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NEW JERSEY PACHOMETER TESTS:

An Evaluation of the Equipment and the Variability of Bridge Deck Reinforcing Cover

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ABSTRACT:

A pachometer was used to collect data from twenty-three randomly selected bridge decks to determine the variability of depth of cover. This data has been used to develop recommended depth of cover specifications for New Jersey that will minimize the probability of spalling distress. A recommended operational procedure is presented which will give reliable, precise results for future use when using the pachometer to locate and to measure cover depth over reinforcing bars. The New Jersey pachometer was found to be very dependable and trouble free, needing no maintenance except replacing dead batteries.

KEY WORDS:

Bridge decks, bridge design, concrete durability, corrosion, deicing, depth, durability, reinforced concrete, reinforcing steel.

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I. OBJECTIVES

The present program of pachometer testing was undertaken for two reasons:

First, to determine the accuracy and precision with which the location, size, and depth of reinforcement bars could be measured with a pachometer.

Second, to gather information concerning the variability of bridge deck reinforcement bar cover.

This latter information will be used by others to develop specifications that will minimize the risk of insufficient cover and reduce the attendant spalling problems.

II. INTRODUCTION

The pachometer is an electromagnetic device which can be used to locate reinforcing steel in concrete and measure its depth of cover. It is convenient, fast, and accurate and is rapidly becoming "standard equipment" with many highway agencies.

A. Nature of Equipment

The pachometer consists of two parts: a U-shaped probe and a meter calibrated to indicate the depth of cover over steel reinforcing rods (shown in Figure 1). The dimensions of the device are 9 inches (width) by 8-1/2 inches (height) by 4 inches (thick). Weight is 7-1/2 pounds.

FIGURE 1

Overall View of Pachometer

The meter scale is shown in Figure 2. Depth of cover of reinforcing bars is determined by reading the thickness of concrete, as indicated by the meter pointer, from the scale corresponding to the diameter of the reinforcing rod.

Cover depths determined during this evaluation were measured by using the 0-100 linear scale in conjunction with an appropriate calibration curve. The gauge's logarithmic scales are used to indicate the depth directly, however use of these scales was felt to be less accurate because interpolation is frequently required. The latter method was, therefore, not employed in this research.

B. <u>Nature of the spalling problem and influence of depth of cover</u>

It is an accepted fact that spalling of bridge decks is the result of corrosion of the top reinforcing steel. For example, researchers[1] have reported that deterioration of reinforcement bars is reduced from 63 percent at 1-5/16 cover to 2 percent with 2 inches of concrete cover. Up to 3 inches of concrete cover is considered desirable, while 2 inches is the recommended minimum acceptable cover.

As in any construction operation, achievement of a known reinforcing bar depth is subject to variation, therefore any specifications which are developed should take this variability into account. In order to determine the "typical" values of rebar variation in New Jersey it was necessary to make a statistical survey of several bridge decks throughout the State. A list of bridge decks used for this study is included in Appendix A and the results are presented in a separate report[2]. (See Appendix B for standard deviations, mean, maximum cover and minimum cover observed for New Jersey bridge decks.) In general, the older bridges

FIGURE 2

View of Pachometer Dial

with a specified 1-1/2" cover had a mean cover depth of 1-5/8", and the bridges with a specified cover of 2" has a mean cover depth of 1-7/8". With a standard deviation of 3/8", the specified 1-1/2" cover bridge decks were deficient in cover 1/3 of the time and the specified 2" cover bridge decks were deficient in cover 2/3 of the time. (The standard deviation is a measure of the spread around the average value of a group of numbers.) Analysis of this variability indicates that a specified depth of 3-1/8" is needed to protect all the steel from moisture and deicing salts, while a specification of 2-1/2" can protect 90 percent of the steel.

III. TESTING PROGRAM

A. Accuracy and Precision

A calibration curve was constructed either before or immediately after each pachometer test using a grid of reinforcing rods of the same size and approximate spacing as those in the bridge deck which was measured. This frequent check of the calibration curve is necessary to correct for any possible drift as the power supply of 3 "AA" size batteries decreased with continuous use. In the calibration procedure, the pachometer is held at various heights above the steel grid and readings on the linear scale are recorded. The distances to the top of the reinforcing bars are measured and these measurements plotted with pachometer readings on rectangular coordinate graph paper. As the batteries grow weaker from continuous use, the calibration curve will shift in a direction which gives higher readings for equivalent depth of cover.

Tests were also conducted to check the precision of the pachometer. Because of its proximity to the research facility, a recently constructed bridge over Whitehead Road was selected to carry out this phase of the experiment. The precision testing involved marking twenty-nine locations on the bridge deck with painted yellow crosses, measuring each of these points on five different days and comparing the results. The largest difference between any of the duplicate readings was 1/8 inch and many readings coincided exactly. The standard deviation of the five readings for twenty-nine different points was 1/32 inch. Results such as these lead to the conclusion the New Jersey pachometer is a precise instrument and will give consistent results.

Operator reliability was also checked by having four operators measure bar depth and location on a concrete test slab. Comparison of the resulting data showed 1/16 inch to be the largest variation in the measurements made by the four operators. This difference is not significant enough to indicate any great operator variability. Another research agency[(3)] has similarly found that operator error is not a significant source of variation when using the pachometer.

B. Locating Bars

Wooden forms and concrete slabs were used to determine how accurately reinforcement bars could be located (horizontal position). The forms and blocks were covered with paper to prevent the operators from seeing the exact location of the bars. Comparison of actual bar locations with the locations determined by the operators showed no appreciable difference. Additionally, grid patterns were drawn on bridge decks during concrete cover surveys and these grids were in excellent agreement with those indicated on bridge plans.

Shortly after receiving our pachometer, a request was made to take two cores from newly constructed bridge which began experiencing premature scaling. The location where cores were to be taken was checked with a pachometer and revealed that reinforcing bars would be cut by the coring operation. It was decided to shift the core locations slightly in order to miss the reinforcing rods. Both cores were taken at the new locations and neither coring operation cut a reinforcing bar.

C. Determination of Bar Size

Preliminary tests of the pachometer's ability to determine bar size were not very successful. The manufacturer's literature states that the accuracy of this function is plus or minus one bar size. Our testing indicated that it was difficult to achieve even the manufacturer's claimed accuracy for this function, consequently this particular feature of the pachometer was not used. Since knowledge of the bar size is essential to accurately interpret depth of cover readings, it is recommended that bar size be determined from the plans when possible.

D. Influence of Surface Texture

The surface texture of the concrete can have an effect on the operation of the pachometer. Heavy surface texture can cause the pachometer needle to oscillate, giving the apparent indication of a closely spaced group of reinforcing rods. Picking a location about a foot away and taking another reading is the best way to eliminate any errors caused by these questionable readings. If the pachometer still experiences these oscillations, it is best to draw the reinforcing rod pattern on the bridge deck and check how it compares with the reinforcing indicated on the bridge plans. However, with a little experience, it is usually possible for the operator to recognize when the needle is indicating a reinforcing rod location or skimming over an uneven bridge deck.

IV. BRIDGE DECK STUDY

Bridge decks used for this study in Appendix A vary with respect to age, finishing technique, riding quality and the presence/absence of surface distress. In selecting these bridges, the following items were considered:

A. Finishing Technique and Reinforcement Cover

The use of an approved self-propelled finishing machine for bridge decks became mandatory in New Jersey (except where precluded by note on plans because of adverse geometric or economic considerations) for all projects advertised for bids after July 1, 1973. At least one state[4] has associated deficient cover with longitudinal machine finishing. Any relationships found to exist in New Jersey between finishing techniques and reinforcement cover will assist in the evaluation of this proposed specification.

B. Durability and Reinforcement Cover

The depth of cover and potential for spalling is of interest for two reasons: First, certain of the bridges have received experimental anti-scaling treatments and will be the subject of continuing durability evaluation. The information as to reinforcement cover thus will be valuable supplemental information to the durability study. Secondly, it is felt that an increase in reinforcement cover in New Jersey may be in order[2]. By determining the mean depth and variability of the cover depth on the listed bridges, a realistic target for increase depth of steel can be determined.

V. OPERATING PROCEDURE

As previously noted, accurate and precise results were obtained with the New Jersey's Model C-4946 pachometer. It is felt that if the procedures below are followed, future work will result in similar good results.

A. Ideally, calibration curves should be made daily to check pachometer accuracy. This procedure requires about a half hour of time. Wood shims of various heights are placed on top of a grid of reinforcing rods similar in spacing and size as those in the bridge to be measured and readings on the linear scale are recorded. Depths to the top of the reinforcing rods are measured with a vernier depth gauge and this information is used to construct the calibration curves. (See Figure 3 for typical grid of reinforcing rods.)

B. The calibration curve will shift as the power source becomes weaker. In our work, battery voltage was checked before each calibration curve was made and, when the voltage was less than 3.3 volts, all batteries were replaced. We replaced the 3 "AA" size alkaline batteries with 3 "D" size flashlight batteries and used an appropriate battery holder. The 3 "D" cells have a longer useful life and cause less needle drifting. No matter which size batteries are used, it is advisable to use a recent calibration curve to achieve the greatest accuracy.

FIGURE 3

Typical Reinforcing Rod Grid for Pachometer Calibration

C. When performing cover depth measurements, the instrument must be carefully adjusted. The meter pointer should be "zeroed" exactly at 100 on the linear scale before each reading while holding the probe at least one foot away from any magnetic material which might influence it. Setting the meter needle on 100 before each reading will partially compensate for any changes in battery voltage caused by prolonged use. It is also advisable to turn the instrument on for several minutes prior to use to allow the battery output to stabilize.

D. The following procedure (keyed to Figure 4) is suggested to measure the cover over reinforcing bars.

1. Locate bar AA' by moving the probe across AA' and noting where the needle deflection indicates a minimum amount of cover. (The probe axis is always kept parallel and moved perpendicular to the reinforcing bar being located.)
2. Mark this location of AA' on the bridge deck with keel.
3. Rotate the probe 90° so line AA' is located about in the middle of the probe. Move the probe along line AA' again noting the needle deflection giving the least depth of cover.
4. Mark this location of BB' on the bridge deck with keel.
5. The intersection of AA' and BB' is where a pachometer reading is to be taken.

EQUIPMENT EVALUATION

The pachometer is easy to operate and its techniques can be learned in a short time. One slight drawback is that continuous use by one operator is very tiring due to the need for repeated bending down to take the measurements.

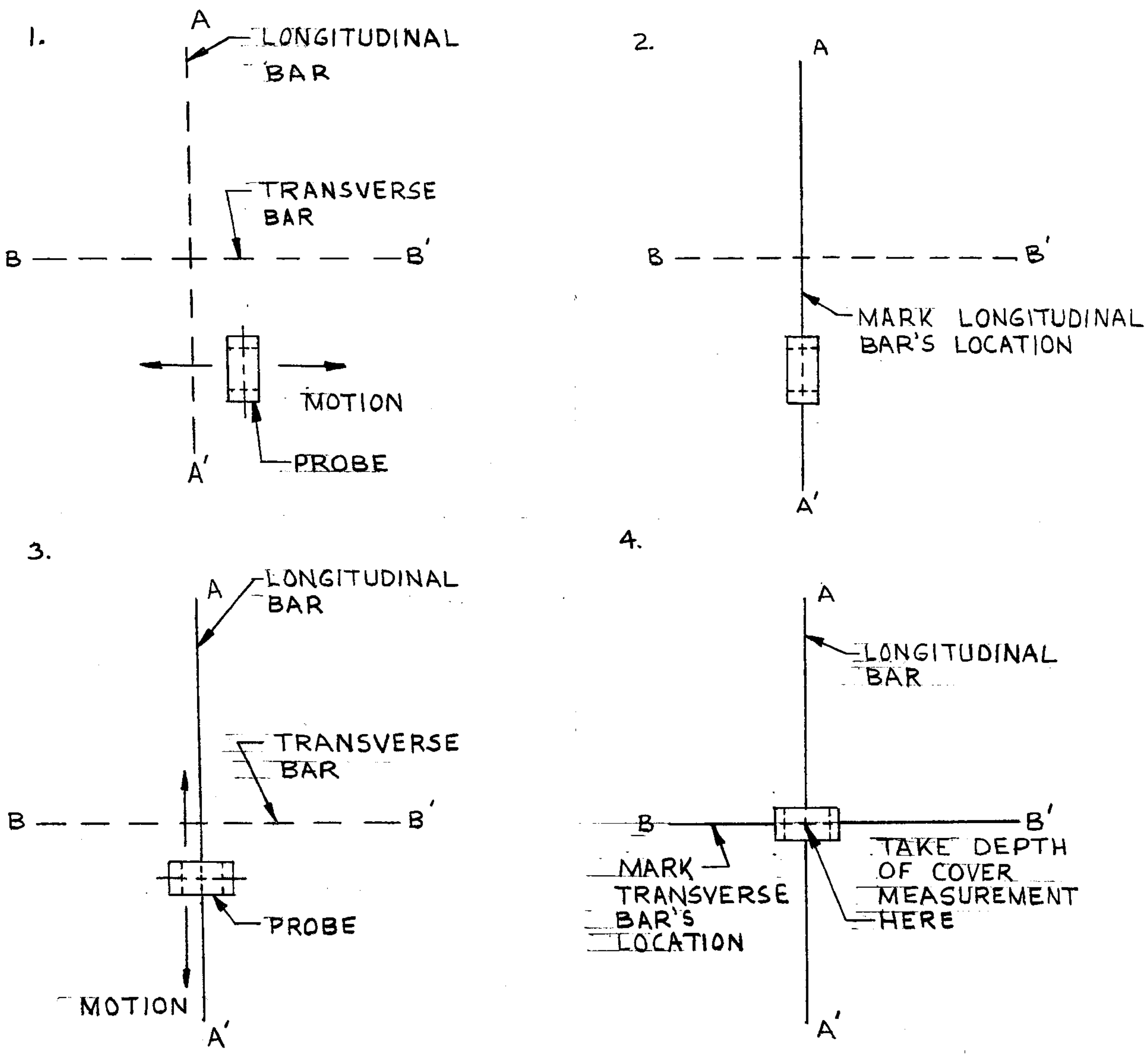

FIGURE 4

Locating the Intersection of Longitudinal and Transverse Reinforcing Rods to Determine the Depth of Cover

Minor deficiencies noted in our work were that the power supply of 3 "AA" size alkaline batteries had to be replaced frequently, loosening of lugs which hold the battery pack, and a general lack of ruggedness built into the pachometer.

Plug looseness was mentioned to Mr. P. I. Cauley of James Electronics. He acknowledged this was a problem but offered no permanent solution. It was suggested we could break the seal on the pachometer to make the necessary repairs, and the guarantee would not be voided if we sent him a letter stating we made the above mentioned repairs.

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TYPICAL BRIDGES FOR

FIELD MEASUREMENT OF CONCRETE COVER

Structure No.	Route & Section	Description	Approx. Age and Date Opened	No. of Spans	Typical Span	Remarks
1	I-295, 1S	U.S. 322 EB over I-295	4-1/2 years (4 years)	3	50' x 86'	"Rough"*; hand-finished; some spalling/pop-outs
2	I-295, 1S	U.S. 322 WB over I-295	4-1/2 years (4 years)	3	50' x 86'	"Smooth"; longitudinal machine finished
3	I-295, 3B & 4A	I-295 over Burlington-Mt. Holly Road	1-1/2 years (6 months)	2	50' x 110'	"Smooth"; transverse machine finished; durability under study
4	I-295, 3B & 4A	Beverly Road over I-295	1-1/2 years (6 months)	4	38' x 150'	"Smooth"; transverse machine finished; durability under study
5	I-80, 1K	I-80 over Waterloo Road	1-1/2 years (not open)	2	60' x 114'	"Rough"; hand-finished, durability under study; some pop-outs
6	I-78, 5AF	Frelinghuysen Avenue Viaduct	2 years (not open)	multi	55' x 105'	"Rough"; transverse machine finished; some scaling/spalling
7	N.J. 174, 1F	U.S. 1 over Whitehead Road	2 years (not open)	2	40' x 103'	"Smooth"; transverse machine finished

*Riding quality rating based on roughometer and/or straightedge data.

APPENDIX A

INDIVIDUAL BRIDGE DATA

Route & Section	Description	Mean	Standard Deviation	Mean-Specified Depth	Maximum	Minimum	Specified Depth
I-295 1S	U.S. 322 over I-295 East-bound Span 3	1.869	0.279	+0.369	2.600	1.18	1-1/2
I-295 3B & 4A	Beverly Road over I-295 Span 1	1.726	0.257	+0.228	2.22	1.15	1-1/2
I-295 3B & 4A	Beverly Road over I-295 Span 2	1.612	0.278	+0.112	2.12	0.97	1-1/2
I-295 3B & 4A	I-295 over Burlington-Mt. Holly Road	1.559	0.286	+0.059	2.14	0.64	1-1/2
I-80 1K	I-80 over Waterloo Road	1.725	0.184	-0.275	2.13	1.26	1-1/2

INDIVIDUAL BRIDGE DATA

Route & Section	Description	Mean	Standard Deviation	Mean-Specified Depth	Concrete Cover Maximum	Concrete Cover Minimum	Specified Depth
I-78 5AF	Frelinghuysen Avenue Viaduct 4A	1.751	0.189	+0.251	2.070	1.030	1-1/2
I-78 5AF	Frelinghuysen Avenue Viaduct Span 7B	1.267	0.227	-0.233	1.740	0.720	1-1/2
I-78 5AF	Frelinghuysen Avenue Viaduct Span 5B	1.309	0.219	-0.191	1.690	0.820	1-1/2
I-78 5AF	Frelinghuysen Avenue Viaduct Span 1A	1.883	0.240	+0.383	2.410	1.370	1-1/2
I-78 5AF	Frelinghuysen Avenue Viaduct Span 5A	1.628	0.267	+0.128	2.050	0.950	1-1/2
I-78 5AF	Frelinghuysen Avenue Viaduct Span 2E	1.789	0.199	+0.289	2.220	1.260	1-1/2
I-295 1S	U.S. 322 over I-295 West Span 1	3.125	0.321	+1.625	3.880	2.470	1-1/2
I-295 1S	U.S. 322 over I-295 West Span 2	3.029	0.360	+1.529	3.750	2.420	1-1/2
I-295 1S	U.S. 322 over I-295 West Span 3	2.717	0.338	+1.217	3.350	1.780	1-1/2
I-295 1S	U.S. 322 over I-295 East Span 1	1.715	0.246	+0.215	2.190	1.080	1-1/2
I-295 1S	U.S. 322 over I-295 East Span 2	1.740	0.267	+0.240	2.140	1.060	1-1/2

INDIVIDUAL BRIDGE DATA

Route & Section	Description	Mean	Standard Deviation	Mean-Specified Depth	Concrete Cover Maximum	Concrete Cover Minimum	Specified Depth
N.J. 174 1F	U.S. 1 over Whitehead Road NB	1.882	0.484	-0.118	2.850	1.100	2
N.J. 174 1F	U.S. 1 over Whitehead Road SB	2.043	0.367	+0.043	2.850	1.230	2
N.J. 174 1F	U.S. 1 over Whitehead Road Canal Span 1 NB	2.239	0.209	+0.239	2.920	1.830	2
N.J. 174 1F	U.S. 1 over Whitehead Road Canal Span 2 NB	1.597	0.366	-0.403	2.500	1.040	2
N.J. 174 1F	U.S. 1 over Whitehead Road Canal Span 3 NB	1.977	0.244	-0.023	2.420	1.460	2
N.J. 174 1F	U.S. 1 over Whitehead Road Canal Span 4 NB	1.629	0.295	-0.371	2.170	1.080	2
N.J. 174 1F	U.S. 1 over Whitehead Road Canal Span 5 NB	1.653	0.204	-0.347	2.120	1.270	2

APPENDIX B