BRIDGE DECK DELAMINATION STUDY

FINAL REPORT
RESEARCH PROJECT HR-179

HIGHWAY DIVISION
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DEPARTMENT OF TRANSPORTATION
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FINAL REPORT

for

IOWA HIGHWAY RESEARCH BOARD
Project HR-179

"BRIDGE DECK DELAMINATION STUDY"

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ABSTRACT

The Delamtect was introduced to the Iowa Department of Transportation through a 1975 Federal Highway Administration demonstration project. The Delamtect is a small mobile unit for conducting a rapid bridge deck survey to determine the extent of delaminations (subsurface fractures). Comparison of the Delamtect with manual sounding methods and drilled cores has demonstrated its reliability . This research has shown the Delamtect to be a more effective, more economical and safer method of surveying bridge decks than manual sounding methods. The Delamtect can also be used to provide a measure of the bond within membrane systems.

BRIDGE DECK DELAMINATION STUDY

SUMMARY

Scope and Purpose

The purpose of this research was to reduce bridge deck repair costs by providing a more effective, more economical and safer method of locating subsurface fractures (delaminations) and evaluating protective membrane systems. The specific objectives within this purpose were to determine the effectiveness of the Delamtect for:

1. Surveying deterioration of older decks prior to resurfacing.

2. Verifying that resurfacing operations were successful.

3. Determining the degree of bond developed within a membrane system.

One Delamtect survey device was purchased in January, 1976 for research purposes. This research was conducted by the Special Investigations Section of the Office of Materials through March, 1978. No additional personnel were employed for this research and the evaluation of the Delamtect was included in the overall bridge and pavement testing program throughout the State of Iowa. The bridges utilized for the evaluation were generally selected from the Federal Highway Administration (FHWA) National Experimental and Evaluation Program (NEEP).

Conclusions

From the results of this investigation, the following conclusions are drawn:

1. The Delamtect is a more effective, more economical and safer method of surveying bridge decks than past sounding methods.

2. The Delamtect is reliable and repeatable in outlining areas of the delamination prior to resurfacing.

3. The Delamtect is effective in verifying that resurfacing operations were successful.

4. The Delamtect can be used to provide a measure of the degree of bond within a membrane system.

Recommendations

Based upon the findings of this research, it is recommended that:

1. Six additional Delamtect units be purchased.

2. One Delamtect unit be assigned to each district.

3. The Delamtect units be equipped with the optional earphone audio signal and paint spray systems.

INTRODUCTION

A goal of highway engineers is to design and construct bridges to provide mainenance free service thoughout the design life. Unfortunately, there are far too many cases where this is not true. One of the major concerns is the premature surface spalling deterioration. This spalling is usually induced by deicing salt (as salt water) penetrating the concrete and "attacking" the reinforcing steel. This salt causes corrosion of the top layer of reinforcing steel. The product of the corrosion occupies about twice the volume of the original metal. This expansive force creates stress that produces subsurface fractures. Under the continual impact of traffic, these fractures, commonly referred to as delaminations, result in spalling.

In 1962, the Iowa State Highway Commission (now the Iowa D.O.T.) discussed the subject of deteriorating concrete bridge decks at a District Engineers Meeting. This meeting generated a survey of bridge deck deterioration throughout the State. This was to produce a summary of the extent of the deterioration and a recommended method of repair. The common method of repair, at that time, using bituminous materials was unsatisfactory as it provided only temporary repair.

Iowa began using a high cement content Portland Cement Concrete for partial depth repair in June 1964. In August of 1964, a contract was awarded for research project (HR-95) to resurface a 240 ft. bridge with a low slump, dense Portland Cement Concrete. This was the beginning of the "Iowa Method" overlays, where the unsound concrete is removed and a cement sand grout is applied to provide a bond for the new dense concrete layer. This P.C. resurfacing program has continued to expand until there are 88 bridges scheduled for 1978 construction bringing the number to 360 for the fifteen year period.

A very important factor in the success of the "Iowa Method" resurfacing is the removal of the delaminated, unsound concrete. A procedure was developed where the entire deck was tapped with a hammer or steel rod. The areas yielding a "hollow" sound were outlined and included for removal down to the reinforcing steel. Chain drags and metal bar drags were later used to reduce the time and effort of conducting this sounding operation.

On June 16, 1975, the FHWA presented Demonstration Project No. 33, "Bridge Deck Evaluation Techniques" on a US 30 bridge over the Des Moines River in Boone County. One of the devices included in that demonstration was a Delamtect developed to conduct a rapid survey of the extent of delaminations.

The FHWA demonstration primarily advocated the use of the Delamtect to detect delaminated areas in the deck concrete. The literature also stated that the device could be used over a 3 to 4 in. bituminous overlay, but could not distinquish between delaminations and unbonded overlays. This generated the idea of using the Delamtect to evaluate the bond of membrane systems (with A.C. wearing surface). This type of bridge deck membrane system was placed on some new Iowa bridges in 1975 to protect the reinforcing steel. Problems were encountered with some sheet membranes in developing or maintaining sufficient bond. A vapor "outgassing" from the underlying P.C. Concrete either filled voids left during construction or destroyed bond causing blistering. When the blistered areas were tapped with a hammer or steel rod, a hollow sound was detected, but much less distinct than on P.C. Concrete.

DESCRIPTION OF THE DELAMTECT

The Delamtect is a small mobile unit manufactured by S.I.E. Inc., of Forth Worth, Texas. The electronic, acoustical device imparts a tapping impulse into the surface of the concrete. An oscillating solenoid mounted on two steel wheels generates this impulse. The receivers that "listen" to locate the hollow areas are two oil filled inner tube tires. A hydraphone (pressure transducer) is mounted near the bottom within each of these oil filled tires and monitors the response from the tapping. A response from each wheel is transmitted to a dual channel strip chart recorder. Each steel transmitter wheel operates three inches from the reciever tire, thus, evaluating a three inch wide strip. The two three inch wide strips traverse nine inch center to center for each pass.

OPERATION OF THE DELAMTECT

The S.I.E. Company provides an operators manual containing general instructions for the use of the Delamtect. Test Method No. Iowa 1010 (Appendix A) outlines more explicit instructions for detection of delaminated areas on bridge decks. Testing of bridges with horizontal or vertical curves requires modified layout procedures but the Delamtect is just as effective. The transverse paths must be marked on the bridge more often as the cord line does not function on the horizontal curves nor on vertical curves in a wind.

The calibration and adjustment of the unit is covered in the manufacturer's operator's manual. Generally, the adjustments are easily made with the "trim pot" adjustments in the storage compartment. There have been a few cases where internal adjustments were necessary to allow "trim pot" adjustment.

The deflection response of the Delamtect will be greater for large, shallow areas of delamination and less for small, deep areas. In an effort to establish a set of standards to check resultant deflections, a set of 3 ft. x 3 ft. thin slabs (½ in., 1 in., 2 in. thick) were made. The resultant deflections were exceptionally variable. A small difference in lateral position would yield considerable difference in reading. Experimentation with a variable thickness ramp seemed to yield more consistent results. The magnitude of deflection varied with the thickness and produced a repeatable trace shape. No check "standards" have been established to date.

TESTING AND EVALUATION USING THE DELAMTECT

Surveying Bridges Prior to Resurfacing

In Iowa, a delamination survey is conducted on all bridges to be included in the deck resurfacing program. This survey is used for the design and estimating of quantities for the project. The preparation of the deck for resurfacing is separated into three bid items with brief descriptions as:

1. Class A Bridge Floor Repair - Removal of concrete to at least the level of top reinforcing steel, but not full depth.

2. Class B Bridge Floor Repair - Full depth removal.

3. Bridge Floor Overlay - Scarification to a depth ¼ in. below the original surface.

Just prior to the resurfacing, a second survey is conducted and areas requiring Class A or Class B repair are painted on the deck surface to aid the contractor.

The equipment that is generally used for this pre-construction survey consists of bar drags, chain drags, hammers or other metal devices. Even though these depend upon the perception by the ear of the operator, with some operator experience, these methods have proven to be very reliable. This procedure is somewhat slow and tedious and requires diligence of the operator. There are also times when traffic noise interferes with the operator's ability to hear and perceive the "hollow" sounding areas.

The Delamtect has been compared with the manual sounding methods mentioned above on selected bridges from the National Experimental and Evaluation Program of the FHWA. The Delamtect has demonstrated complete agreement when compared to delaminations as located by manual methods. Using the manual sounding methods, the operator relies on perception by his ear to judge a particular area as "hollow" or "not hollow." The only delamination information utilized in the resurfacing program is separation into the "hollow" or "not hollow" classifications. The Delamtect not only makes this classification, but yields various magnitudes of deflection related to the size and depth of the delamination. Even though no significant use is presently being made of these varying magnitudes of deflection, they are interesting in demonstrating the repeatability of the Delamtect. If the Delamtect is operated over the same path, near duplicate traces are produced. The slight differences are believed to result from slight deviations in the path traversed.

The reliability of the Delamtect has also been demonstrated by core drilling of delaminated areas to identify the location of the fracture.

The Iowa D.O.T. Delamtect was ordered without the earphone or paint spray options. The paint spray option was later purchased and added to the Delamtect. This is a definite asset in identifying hollow areas on the deck surface. The earphone system has not been ordered, but would also be a benefit in freeing the operator of continual observation of the trace. This would result in improved event notation.

Evaluation of Bridge Resurfacing Projects

Due to manpower limitations, very few bridge decks had been surveyed by manual sounding after resurfacing. The Delamtect has been used extensively in a survey of dense P.C. Concrete resurfacings which date back to 1965. As would be expected, the Delamtect is also reliable for post construction evaluation. These surveys have verified the absense of delaminations or unbonded areas on recent projects. Hollow areas have been identified and investigated on older projects. Because there was no post construction survey, there is no way to determine if the hollow areas are a result of poor surface preparation at the time of construction. The Delamtect would provide the capability of more effective post construction evaluation and thereby verify that desired results, performance and longevity are obtained.

Evaluation of Bond Within Membrane Systems

In 1974, a protection system was required on all bridge decks with federal funding. Iowa applied Neoprene, Bituthene and Protectowrap membrane systems on I-380 bridges in Cedar Rapids. During the hot summer months of 1975, following construction in the fall of 1974 and before being opened to traffic, many blisters were observed on the Neoprene membrane system. Some manual "sounding" had been conducted to locate "hollow" areas, but this was rather slow and the limits of the areas were not easily defined on the asphalt concrete.

Initial use of the Delamtect to survey membrane systems generated doubt as to the effectiveness. This first attempt was to evaluate the bonding of the Neoprene system and all testing seemed to yield substantial deflections. This Neoprene system consisted of a layer of UWM-28 (polyurethane) adhesive placed on the concrete deck, a Neoprene sheet, another layer of UWM-28, a protection board and the asphalt concrete wearing coarse. At first, some individuals were of the opinion that the greater deflections were a result of the layers of flexible materials. Between the substantial deflections, there were very short sections of trace exhibiting no deflection which does not support the "deflection resulting from flexible material" opinion. Because the unbonded areas were oriented primarily longitudinally, testing was conducted using transverse passes with the unit.

Testing of the Bituthene and Protectowrap systems produced traces with essentially no deflections (a high degree of bond). Based upon this membrane testing data, the Delamtect was very effective in evaluating the lack of bond. It indicated very poor bonding of the Neoprene system which was confirmed both by the blisters and exploratory removal of some asphalt mat and Neoprene membrane.

The Delamtect again demonstrated its ability to produce a trace with not only similar shape, but if operated over the same longitudinal path, the magnitude of deflections are also duplicated. This method could then be used to assign a quantitative value to the bonding on a particular test date.

ADVANTAGES OF THE DELAMTECT

Reliability

Reliability is one of the most important advantages of the Delamtect. It has been proven effective in locating "hollow" areas resulting from delaminations or lack of bond. There is very little operator labor or hearing perception required, therefore, reducing the dependence on the diligence of the operator. It will yield almost perfect repetition of deflection due to the "hollow" areas.

Economics

The Delamtect is a very rapid survey method. The field survey of a typical 200 ft. x 30 ft. bridge with manual sounding requires approximately 12 man hours. The same field survey with the Delamtect can easily be completed in one hour and could be accomplished by three technicians (three man hours). The time for reduction of the data in the office would vary depending on the amount of delaminations, but would require approximately six man hours for either method. The signing and protection required from the Office of Maintenance would be reduced from a four hour period to a one hour period.

On four-lane roadways, the traffic is funneled into the open lane and signing personnel are utilized for manual sounding, but on two-lane raodways, traffic control by one or two flagmen would be continually required. Every bridge would have different survey and signing requirements, but for the survey (including data reduction) of a 200 ft. x 30 ft. bridge, the manual method would require approximately 26 man hours and the Delamtect Method, 11 man hours. On a four-lane roadway, this would be approximately 18 man hours for manual and 9 man hours for the Delamtect.

Safety

The safety of both the motorist and the survey technician would be improved as the time when traffic is obstructed would be approximately 25% of that required for a manual sounding survey.

ACKNOWLEDGEMENTS

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Test Method No. Iowa 1010
April 1978

IOWA DEPARTMENT OF TRANSPORTATION
HIGHWAY DIVISION

Office of Materials

METHOD OF TEST FOR DETECTING
DELAMINATIONS USING THE DELAMTECT

Scope

This test method covers the survey of bridge decks to determine the extent of delaminations using the Delamtect.

A. Apparatus

1. Delamtect (Figure 1 and 2)
2. Tape measure
3. Cord line (500' long)
4. Lumber crayon

Figure 1
Delamtect in Operation

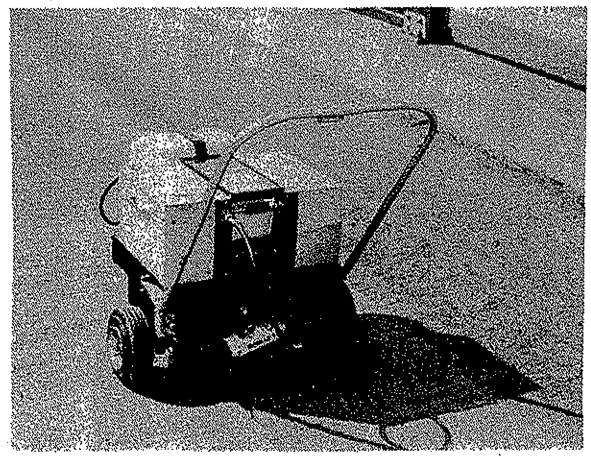

Figure 2
Rear View of Delamtect

B. Test Record

Information to be recorded in field book:

1. Project No. including County and Design No.
2. Year of last deck surfacing
3. Location description (route Nos., stream name, R.R. name etc., distance from known reference)
4. Dimensions (length and width - curb to curb)
5. Skew if known
6. Surface type (PCC or AC)
7. Any special features (known or observed)
8. Names of crew
9. Date of survey

Information to be recorded on strip chart:

1. Project No. and County
2. Location and description (Road, stream etc., and date on each end of chart)
3. Survey beginning location (side and end)
4. Identify electrical zero, background response and calibrator bar readings before and after each bridge survey
5. Pass number and direction of travel
6. Ends of bridge, joints, expansion devices

C. Test Procedure

1. Read the instructions in the Operator's Manual for the SIE Delamtect.
2. Verify that the battery has sufficient charge.
3. Turn power switch, "ON," transmitter and chart drive switches "OFF" to let the Delamtect warm up while marking the bridge for survey.
4. Bridge layout: beginning at curb face, mark 18" spacings across each end of the bridge deck.

5. Delamtect Calibration:

   a. Place calibrator bar behind the Delamtect and pull the Delamtect up onto the calibrator bar. Push down on handle to lift the swivel wheel off the surface to assure that the Delamtect is properly located on the calibrator bar, then let swivel wheel back to surface.

   b. With power "ON," turn chart drive "ON" to run about 1" of chart paper. (Figure 3) Mark this trace "EZ" (electrical zero).

   c. With power "ON," function "CALIBRATE," transmitter "ON" and chart drive "ON," adjust Trim Pots mounted at top of storage cabinet so that the trace is 20 minor chart divisions above "EZ." Mark this trace "C" (calibrate). Switch function to "OPERATE" and the pen should deflect to about 35 minor chart divisions above "EZ."

   d. With the Delamtect on a sound portion of the bridge deck, power "ON," transmitter "ON," function "OPERATE," turn chart drive "ON" and run about 1" of paper. Mark this trace "BR" (background response).

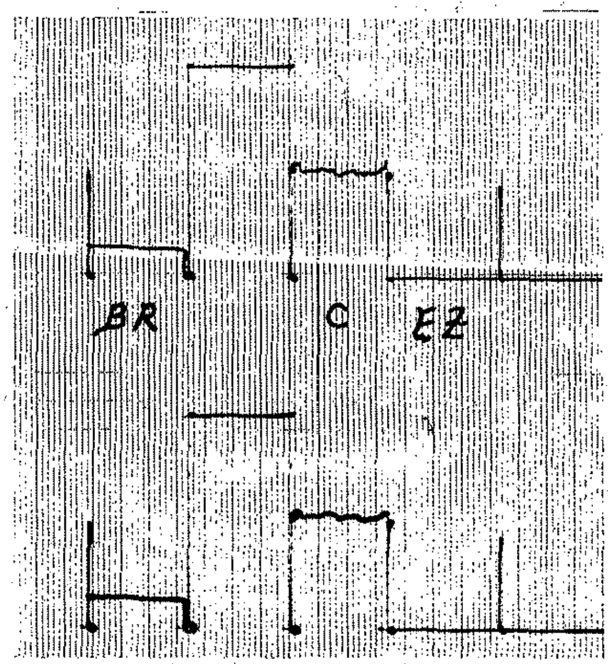

Figure 3
Strip Chart of Calibration Procedure

6. Operation

   a. Stretch the cord line between marks on each end of the bridge.

   b. Be sure the chart drive roller is in contact with the chart paper as the mechanical chart drive advances the chart paper the proper speed to correlate with the distance traveled.

   c. Note pass number and direction of travel on chart paper.

   d. With power "ON," transmitter "ON," function "OPERATE," push the Delamtect at a normal walking speed following the cord line with the swivel wheel. Mark ends of bridge, expansion devices, etc., with the event marker which is activated by the button on the side of the handle.

   e. After deck has been surveyed using 18" spacings, repeat steps 5a through 5d before turning power "OFF."

7. Delaminations (deflection of 4 or more minor chart divisions above "BR") may be marked on bridge at time of survey by activating the paint spray.

D. Data Interpretation and Plotting

1. Select a reasonable longitudinal scale and use an exaggerated transverse scale (example: longitudinal 1"=10', transverse 1"= 4')
2. Lay out the test lines on 9" centers to the selected scale.
3. Plot the limits of all portions of each trace exhibiting deflection of four or more minor divisions above the normal background response level (figure 4).
4. Connect the limits of these plots and outline the individual delaminated areas.
5. Establish a block outline around general areas of delamination.
6. Determine the total area contained in the block outline areas.
7. Divide the area obtained in point "6" by the total bridge deck area and multiply by 100 to yield the percent of delamination.

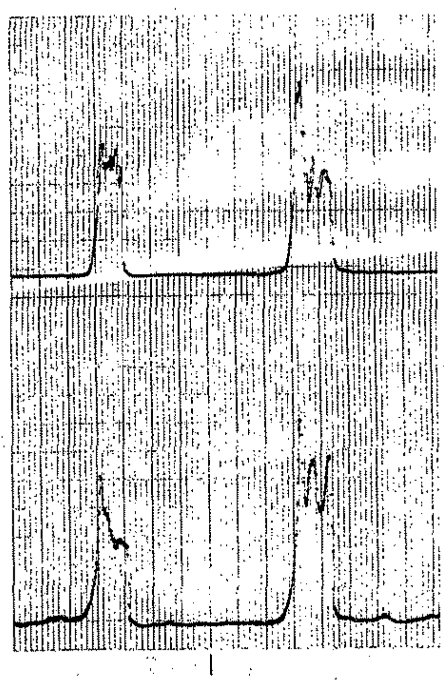

Figure 4
Strip Chart Showing Deflections Resulting From Delamination

E. Precautions

1. Before moving onto the traveled portion of the roadway, be certain that the required safety devices are in place. Wear a safety vest while on or near the traveled way.