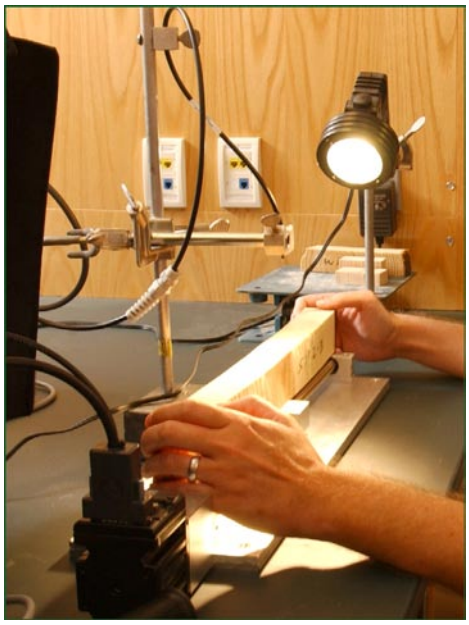
RESEARCH in Progress

Forest Products Laboratory

Condition Assessment of In-Service Wood in Bridges and Structures by NIR Spectroscopy

There has been significant progress in the use of fiber-reinforced polymer (FRP) composites to enhance the performance of engineered wood composites, but opportunities also exist to use this technology for in-service repair of wood structures. One important element for in-service repair is the accurate assessment of the condition of the aged wood surface, especially in bridge structures. This information would make it possible to establish prescriptions for surface preparations to ensure bond quality. Because this must be accomplished in the field, one attractive option for assessing the condition of weathered wood is near infrared spectroscopy (NIRS), especially the commercialized, portable, battery-operated spectrometers.



Near-infrared scan of wood specimen.

Near infrared spectroscopy, in conjunction with multivariate statistical analysis of the spectral data, offers the unique ability to predict chemical and physical properties of the wood surface. This project will explore the potential development of NIRS as a field sensor to monitor the condition of in-service wood structures. Particular interest will be paid to characteristics influencing bond formation with FRP.

Background

Near infrared spectroscopy is a rapidly growing technique for nondestructively evaluating organic materials. It has found widespread use in the food and agriculture industry as well as the pharmaceutical, petroleum, polymer, and pulp and paper industries. Advantages include minimal sample preparation, rapid acquisition times, and non-contact, nondestructive spectral acquisition. For these reasons, NIRS techniques show promise for nondestructive evaluation of the properties of wood and wood-based materials.

Recent work has shown that NIRS can be used to predict the mechanical properties of a range of softwood species without significant loss in model quality and was sensitive to the extent of decay of wood exposed to different conditions. Results suggest that the technology may also be useful in assessing the characteristics of wood that has been exposed to the elements. Further work has demonstrated the ability to predict internal bond of medium-density fiberboard panels from their near infrared (NIR) spectrum. This is also encouraging because it indicates that information on substrate properties influencing adhesion may be contained in the NIR spectral data.

Typically research has focused on using the full NIR spectral range (1,000 to 2,500 nm) or both the visible and NIR spectral ranges (400 to 2,500 nm). This is because the range of 1,000 to 2,500 nm contains the most distinct spectral information on the first overtone and combination bands that make up NIR spectra. Recent studies have shown that the full chemical composition of wood chip could be measured using the spectral information between 800 and 1,100 nm, and the lignin content of kraft pulps subjected to different bleaching sequences could be measured using a spectral range of 360 to 740 nm. In both cases the correlation coefficients were generally above 0.90, indicating that large reductions in the spectral range

did not have a significant negative effect on the quality of the models.

Defining the effects of reducing the spectral range is very significant since this reduced spectral range can be accessed with very inexpensive spectrometers that can acquire spectra in fractions of a second. Additionally, reduced wavelength spectrometers are smaller, lighter weight, battery operated and much more amenable to field use

Objective

The primary objective of this research is to explore the potential utility of NIRS as a field sensor to assess the condition of in-service wood bridges and structures.

A secondary objective is the immediate and long-term bonding characteristics of weathered wood attached to two different FRPs.

Approach

To establish baseline weathered conditions, Southern Pine and Douglas-fir samples will be exposed to several controlled weathering conditions. NIR spectral data will be collected as a function of the number of weathering cycles. NIR spectral data will be measured over the visible and full NIR wavelengths and over a reduced NIR spectrum.

Wood–FRP bonded samples will be prepared using the weathered samples to evaluate the immediate and long-term bond strength between wood and FRP.

Multivariate correlations between the NIRS results and strength of the FRP bond will be investigated. The effects of sanding or removal of the highly weathered surface will also be examined.

A second set of experiments will be conducted on wood samples obtained from structures recently removed from service to demonstrate the potential for field application.

Expected Outcomes

Results of this research will offer several benefits:

- Development of NIRS for in-service condition assessment of wood structures
- Models to predict important characteristics of weathered wood substrates
- Evaluation of the effect of reduced spectral wavelengths on model predictions
- Evaluation of the immediate and long-term bonding characteristics of in-service weathered wood to FRP
- Baseline information for the development of in-service repair of wood structure with FRPs

Timeline

Full and NIR scans of Southern Pine weathered in Mississippi for 57 months have been completed, and model development is currently being completed. Bond specimens from this Southern Pine are being prepared for testing during June 2004. Controlled weathering of specimens will be completed by July 2004, with collection of NIR spectral data and model validation and refinement to follow. Bonding specimens from the controlled weathering specimens will be prepared and tested in fall 2004.

Cooperators

Cooperators in this research include Prof. Timothy Rials and Dr. Michela Zanetti of the University of Tennessee.

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