptability) could be modeled. Alkali silica reactive (ASR) aggregates were received from Texas to determine if a problematic chert could be identified by the technology.

The results of these studies were quite remarkable. In all cases, using unknown samples, the laser technology was capable of identifying with a high degree of accuracy the quality of the aggregate. For example, it was possible to model beds in selected Kansas quarries and identify whether aggregates used in the construction process were derived from approved or non-approved beds. It was possible to model aggregates that pass or fail KSDOT tests for D-cracking aggregates. Using the known AIR content of a series of limestones from New York, it was possible to establish a highly accurate calibration model for estimating the acid insoluble residue (AIR) content of New York State limestone aggregates. Using known levels of the ASR reactive chert from Texas, it was possible to identify and quantify the percentage of ASR reactive chert in limestone samples.

The Technical Development Team believes that the success of the technology is based on several operating factors that together combine to generate a powerful, analytical tool. These factors are briefly discussed below.

The LIBS emission process in general is fundamentally similar to atomic emission spectroscopy (AES), where the detection of the intensity and wavelength of energy released from excited atoms, in the form of light (typically in the visual and ultraviolet range) is used to identify the atoms or ions present in the sample (e.g. determine the concentration of specific elements). In conventional AES testing, elemental quantification is the primary objective of the analytical effort. However, in the subject application, which is intended to characterize construction aggregate, the primary objective is the relationship amongst all the elements present (or more accurately the wavelength and intensities of the spectral emission) to provide a modeled fingerprint of the complete sample. The results to date suggest that the multivariate models generated using laser ablation to generate emission spectra, which include over 13,600 wavelengths of data, provide precise and accurate fingerprinting that can be calibrated with material properties. Since the frequency of laser firings can typically be set to range from 1 to 50 Hz, a very large sample population is generated (e.g., thousands of analyses per minute). The combination of the emission spectra with over 13,600 data points and the number of laser shots (i.e., samples) provide the means to generate models with unprecedented levels of information.

Objectives:

The primary objectives of this research effort is to further calibrate laser-spectral models to develop the means to monitor aggregate materials from participating State agencies, and to demonstrate the use of the technology in actual field applications. The overall objective is to transition the technology from a lab-based application to a field based system.

Testing of aggregates and the calibration models developed in the NCHRP 150 research effort were accomplished using a laboratory-based laser-optical system. The proposed pooled fund work plan is designed to transition the technology from the laboratory to the field through the calibration, deployment and demonstration of the technology at selected field demonstration site(s). As part of the NCHRP 150 project, a field prototype sampling and laser targeting system field prototype, referred to as the SLT system (Sampling and Laser Targeting System), is under development for use in the pooled funding effort. The SLT system is a bulk sampling and laser-targeting system that is designed to analyze a diverted portion of the bulk material by passing target aggregate material passed a laser that is strategically located to provide for continuous or semi-continuous monitoring of the bulk aggregate stream. Diversion of samples of the bulk material into the SLT system is designed to remove the aggregate from the bulk stream during material transport, such as conveying. This material diversion provides the means to minimize interferences that would be encountered in an in-line monitoring system, without diminishing the effectiveness of the laser monitoring system to obtain large quantities of data necessary to properly characterize the targeted material. It also provides the means to ensure safe operation of the laser by enclosing the entire system in a separate sealed housing disconnected from the main bulk material conveying system, thereby ensuring a contained and safe operation.

The SLT can be deployed in a laboratory environment as well where buckets of samples are periodically introduced for analysis or in a continuous or semi-continuous field operation where materials are diverted from a conveying operation to the SLT for analysis.

Scope of Work:

The scope of work includes two stages or levels of effort that will be undertaken on selected aggregate samples collected from State DOTs participating in the effort. These include:

1. Aggregate Calibration Testing
2. Field Testing and Demonstration

Stage 1: Aggregate Calibration Testing

In the Stage 1 effort, aggregate samples will be collected from participating states/companies for calibration testing to model aggregate characteristics or engineering properties specific to that state. These properties could include engineering test properties such as D-cracking, alkali-silica reactivity, acid insoluble residue, soundness, LA abrasion, pre-approved material identification or scanning for known problem aggregates in the batch. Modeling and developing engineering tests profiles provides the means to use the technology to predict whether the aggregate will pass or fail specified tests or engineering criteria set by the state/company. Modeling pre-approved materials provides the means to model approved sources and, as a result, provide a means to determine whether material used in the production process is from a pre-approved source. Modeling known problem aggregates provides the means to prevent such aggregate from entering into the production process. Participating State DOTs or companies will be involved in the planning and development of criteria to be calibrated during this effort. The Stage 1 effort will be undertaken by processing samples collected from each participating state/company through the SLT System situated in a laboratory environment to develop the multivariate models that will be used to calibrate the specific characteristic or property with the modeled output. Unknown samples will be tested during this stage to verify that the calibrated models will successfully predict the selected characteristic or property specified by the participating state/company.

Stage 2: Field Testing and Demonstration

In the Stage 2 effort, the SLT system will be deployed in a field application (at a hot mix asphalt plant, a portland cement concrete facility, a recycled asphalt pavement facility, an aggregate processing facility, etc.) in selected states for field testing and demonstration. The field demonstration program will involve the integration of the SLT system into an operating installation and will involve 3 to 6 months of equipment setup and field monitoring.

During both Stage 1 and Stage 2 testing, the results of the analysis will be evaluated and used as the basis for assessing the effectiveness of the system, and if necessary the need for system modifications.

Project Duration: 36-month total project duration is anticipated.

Total per state/company cost of project:

Three levels of participation are being offered for this three year pooled fund study. Note $6,000.00 total from each participating state, no matter the level of participation, will be reserved for participating states to travel to review meetings and a site visit. Travel is based on each state sending one representative to three meetings during the course of the project: two review meetings and one site visit at $2000.00 per trip or a total travel budget of $6,000.00 per state. Any unused travel money will be put to the project research budget.

Level 1

Monetary funds only.

$30,000 per year for three years

Level 2

Stage 1 Effort Only

At this level states/companies will submit aggregate for calibration testing to model aggregate characteristics or engineering properties specific to that state/company. Unknown samples will be tested in the lab to verify that the calibrated models will successfully predict the selected characteristic or property need by each state/company.

$50,000 per year for three years

Level 3

Stage 1 and Stage 2 Efforts

At this level states/companies will submit aggregate for calibration testing to model aggregate characteristics or engineering properties specific to that state/company. Unknown samples will be tested in the laboratory environment to verify that the calibrated models will successfully predict the selected characteristic or property need by each state/company. In addition, the Sampling and Laser Targeting System (SLT system) will be deployed in a field application within the participating state or at the company facility.

$75,000 per year for three years (three states maximum at this level)

Total 36 month minimum funding effort being requested to launch this project: $500,000

Comments:

100% SP&R Approval has been requested

Development and implementation of the subject technology could provide State DOTs and material suppliers with a real time, nearly instantaneous recording tool to address the need for transportation infrastructure material quality control monitoring. Aggregates are often sent to concrete and asphalt mix suppliers as quickly as they are being produced. Quality control processes that can accommodate a sampling frequency and rapidity of turn-around, commensurate with the pace of production, would be a giant step forward in improving the means to monitor aggregate materials. This is especially so during the construction process, where asphalt and portland cement concrete products are manufactured and used within hours of actual construction.

Documents:

Documents to be added to the solicitation will be:

NCHRP150 Final Report

Automated Laser Spectrographic Pattern Matching For Aggregate Identification

Final Report for Highway IDEA Project 150