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DETECTION OF BRIDGE DECK DETERIORATION

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The Delamination Detector has been used for bridge deck inspections by maintenance personnel in several Texas Highway Department Districts.

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Detection of Bridge Deck Deterioration

by

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This report summarizes the research efforts in the phase of the study which was directed toward diagnosing deterioration in concrete bridge decks. Principal emphasis in this phase has been placed on techniques for evaluating a) delamination and b) poor quality concrete. These two factors were considered to be of primary importance in bridge decks. Research Report 130-4, entitled "An Instrument for Detecting Delamination in Concrete Bridge Decks," described the development and preliminary testing done in the "delamination" portion of the research. Research Report 130-7, entitled "An Investigation of the Applicability of Acoustic Pulse Velocity Measurements to the Evaluation of the Quality of Concrete in Bridge Decks," described the development and initial testing directed toward the detection of poor quality concrete. In both of these research efforts, primary emphasis was placed on nondestructive testing techniques for diagnosing deterioration. In later research, some slightly destructive concrete evaluation techniques were investigated.

Delamination Detection

Probably the most serious form of deterioration commonly found in reinforced concrete bridge decks is delamination which ultimately results in large scale spalling. This type of failure occurs most freqeuntly where salt is used for winter deicing and is believed to result chiefly from salt induced corrosion of the reinforcing steel. The Delamination Detector, which is an instrument for locating this type of failure, was developed in this study. It is roughly the size and shape of a power lawn mower and has been found to be reliable and easy to operate.

Verification of the ability of the device to detect delamination was made by coring two locations in each of ten bridge decks, one in an indicated and another in a nonindicated area. Complete agreement was obtained. The delaminations in these bridge decks varied in depth from ½ to 4½ inches. Several of the decks had asphaltic surfacing layers which varied in thickness from ¼ to 3½ inches. These successful tests were thought to be very significant because the distinctive "hollow sound" produced by conventional sounding techniques is greatly diminished when delaminations in a deck become deep or when a deck is resurfaced with an asphaltic layer.

The Delamination Detector has been used by maintenance personnel in several Texas Highway Department Districts. Probably the most extensive use was by the maintenance personnel in the El Paso District who surveyed about 130 bridges, most of which had asphaltic concrete or epoxy overlays. The instrument was found by maintenance personnel to be a reliable and effective means for delamination detection. It appears particularly valuable for evaluating many overlayed bridges upon which conventional sounding techniques have been found to be ineffective.

Corrosion Potential

The California Division of Highways has reported that electrical potential measurements can be made on the surface of a concrete bridge deck which are indicative of active corrosion of reinforcing steel. These measurements are obtained by making an electrical connection to the reinforcing steel and a second electrical connection between a saturated copper-copper sulfate half cell and the upper surface of the deck. The latter connection is made with a sponge saturated with copper sulfate solution. The electrical potentials are measured using a high input impedance voltmeter.

Under the Federal Highway Administration Region 15 Research and Development Demonstration Projects Program, measurements have been made on bridges in forty-eight states and the District of Columbia. The results to date indicate that the system gives reasonably accurate indications of the degree of

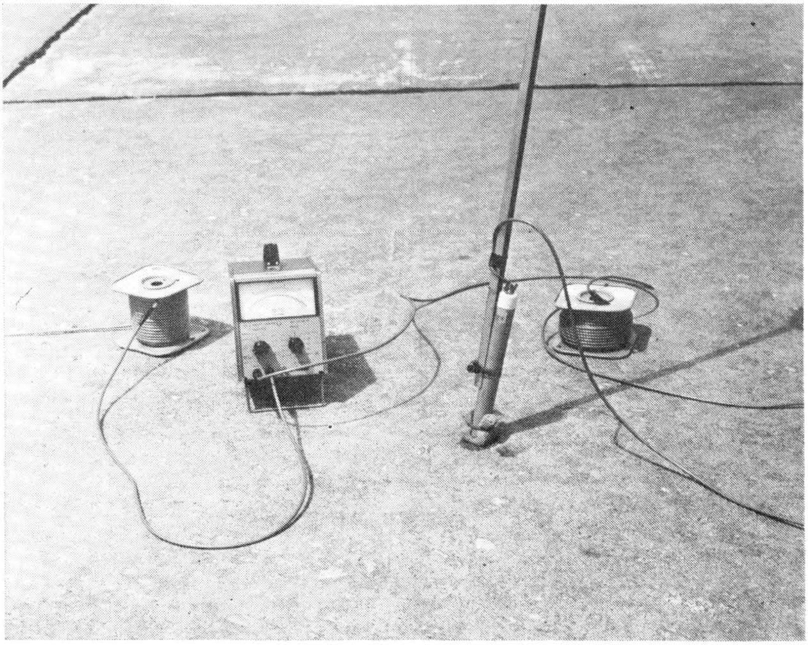

Figure 1. Electrical potentials between a copper-copper sulfate half cell and the steel reinforcements are measured with a high impedance voltmeter to detect active corrosion.

corrosion in bridges. Measurements have been confirmed with actual on site inspections.

Acoustic Velocity

An investigation into the suitability of acoustic velocity measurements for determining concrete quality indicated that the compressional wave velocity could be measured from the accessible upper surface of a bridge deck. It was also learned that the elastic modulus of concrete could be reliably estimated from the concrete's compressional velocity and unit weight.

A portable field-type velocity measuring instrument was developed in this study for use on bridge decks. This device employs a probe which places an array of four acoustic transducers into contact with the concrete. Velocity is measured, using the "timing along" technique, by observing the time of travel of the acoustic waves between two identical receiving transducers. Waves are produced and propagated successively in opposite directions and the two time-intervals are measured and averaged in order to cancel coupling delay errors.

Cores were taken from many different slabs which had been measured with the velocity meter. The measured velocities were

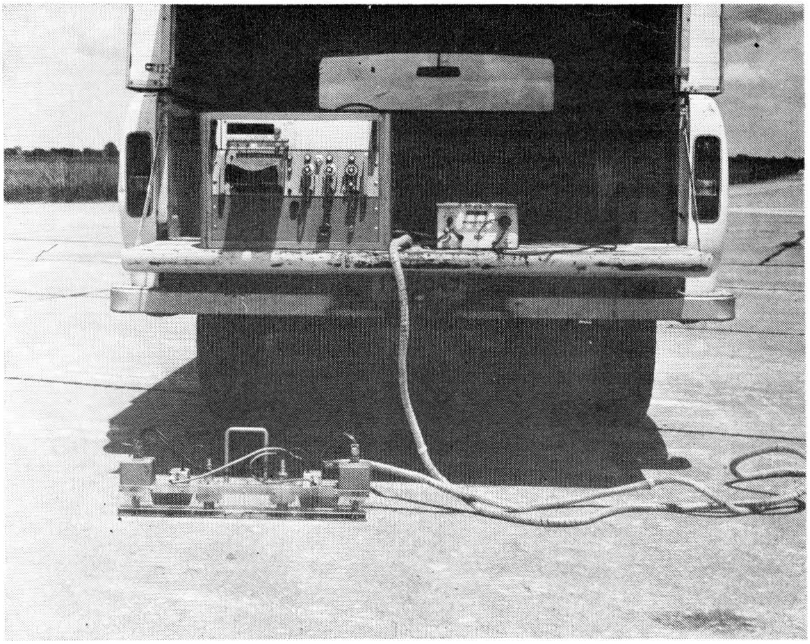

Figure 2. The control unit of the field-type acoustic velocity measuring instrument is operated from a pickup tailgate as the probe unit is moved to various points on the deck.

found to be slightly correlated with the measured core compressive strengths. In a linear regression to determine core strength from velocity the coefficient of variation was found to be 19.9 percent.

It was found on many bridges which had been in service for several years that it is difficult to measure the acoustic velocity due to the attenuation introduced by numerous surface cracks. Often these surface cracks were visible only after moistening the surface. This problem was not encountered on the newer bridge slabs.

This instrument is believed to be a useful research tool when it is desirable to nondestructively estimate the elastic modulus of the concrete. It is not believed to be practical for routine bridge deck inspections, because too many bridges are difficult to measure even for a highly trained operator.

Windsor Probe

The Windsor Probe Test System has been used in field investigations to estimate the in-situ strength of concrete in pavements, bridges, walls, pipes, etc. The device is easy to use and requires no surface preparation prior to testing. Basically, tests

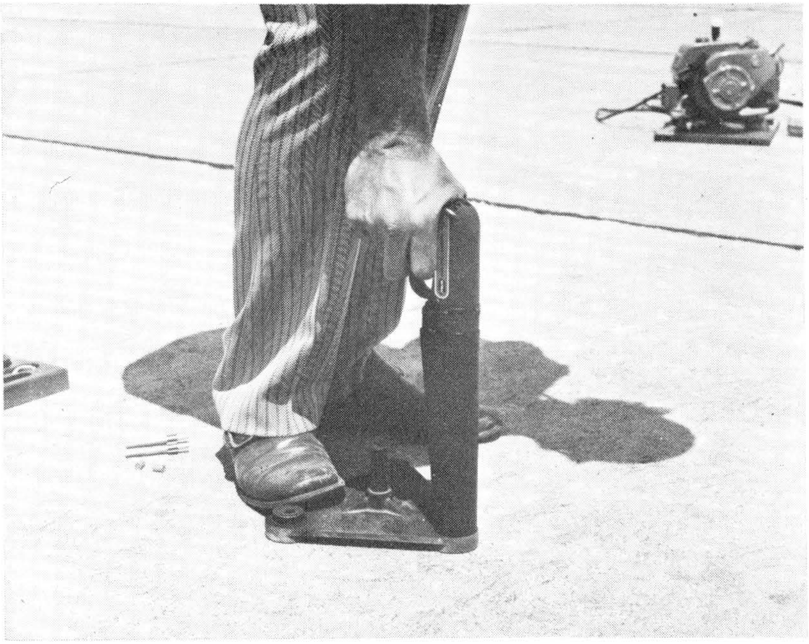

Figure 3. The Windsor Probe test system is used to shoot a standard probe into concrete to determine penetration resistance and thus indicate concrete quality.

with it consist in shooting a standard probe into the concrete to be tested with a standard explosive cartridge. The depth of penetration is described by measuring the height of the exposed probe. A special gun or driver unit is provided for shooting the probes. Gage plates are also provided to facilitate the measurement of the average height of the exposed probes in a standard group of three shots. The higher the probes, i.e., the more resistant to penetration, the stronger the concrete.

Cores were taken from many different slabs which had been measured with the Windsor Probe. The average probe heights were found to be weakly correlated with the measured compressive core strengths. In a linear regression to estimate core strength from the probe height the coefficient of variation was found to be 20.3 percent.

The system is believed to be practical for bridge deck survey measurements to locate deteriorated areas. The test is slightly destructive. In addition to the small hole made by the probe penetration, a spall about six inches in diameter and up to three fourths of an inch deep at the center is often produced by the test.

Schmidt Rebound Hammer

The Schmidt Rebound Hammer is a very widely used instrument for estimating the quality of in-situ concrete. Basically, the test consists of striking a rod, in contact with the concrete, with a standard hammer and measuring the height of the hammer

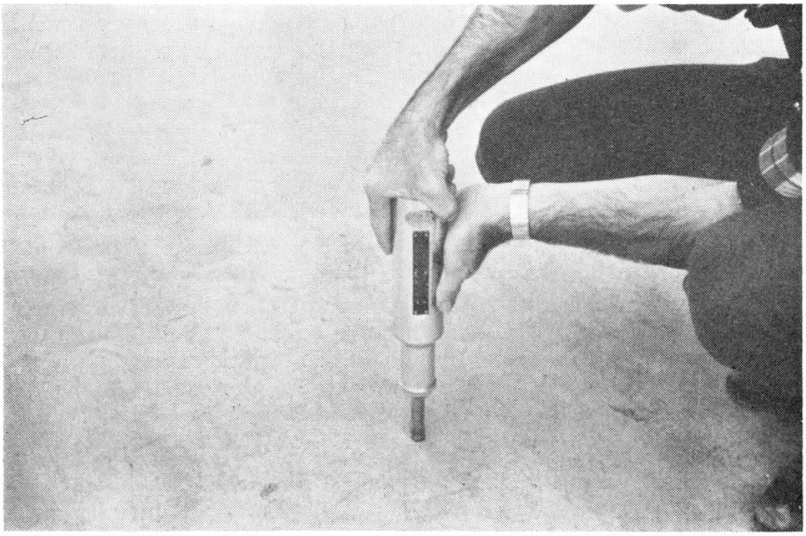

Figure 4. A Soiltest Model CT200 rebound hammer being used to indicate concrete quality.

rebound. The higher the rebound the stiffer (and better quality) the concrete.

Several authors have suggested that the Schmidt rebound hammer can be used to estimate the compressive strength of concrete in-situ. They agree that the type of coarse aggregate, surface condition of the concrete, its moisture condition, etc., have a pronounced effect on the results of the relationship between rebound reading and strength. Also there is common agreement that the instrument can be used to determine the uniformity of concrete and thus is an effective tool for locating weak spots. A Soiltest Model CT200 rebound hammer was used for investigation in this study.

The results from this test were found to be slightly correlated with the compressive strengths of cores taken from the many different slabs. In a linear regression to estimate core strengths from rebound values the coefficient of variation was found to be 21.2 percent. The instrument is fast and easy to use and is believed to be practical for bridge deck measurements to locate deteriorated areas.

Direct Tensile Test

An important characteristic of concrete, which is seldom considered in field evaluations, is its tensile strength. This characteristic is highly significant in quality bridge deck construction.

In 1956, the Shell Chemical Corporation introduced a "Highway Tensile Tester." This tester was developed for evaluating the quality of resinous cement overlays and to pre-evaluate the surfaces upon which they were to be applied. A device similar to the Shell tester was fabricated in this study. The chief modification was that a hydraulic cylinder, instead of a screw, was used to apply tension, in order to eliminate the possibility of horizontal forces on the screw handle being converted into unwanted tension. To measure the in-place tensile strength of the concrete, a two-inch-diameter cylinder is bonded to the surface of the bridge deck with an epoxy adhesive. After the adhesive is hardened, the cylinder is pulled from the deck causing a tensile fracture to occur in the concrete.

The results from this test were somewhat better correlated with the compressive strength of cores taken from different slabs than any of the other techniques investigated. In a linear regression to estimate core strength from the average tensile strength the coefficient of variation was found to be 17.7 percent.

The test is somewhat time consuming. It requires a curing time of about 90 minutes for the epoxy to harden prior to testing. On a warm day about 40-50 tests could be made in an 8-hour day. The test is probably a better indicator of the general quality of the concrete in the deck than the other techniques and it is believed to be practical for bridge deck measurements.

Figure 5. A small dome shaped piece of concrete is pulled out by applying measured tension to a two-inch-diameter cylinder that has been bonded to the surface.

Conclusions

From the results to date in this study the following conclusions appear warranted:

1. The technique utilizing the delamination detector developed in this study has been found to be practical and effective for determining the extent of delamination in bridge decks.

2. It appears that all of the six measurement techniques investigated have merit and can be used to locate weak spots

or deterioration in bridge decks; however, each one is designed to measure a different characteristic property.

3. The Direct Tensile Test, Velocity Meter, Windsor Probe and the Rebound hammer can each be used to estimate core compressive strength within about 20 percent.

Implementation Statement

The delamination detector has been found to be a practical and fieldworthy tool for use by highway maintenance personnel. Research has demonstrated that multiple-path automatic detection is practical.

The Direct Tensile Test, Velocity Meter, Rebound Hammer, and Windsor Probe are each designed to measure a different characteristic property of in-situ concrete. All of them have merit and any one of them can be used to locate weak spots or deterioration in bridge decks. These tests can supply valuable data to the engineer faced with the problem of possible major maintenance of a bridge deck.

The published version of this report may be obtained by addressing your request as follows:

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