SP- 156100
(New)

SPECIAL PROVISIONS
FOR
TEST METHOD FOR DETERMINATION OF DENSITY OF BITUMINOUS CONCRETE IN-PLACE BY THE NUCLEAR METHOD

Scott County
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THE STANDARD SPECIFICATIONS, SERIES 2015, ARE AMENDED BY THE FOLLOWING MODIFICATIONS AND ADDITIONS. THESE ARE SPECIAL PROVISIONS AND THEY SHALL PREVAIL OVER THOSE PUBLISHED IN THE STANDARD SPECIFICATIONS.

A. Scope

This method covers the determination of the density of bituminous concrete in-place by gamma radiation using backscatter or direct transmission techniques.

B. Significance and Use

1. The nuclear density method is employed to determine the density of bituminous concrete. It may be used to establish the optimum density for a given rolling effort and pattern and to check the bituminous concrete for compaction specification compliance.

2. The density results obtained by this method are relative. If approximations of core density results are required, a correlation factor may be developed to convert nuclear density to core density by obtaining nuclear density measurements and core densities at the same locations. The Department's "Standard Test Method for Correlating Nuclear Gauge Densities with Core Densities" shall be used to determine the appropriate correlation. It may be desirable to check this factor at intervals during the course of the paving project. A new correlation factor should be determined when there is a change in the job mix (outside the allowable adjustments defined in the section of the QC/QA Special Provision entitled "Start of Mix Production and Job Mix Formula [JMF] Adjustments); a change in the source of materials or in the materials from the same source; a significant change in the underlying material; a change from one gauge to another; or a reason to believe the factor is in error.

   Note: Accuracy of the nuclear test modes (backscatter vs. direct transmission) is not equal and is affected by the surface texture and thickness of the mixture under test. The nuclear test mode to be used and the number of tests required to determine a satisfactory factor is dependent on the conditions stated above.

3. The user should recognize the density readings obtained on the surface of thin layers of bituminous concrete may be erroneous if the density of the underlying material differs significantly

from that of the surface course. Department thin-lift correction procedures may be used for this situation. In addition, small tonnage projects or mixture start-ups may require Department thin-lift correction procedures.

4. All projects containing 3000 tons or more of mixture will require a correlation factor be determined and applied for measurement and acceptance of density testing. Other types of mixtures, where applicable, may also utilize this procedure for determination of density.

5. The "individual required test result" (as stated in the Special Provisions) to be plotted on the Control Chart is the average of the five nuclear readings obtained at each test site locations.

C. Apparatus

1. The system shall consist of the following items. The exact details of construction of the apparatus may vary.
   a. Gamma Source - A double encapsulated and sealed radio isotopic source such as cesium-137 or radium-226.
   b. Detector - Any type of gamma detector, such as Geiger-Muller tube or scintillator crystal.
   c. Readout Instrument - Such as scalar or direct readout meter.
   d. Reference Standard - Provided for the purpose of checking equipment operation and Background count.

2. Safety - The equipment shall be so constructed as to be licensable in accordance with applicable health and safety standards.

D. Standardization of Equipment

1. Standardization of equipment on a reference standard is required at least once a day.
   a. The gauge shall be warmed up at least 20 minutes.
   b. The reference standard count shall be taken on material 100 pounds per cubic feet or greater.
   c. The reference standard count shall be taken a minimum of 30 feet away from another gauge and minimum of 15 feet away from any other mass.
   d. All reference standard counts shall consist of a 4 minute count.
   e. The density reference standard count shall be within 1% of the average of the last four daily reference standard counts.
   f. If four reference standard counts have not been established, then the reference standard count shall be within 2% of the standard count shown in the count ratio book.
   g. If the reference standard count fails the established limits, the count may be repeated. If the second count fails also; the gauge shall not be used.
   h. All daily reference standard counts shall be recorded in a permanent-type book for a gauge historical record. This also applies to direct readout gauges.

2. A calibration check of the equipment by an authorized dealer or manufacturer is required every 12 months. Dated inspection records shall be kept and be made available to the Engineer upon request.

   The calibration check shall provide proof of 5 block calibration. Calibration standards shall consist of magnesium, magnesium/aluminum, limestone, granite, and aluminum. All calibration standards should be traceable to the U.S. Bureau of Standards. Proof shall consist of documented and dated calibration counts accompanied by copies of an invoice from the calibrating facility.

E. Preparation and Testing

1. Density testing on base and intermediate courses shall comply with Materials I.M. 514 with the addition of two nuclear tests at each core location. After the first test the nuclear gauge shall be

turned 180 degrees and the second test will be taken. The data taken from the two tests shall be averaged and then correlated with the density taken from the core sample. This procedure shall be done on the first day's run of surface course as well. A correlation chart shall be kept and the value determined will be applied to nuclear density averages taken on the surface course. Tests shall be taken by two different nuclear gauges to establish a correlation between the gauges for use during assurance sampling and to insure accuracy from the main test gauge.

2. Density tests (core or nuclear gauge) shall be performed at randomly located sites based on the frequency specified in the Standard Specifications. Each section on the surface course at random locations shall be tested with the nuclear gauge. Each test shall consist of five equally spaced nuclear density locations across the mat. These locations shall be offset in order to provide a diagonal configuration across the mat. (See Figure 1.) No individual location shall be closer than 2 feet to either edge of the mat. At each location the gauge will be turned 180 degrees and read a second time. The two readings will be averaged and then the five averages will be averaged to determine the density at that location. The correlation factor as determined from the base and intermediate course(s) will be added or subtracted to the density at each location.

3. The Engineer may alter the five nuclear density mat locations to accommodate narrow mat widths (8 feet or less.)

4. Since the measured value of density by backscatter is affected by the surface texture of the material immediately under the gauge, a smoothly rolled surface should be tested for best results. A filler of limestone fines or similar material may be desirable to fill open surface pores of the rolled surface.

5. If the direct transmission method is used, a smooth hole, slightly larger than the probe, should be formed in the pavement.

F. Procedure--Backscatter and Direct Transmission

1. The direct transmission method shall be used when the layer to be tested equals or exceeds 6 inches.

2. The gauge shall be seated firmly at least 2 feet away from any pavement edge or object. If the direct transmission method is used, the probe shall be inserted so that the side of the probe facing the center of the gauge is in intimate contact with the side of the hole. All other radioactive sources shall be kept at least 30 feet from the gauge so that the readings will not be affected.

3. The same warm-up time as required for the reference standard count shall be used. After a 1 minute or a 4 minute count, the density shall be determined from the count ratio book or from the direct readout display.

G. Report

The report shall include the following:

- Date of testing
- Compacted thickness of layer tested
- Location (station, reference to centerline) of test
- Depth of probe if using direct transmission
- Mix Design Number
- Type of mix and surface texture (open, smooth, roller-tracked, etc.)
- Number and type of rollers
- Reference standard count
- Count rate expressed as ratio of standard count for each reading and the corresponding density value or the direct reading density value expressed in pounds per cubic foot

STANDARD TEST METHOD FOR CORRELATING NUCLEAR GAUGE DENSITIES WITH CORE DENSITIES

A. Scope

This method covers the proper procedures for correlating nuclear gauge densities to core densities. Procedures are applicable to both direct transmission and backscatter techniques.

B. Significance and Use

1. Density results from a nuclear gauge are relative. If an approximation of core density results is required, a correlation must be developed to convert the nuclear density to core density.

2. A correlation developed in accordance with these procedures is applicable only to the specific gauge being correlated, the specific mixture, each specific thickness (direct transmission only), and the specific project upon which it was correlated. A new correlation should be determined within a specific project if there is a significant change in the underlying material.

C. Site Selection

1. The nuclear density tests and cores necessary for nuclear/core correlation shall be obtained during the start-up of each specific mixture for which a density specification is applicable.

2. Two correlation locations shall be selected. The first site will be located on one of the two growth curves from the first acceptable test strip. The second location shall be chosen after an acceptable rolling pattern has been established and within the last 100 tons of material placed during start-up. The material from the second site shall correspond to the same material from which the second hot-mix sample was taken.

3. If a mixture start-up is not required, one of the two correlation locations shall be in an area containing a growth curve.

D. Procedures for Obtaining Nuclear Readings and Cores

1. Backscatter Mode
   a. At each of the two correlation locations, five individual sites shall be chosen and identified.
   b. Two nuclear readings shall be taken at each of the ten individual sites. The gauge shall be rotated 180 degrees between readings at each site. (The two uncorrected readings taken at a specific individual site shall be within 1.5 pounds per cubic feet. If the two readings do not meet this criterion, the procedure will be repeated until the tolerance is achieved.) The nuclear densities are to be recorded on the correlation form.
   c. Two cores in good condition shall be obtained from each of ten individual sites. Care should be exercised that no additional compaction occurs between the nuclear testing and the coring. The cores shall be tested for density in accordance with Materials I.M. 321. (The two core densities at a specific individual site should be within 1.5 pounds per cubic feet of one another. If the two densities vary by more than this amount, the cores shall be examined for damage, which may have affected the results. Judgment must then be used to determine if either or both of the cores should not be used.) The core densities are to be entered on the correlation form.
   d. Extreme care shall be taken in identifying which location each of the density readings represents. The data points have to be paired accurately or the correlation process will be invalid.

2. Direct Transmission Mode
   a. At each of the two correlation locations, five individual sites shall be chosen across the mat as shown on Figure 1.
   b. A smooth hole in the pavement, slightly larger than the probe, shall be formed to a depth 2 inches greater than the test depth. The probe shall be inserted so that the side of the probe facing the center of the gauge is in intimate contact with the side of the hole. Two nuclear readings shall be taken at each of the ten individual sites. The gauge shall be rotated 180 degrees around the hole at each site. (The two uncorrected readings taken at a specific individual site shall be within 2.0 pounds per cubic feet. If the two readings do not meet this criterion, the procedure will be repeated until the tolerance is achieved.) The nuclear densities are to be recorded on the correlation form.
   c. Two cores in good condition shall be obtained from each of the ten individual sites. The cores shall be obtained from beneath the center of the gauge no closer than 3 1/2 inches from the access hole. The thickness of the core should represent the thickness of the layer being tested.
   d. The layer shall be carefully separated for testing in accordance with Materials I.M. 320. Care should be exercised that no additional compaction occurs between the nuclear testing and the coring. The cores shall be tested for density in accordance with Materials I.M. 321. (The two core densities at a specific individual site should be within 2 pounds per cubic feet of one another. If the two densities vary by more than this amount, the cores should be examined for damage, which may have affected the results. Judgment must then be used to determine if either or both of the cores should not be used.) The core densities are to be entered on the correlation form.
   e. Extreme care shall be taken in identifying which location each of the density readings represents. The data points have to be paired accurately or the correlation process will be invalid.

E. Mathematical Correlation - Linear Regression

1. The two nuclear readings at each individual site shall be entered on the correlation form and then averaged. The two core densities taken at each individual site shall be entered on the correlation form and also averaged. After the averaging, there will be ten paired data points, each pair containing the average nuclear density and average core density for each of the ten individual sites.

2. The paired density values shall be correlated using linear regression.

3. For the purpose of this procedure, standard statistical methods for measuring the "best fit" of a line through a series of ten paired data points consisting of core density and nuclear density shall be used.

4. It should be recognized that correlation obtained by this or similar procedures may or may not be valid; each attempt should be judged on its merit. In general, a correlation coefficient for each correlation, linear regression should be calculated and compared to the "r test" for the appropriate number of observations.

5. Reliability factor (r) may range from -1.0 to +1.0. For the purposes of this procedure, an "r" value based on the number of core samples taken shall provide a minimum confidence interval of 99%. In the case of ten paired samples, an "r" value greater than 0.715 is considered acceptable.

6. The correlation shall be stated and used in the form: $y = mx + b$

   where:
   - y = core density
   - x = nuclear gauge density
   - b = intercept
   - m = slope of linear regression (best fit") line

Table of "r Test" Values
Test Values for Correlation Coefficient

Number of Paired Samples (n)	Degrees of Freedom (df)	99%
10	8	.715
11	9	.685
12	10	.658
13	11	.634
14	12	.612
15	13	.592
16	14	.574
17	15	.558
18	16	.542
19	17	.529
20	18	.515
21	19	.503
22	20	.492
23	21	.482
24	22	.472
25	23	.462
26	24	.453
27	25	.445
28	26	.437
29	27	.430
30	28	.423

NOTE: In this table, "n" = 10 to 30 pairs of samples/cores (i.e., 20 to 60 individual samples/cores.) In no case shall a confidence level less than 99% be acceptable.

Nuclear Test Location

Figure 1