EVALUATION OF NUCLEAR METHOD FOR ASPHALT TESTING

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In 1965, at the request of the Bureau of Public Roads, the Department began a program for measuring the densities of bituminous surfaces (on Federal Aid Projects) by coring the finished construction and measuring core densities at the Testing Laboratory in Ann Arbor. Because this procedure was laborious and the results unavailable until several days after completion of construction, Paul Serafin requested a cooperative project with the Research Laboratory to determine the suitability of the nuclear method for measuring density of compacted bituminous mixtures.

Subsequent to project approval (1968), preliminary tests were conducted during the summer of the bituminous surfacing of M 57 from Montrose east to I 75 (Project M 25101C, C7). Cores were taken from the same locations at which densities had been measured by the nuclear gage. Core densities and nuclear densities were compared on a test-for-test basis and a statistical analysis made of their correlation. Although limited in number, the correlation between tests was promising. As a result, Mr. Serafin requested that the project be continued and expanded during the 1969 construction season.

All field testing during 1969 was conducted by the Coring Unit of the Testing Laboratory. The Research Laboratory furnished nuclear gages, instructed the personnel in their use, and statistically analyzed the test results.

TESTING PROCEDURES

The evaluation testing procedure consisted of measuring the bituminous pavement density with a nuclear gage and then measuring the unit weight of a test core obtained from the same location. Nuclear testing was performed in accordance with manufacturer's instructions and utilized the air-gap method. Core densities were determined in the Testing Laboratory by conventional weight-volume measurements. Throughout this phase of testing, measurements were obtained on completed projects; no construction control or testing of hot material was attempted.

Nuclear Tests

Nuclear density measurements were made at each test location with a Seaman Model 75 instrument using the air-gap method in accordance with the manufacturer's instructions. The Seaman Gage is a nondestructive device operating on the principle of interaction between nuclear radiation and matter. Gamma-ray radiation used by the gage for density measurement is supplied by a 4.5 millicurie Radium-Beryllium source. Gamma rays emitted by the gage enter the paving material where some are absorbed by the material and others are scattered in various directions. The gamma rays which are scattered back and recorded by the gage indicate the density of the paving materials.

TABLE I
PROJECT INFORMATION

Project	Paving Date	Coring Date	Pavement Cross Section*	Aggregate
CS 3-58-004	8- 6-69 to 8-11-69	8-27-69	A	20A
CS 12-49-004	7- 2-69 to 7-12-69	7-30-69	B	20A
CS 13-77-003	5-20-69 to 9- 4-69	10-15-69	A	31AA + 3NS
MB 14011-008	8-15-68 to 9- 4-68	7-14-69	A	31AA + 3NS
SS 17072-004	7-22-69 to 8-11-69	9-11-69	A	20A
I 23081-001	9-30-68 to 11-11-68	8-21-69	B	20A
U 41012-006	5- 1-69 to 8-18-69	8-28-69	A	31AA + 3NS
F 73091-008	5-24-69 to 6-20-69	7-29-69	A	31AA + 3NS
CS 78-41-004	7-16-69 to 7-21-69	11-10-69	A	20A

(*) A - Bituminous over Bituminous (2 or more courses of bituminous).
B - Bituminous over gravel.

At each of 127 test locations on 9 projects (Table 1), one nuclear measurement and one core were obtained. The nuclear measurement required two test readings: one with the gage in direct contact with the pavement surface, the other with the gage placed on a metal air-gap stand directly over the area where the contact reading was obtained. The ratio of these two one-minute readings is used with the calibration chart provided by the manufacturer to indicate the in-place density value. This method of using the gage is as recommended by the manufacturer and is the basis for the calibration curves furnished with each instrument. Previous work, using the Seaman gage with aggregates, indicated that satisfactory results also could be obtained using a single reading with the gage in the contact position. Both procedures were included in this study in order that the most accurate and rapid method could be determined.

Because of malfunction, two different nuclear gages (both Seaman Model 75) were used during the testing program. One gage was used for 96 of the tests (gage A) with the remaining 31 tests performed with a second gage (gage B).

Core Density Measurements

Using the weight in air - weight in water method, densities were obtained on the various layers of the cores obtained from the same locations where the nuclear density readings were taken.

TEST RESULTS

Complete evaluation of results involved four separate analyses of the 127 data points; two different sets of nuclear values were each correlated with two sets of core density values yielding the four combinations. The two sets of nuclear readings consisted of: 1) Air-gap ratio density values in pounds per cubic foot, and 2) Contact reading count rates (counts per minute). Two core density values were obtained from each core in order to check the possible effects of different paving courses or layers. First, the density of the wearing course, only, was considered, and second, a weighted average density was determined taking into account wearing course density and thickness, leveling or binder course density and thickness and the gage's depth of measurement response curve as shown in Figure 1.

If differences in densities between surface and lower layers significantly affects nuclear results, this would require consideration in any proposed use of the instrument. Assuming that this effect exists, a better correlation with nuclear values should be expected by using weighted average values rather than wearing course densities.

Correlation analysis was performed on each of the four sets of test values listed below:

A) Nuclear air-gap density vs. wearing course core density
B) Nuclear air-gap density vs. weighted average core density
C) Nuclear contact reading vs. wearing course core density
D) Nuclear contact reading vs. weighted average core density

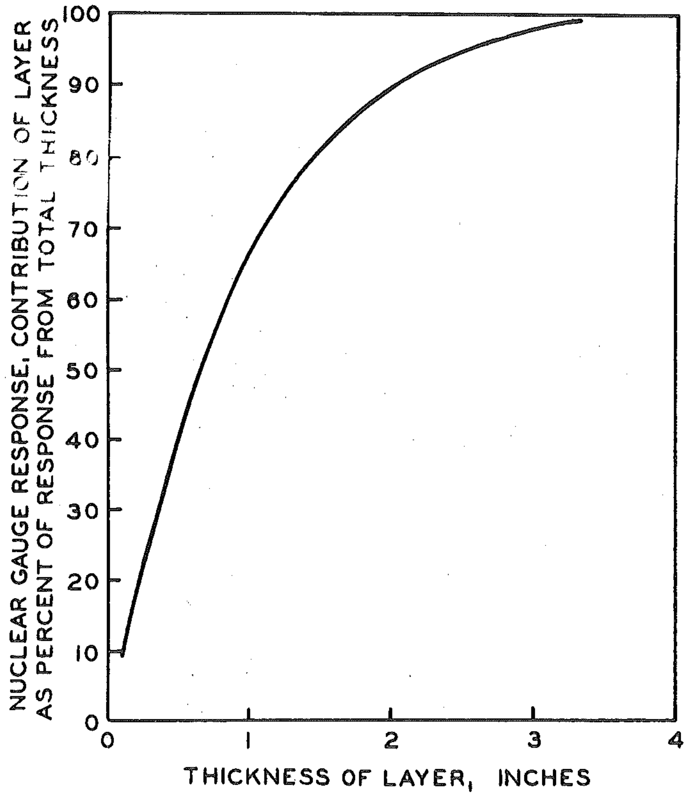

Figure 1.
Nuclear gage
depth of
measurement

The accuracy with which the nuclear method can be used to estimate pavement core densities is shown in the scatter diagrams for these four correlations in Figures 2 and 3. The regression, or best fit, lines were located by correlation analysis so that the total core value variance from the line would be a minimum. Accuracies, as indicated by the standard error of estimate (dashed lines) range from $\pm$ 1.1 to 1.9 pounds per cu ft.

A summary of test results for both gages (Table 2) shows that the correlation coefficient, R, as well as the standard error of estimate, S, is also a measure of the accuracy with which pavement density can be predicted by the nuclear methods. Estimates of density would, in the long run, agree with the true density plus or minus one standard error, in 2/3 of all tests. The correlation coefficient, R, is a measure of how well the two variables are functionally related; an R of 1 meaning all points fall on a line, whereas an R of 0 means no functional relationship between the two variables whatsoever. R can never be greater than 1 or less than -1 (negative values indicate inverse relationships).

As shown in Table 2, wearing course values provide better correlation between nuclear and core values regardless of the nuclear method used

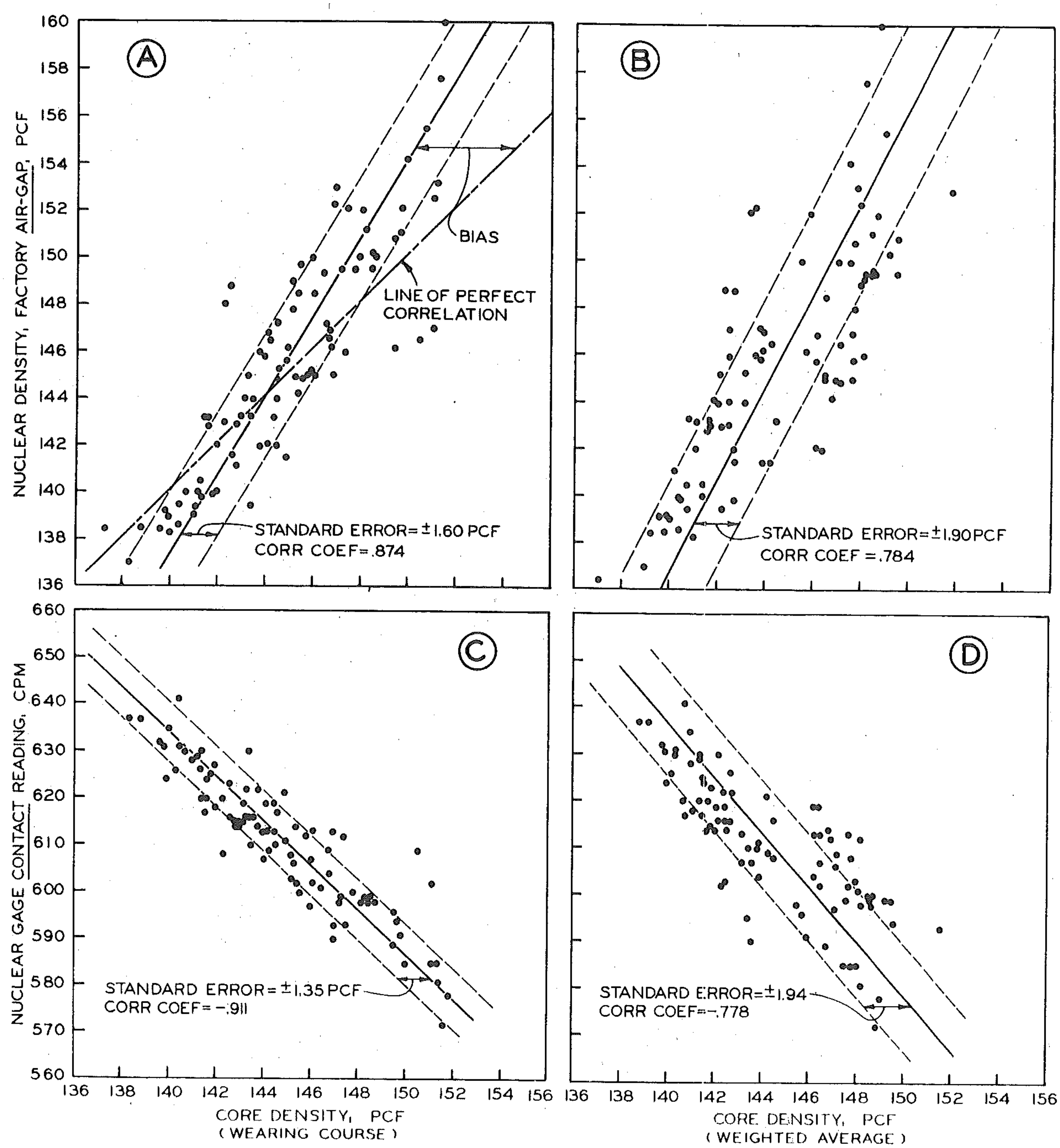

Figure 2. Relationship of nuclear and core density values (Gage A).

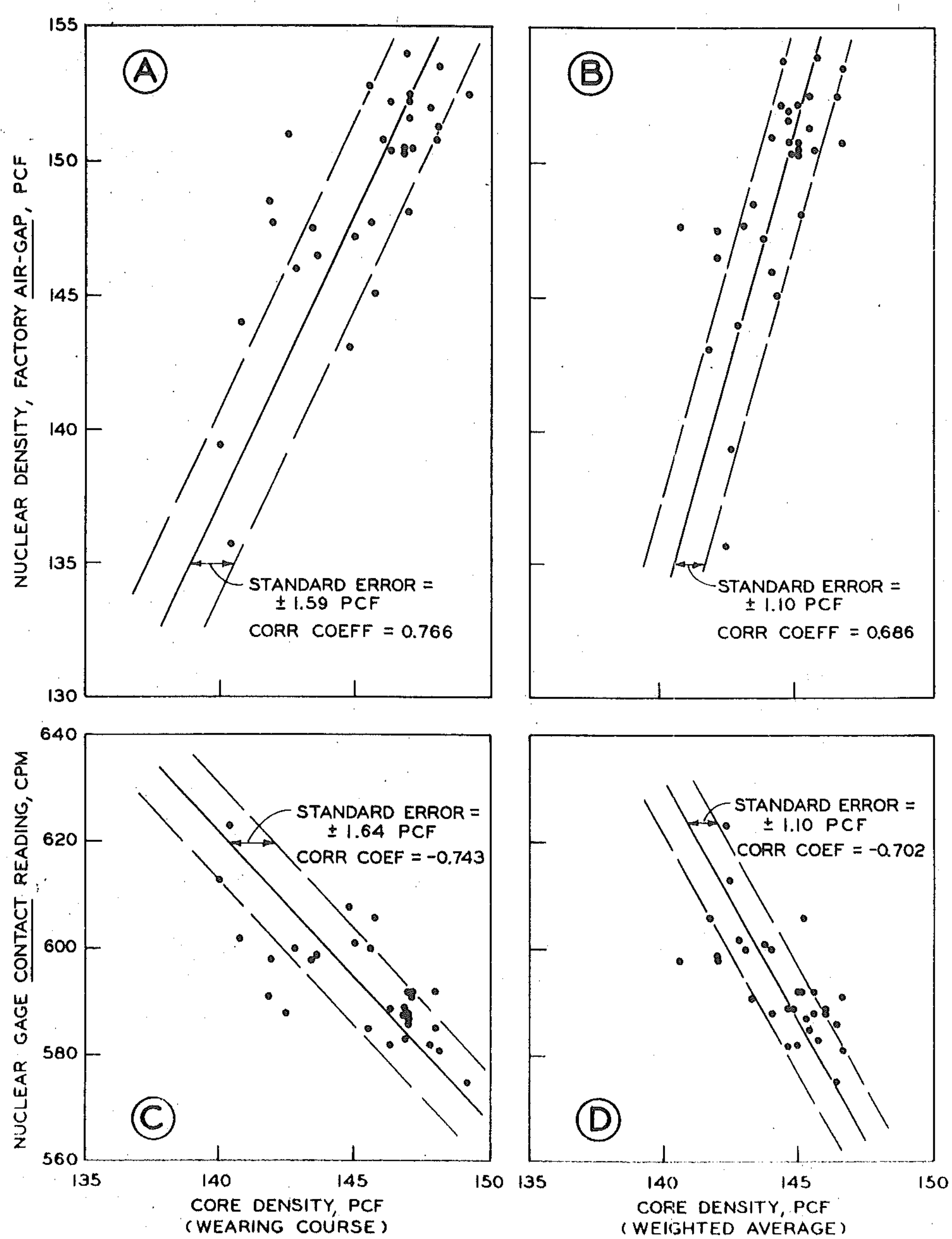

Figure 3. Relationship of nuclear and core density values (Gage B).

TABLE II
SUMMARY OF CORRELATION RESULTS

Comparison Pair	Correlation Coefficient, R		Standard Error of Estimate	
	Gauge A	Gauge B	Gauge A	Gauge B
A. Air Gap - Wearing Course	.874	.766	1.60	1.59
B. Air Gap - Weighted Average	.784	.686	1.90	1.10
C. Contact - Wearing Course	-.911	-.743	1.35	1.64
D. Contact - Weighted Average	-.778	-.702	1.94	1.10
Number of Data Points	96	31	96	31

(air-gap or contact), with their R values being consistently greater for both gages than the R values obtained using weighted average values. Lower standard errors obtained with the weighted average method for gage B should probably not be interpreted as contradicting this trend because relatively few tests were performed with gage B. The standard error values as obtained for the 96 tests with gage A, should, therefore be the more reliable estimates of accuracy to be expected in the long run.

The data shown in Table 2 indicate that the air-gap method of testing is no better than the more rapid contact method. This could be due to either of two factors. First, the air-gap method is intended to minimize errors due to differences in chemical composition of the various materials tested. Quite probably, no detectable or major compositional differences existed in the bituminous mixes tested, thus, no improvement in correlation over contact values was to be expected. Second, from Figures 2 and 3, it can be seen that factory air-gap calibration nuclear values and core values do not have a one-for-one correspondence, i.e., a regression line closely approximating the 45-degree line, even though a relationship obviously exists. This is because the factory calibration chart was in error, and the correlation results, therefore, biased.

CONCLUSIONS

1. Factory calibration charts provided with the instrument were not accurate; bias of as much as 5 pounds per cubic foot was found when the factory air-gap chart was used.

2. Correlation analyses performed indicate that, with appropriate calibration, the particular instruments evaluated can be used to measure bituminous surface course densities with accuracies of from 3 to 4 pounds per cubic foot at the 95 percent confidence level (two standard deviations).

3. Use of the air-gap method does not appear warranted on the basis of this study.

4. Nuclear values apparently were not affected by layers of differing densities below the surface course.

5. Calibration curves furnished with the nuclear gages were not applicable to the field conditions of this study. It is recommended that gages be recalibrated prior to using either by the use of laboratory standards which have been checked against field data or, as was done in this study, by performing a suitable number of field correlation tests.