National Cooperative Highway Research Program

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Development and Field Evaluation of Prototype Soil Moisture Sensors

An NCHRP staff digest of the essential findings from the final report on NCHRP Project 21-2(3), "Development and Field Evaluation of Prototype Soil Moisture Sensors," by G. A. Matzkanin, Southwest Research Institute, San Antonio, Texas; and E. T. Selig and D. C. Wobschall, State University of New York, Buffalo, New York.

THE PROBLEM AND THE SOLUTION OBTAINED

Service behavior of modern highway systems is strongly influenced by the moisture content of component materials. Despite recognition of this important relationship, highway engineers do not have adequate instrumentation for continuous, long-term monitoring of moisture variations. The objective of Projects 21-2 and 21-2(2), conducted independently by Southwest Research Institute (SwRI) and the State University of New York at Buffalo (SUNYAB), was to develop new and innovative sensors for the in situ measurement of moisture in aggregate base and soil subgrade layers of pavements. Two types of sensors were developed: one based on a dielectric coefficient measurement and the other on nuclear magnetic resonance (NMR). Prototype sensors were produced and subjected to laboratory evaluation. Both types were found to be potentially applicable to highway soil moisture measurement problems. The technology on which the prototype sensors are based is described in papers published in Transportation Research Board Record 532.

Under Project 21-2(3), advanced models of the moisture sensors were produced and subjected to field evaluation for a period of one year in soil and base layers of pavements in Arizona and Pennsylvania and in a test road at the U. S. Army Cold Regions Research Laboratory in New Hampshire. Electronic readout equipment was designed and fabricated for use at the field sites.

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Moisture determinations from the NMR and dielectric sensors were compared with moisture measurements obtained by nuclear depth probes and gravimetric analysis of soil borings.

FINDINGS

New and innovative moisture sensors were developed and field tested. Although some discrepancies were observed among the field results, and the field tests were not conclusive with regard to accuracy and reliability, the data obtained with the newly developed sensors appear to be consistent with the indicated moisture conditions. Both types were shown to offer potential for further development as in situ moisture measurement instruments.

General observations and conclusions of the field evaluation phase of the study are as follows:

1. Some operational problems were encountered with several sensors of each type. In the dielectric sensor, these were caused by intrusion of moisture into the electronic circuits, and some electronic components within the sensor failed. In the NMR sensor, operational difficulties were attributed to moisture intrusion into the connector joining the sensor and the cable to the readout instrument, and to temperature sensitivity of the readout instrument gain. Approaches for overcoming these problems in production mobels are available but have not been explored in detail.

2. On the basis of the results of the field evaluation, and with suitable calibration, both sensors are capable of determining in situ moisture content with an estimated accuracy of ±2 percent.

3. Although the actual moisture levels encountered in the field were only in the 20 to 30 percent range, on the basis of the results of laboratory tests, the actual operating range of the sensors is estimated to be 0 to 50 percent.

4. Best results are obtained by calibrating the sensors using the soils of interest.

5. Special installation procedures devised for the sensors produce minimal disturbance of the subgrade soil.

6. Laboratory studies of temperature effects showed that the dielectric sensor can be used to determine with a high degree of certainty when freezing of pore fluid occurs.

7. On the basis of current fabrication costs, the price to the user for production quantities is estimated to be $125 per sensor, $1,000 for the dielectric readout, and $5,000 for the NMR readout.

APPLICATIONS

The results of this research indicate that both the dielectric and the NMR measurement systems can be potentially useful for in situ determination of moisture in pavement subgrades. With proper calibration, the accuracy of moisture measurements with these sensors can be at least comparable to existing in situ sensor types

such as moisture blocks. The sensors were designed to produce as little disturbance as possible to the material in which they were installed. Results of the field tests gave no indication that moisture contents were affected by the presence of the sensors. They measure the water content of a sample volume of approximately several cubic inches. The density of the material must be determined to compute moisture content in relation to dry weight. Because of prototype configurations, they are presently suitable for measurements primarily in fine grain soils.

Because the findings were not conclusive with regard to accuracy and reliability, the results of this research are not readily applicable to field moisture measurement problems. They do, however, provide a basis for further development of sensors and readout equipment by instrument manufacturers. The report also contains sufficient equipment design and fabrication information to assist transportation agency personnel that might desire to continue research on the concepts and techniques that were investigated. The NMR sensor exists at the present time only as a research device, but the dielectric type has been produced commerically. Additional information on availability of the equipment can be obtained from the National Cooperative Highway Research Program, Transportation Research Board, 2101 Constitution Avenue, Washington, D. C. 20418.

The final report of the project will not be published in the regular NCHRP series. A copy of the agency's report may be purchased from University Microfilms International 300 North Zeeb Road, Ann Arbor, Michigan 48106; or may be obtained, on a loan basis, by request to the NCHRP Program Director.

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