125

HIGHWAY RESEARCH CIRCULAR

Number 125

Subject Classification
General Materials, Construction

April 1971

COMMITTEE ACTIVITY
in the
Evaluations, Systems & Procedures
Section of the
Design and Construction of Transportation Facilities Group
Highway Research Board

STATE SURVEY OF

PROCEDURES AND SPECIFICATIONS FOR THE USE OF NUCLEAR GAUGES

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Acknowledgment

The analysis of the state questionnaires was done by the following subcommittee, Donald W. Anderson, Chairman; Dr. Donald R. Lamb, Wilbur J. Dunphy, Jr., Dr. Hamilton Gray.

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COMMITTEE A2H01
NUCLEAR PRINCIPLES AND APPLICATIONS

RESULTS OF THE 1969 QUESTIONNAIRE ON PROCEDURES AND SPECIFICATIONS

In January 1969, the Highway Research Board Committee on Nuclear Principles and Applications requested the 28 state highway agencies which had reported the use of nuclear moisture-density gauges in the 1967 questionnaire on the current use of nuclear gauges in the highway field to supply information on their procedures and specifications. (1) This information is of value to both present and potential users of nuclear gauges and provides manufacturers of the gauges greater knowledge of the desired gauge characteristics.

In the use of nuclear gauges, "procedure" is constituted of those steps taken to ensure proper functioning and the reduction of error within the instrument; "specification" is the method of utilizing the test results obtained.

The request for information asked for copies of each state's procedures and specifications. Twenty-five of the 28 state highway departments which were contacted responded. The responses ranged from a very short statement written on the bottom of the letter requesting information to very comprehensive replies which included detailed manuals describing all aspects of the agencies' use of the gauges.

PROCEDURES

The following items were felt to be pertinent to the procedures followed in the various agencies' use of nuclear gauges:

I. Calibration
   A. Density
   B. Moisture

II. Operation Checks

III. Safety

IV. Operator Training

V. Repair Facilities

PROCEDURES

VI. Gauge Seating

VII. Test Count

VIII. Density Test Configuration

Since many replies did not contain information concerning all listed items, the presentation of each item will include the number of states which did include the information.

I. A. Density Calibration - Fifteen states supplied information concerning the density calibration of their nuclear gauges. The methods of gauge calibration indicated were:

1. Used manufacturer's calibration curves - 13%
2. Established calibration curves with local material compacted into molds - 40%
3. Established calibration curves from stone, concrete or similar standards - 27%
4. Calibration with conventional field tests - 20%
5. Calibration required, however specific method of calibration not stated - 13%

More than 100% response was obtained because of the use of more than one method by two states.

B. Moisture Calibration - Of the twenty-five states using nuclear gauges, seven indicated moisture calibration by comparison with conventional dried moisture samples and one stated reliance upon the manufacturer's calibration curve. The other seventeen states did not specify a moisture calibration method or limited the gauges to use not requiring moisture determinations.

II. Operational Checks - All manufacturers specify that certain checks be performed upon nuclear gauges to detect improper gauge performance and permit minor adjustments to be made. Most gauges are supplied with small portable standards for that purpose. Twenty of the twenty-five replies specified operational check frequencies as follows:

a. Two or more times per day - 50%
b. Daily - 40%
c. Less than daily - 5%
d. In accordance with individual manufacturer's recommendations - 5%

III. Safety - Fifteen replies specified safety procedures in the use of nuclear gauges with the principal item of interest being the monitoring of radiation received by the operator. It is significant that ten states require the operator to wear one film badge when using or transporting nuclear gauges and four require two film badges on the operator. Additionally, one of the four requiring two badges also requires a daily dosimeter reading by the operator. One state Highway department uses film badges for central laboratory personnel only.

IV. Training - Nine replies stated the requirement that the gauge operator attend a formal training program in the principles of the nuclear moisture-density gauge and its proper and safe operation. Most of these programs were described as a three-day school followed by a short period of supervised field training.

V. Repair Facilities - State-owned repair facilities were mentioned in three replies. The other twenty-two highway departments did not specify whether repairs are performed by state personnel, local firms or the gauge manufacturer.

VI. Gauge Seating - The requirements for seating the gauge upon granular material or soil were mentioned in sufficient replies to warrant inclusion in this report. Without exception, the sixteen states referring to this procedure allow deviations no greater than 1/8 inch from a plane surface. Nine require the use of either native fines or clean dry sand to fill small depressions of 1/8 inch or less. Two specify only sand and the remaining five permit only native fines.

VII. Test Count - Eighteen replies contained information describing the number and duration of test counts required for an individual test. In this report an individual test represents a moisture and/or density determination made at a single location. Listed below are the eight different methods described. It may be significant that no one procedure is favored, which indicates that satisfactory results are apparently obtained by any of them.

		No. of Replies	%
1.	One one-minute count	3	17
2.	Two one-minute counts	3	17
3.	Three one-minute counts	2	11
4.	Four one-minute counts	2	11
5.	Two one-minute counts, gauge rotated 90° between counts	3	17
6.	Four one-minute counts, gauge rotated 90° between each count	1	5
7.	Two two-minute counts, gauge rotated 90° between counts	3	17
8.	Two two-minute counts, gauge rotated 180° between counts	1	5
	Total	18	100%

VIII. Density Test Configuration - There are presently three principal density test configurations available with commercial nuclear density gauges. These are: backscatter, for which the gauge is placed directly upon the ground for the density determination; air gap, in which a ratio is determined between a density count taken directly upon the test surface and a count with the gauge in an elevated position at the same location; and the direct transmission method, which determines density by measuring radiation attenuation through the test material.

Twenty highway departments specified the test modes they use. These are listed here in number and percentages. Many agencies use more than one test method, which results in the percentage totaling over 100%.

VIII. Density Test Configuration (continued)

Backscatter	Air Gap	Direct Transmission	
15	9	11	No. of States*
75	45	55	Percent**

*Number of states using each method from total of 20 replies specifying test method or methods used.

**Percent of the twenty state highway departments specifying their test methods.

Additionally, one state, Utah, specified a procedure for use of the Road Logger, a van-mounted continuous recording nuclear density-moisture system. The 1967 questionnaire on the current use of nuclear gauges listed nine states using Road Loggers. The reason for the lack of procedures and specifications for this instrument from other users was not indicated.

SPECIFICATIONS

This section of the report contains data concerning the following items as applied to specifications:

I. Materials Tested by Nuclear Method

II. Specification Test Method

I. Materials Tested by Nuclear Method

One of the principal items of interest to present and potential nuclear density-moisture gauge users is the type of construction material being tested by other users of gauges. There are three basic classifications which will include essentially all natural or manufactured materials used in highway and allied construction and which normally require some form of density control. These are: bituminous surfacing and bituminous treated base; granular materials, with or without non-bituminous additives; and soil. Following is a listing of the three classifications and the number and percent of state highway departments reporting using gauges on each type of material.

Bituminous	Granular	Soil	
9	16	19	No. of States
37.5	67	79	Percent

The number of states total more than the twenty-four informative replies because of the number of states using the gauges on more than one type of material. A twenty-fifth reply stated that preliminary work with a nuclear gauge had not produced satisfactory results and its use for construction control was being discontinued pending further research.

II. Specification Test Method

Of the twenty-five state highway departments replying to the inquiry of this subcommittee, nineteen reported the use of nuclear gauges based upon a single test to accept or reject the tested quantity of materials. Many of these indicated interchangeability between the nuclear and conventional test methods.

Three state's agencies have adopted locally developed methods of specification testing for certain materials. Virginia and West Virginia use a "control strip" consisting of a small section of the material type to be tested to establish the rolling pattern for that material. A semi-statistical method of nuclear testing is used to determine both the maximum density and desired roller pattern in the "control strip" and the density attained during the ensuing construction.

The California Division of Highways utilizes an "area concept" in the density control of soils and aggregates. Principally this method normally requires that six individual density tests be conducted at semi-random locations within the test area. The mean of the test results as well as two-thirds of the individual results must exceed the minimum density limit.

The remaining replies did not specify the method of utilization of the nuclear density gauge in determining acceptance of construction material.

OTHER NUCLEAR APPLICATIONS

The 1967 questionnaire indicated that nine state highway agencies possessed nuclear asphalt content gauges. No procedures or specifications concerning this gauge were included in any of the 25 replies to this subcommittee's request for information. Similarly no reference to nuclear depth density-moisture gauges was received, probably since this system is not normally used for construction control.

(1) "Survey of the Current Use of Nuclear Gauges in the Highway Field", Highway Research Circular No. 85, October 1968.

DISCUSSION OF THE 1969 QUESTIONNAIRE ON NUCLEAR PROCEDURES AND SPECIFICATIONS

It is obvious that no universal agreement exists concerning the proper use of nuclear density-moisture gauges for their greatest accuracy or efficiency. However, what may initially appear to be disagreement is frequently utilization of different means to attain similar ends. In order to assist those less familiar with the use of nuclear gauges an attempt is made here to mildly suggest those means which presently appear to hold the greatest potential and desirability as inferred by the replies to the questionnaire on procedures and specifications.

PROCEDURES

I. Calibration

A. Density calibration curves are most easily and rapidly established with the use of permanent standards. The composition effect of most test material is minimized with modern gauge design and usage and it is probably safe to assume that calibration with construction material compacted into molds, presently the most popular method, will diminish because of the problems normally encountered with this method. For gauge users who do not have access to permanent standards, calibration with conventional field tests, although time-consuming, can be sufficiently accurate with a minimum of investment in equipment. Manufacturer's calibration curves have become increasingly accurate in recent years and may eventually reduce the need for other calibration facilities. However, for the present, most users of nuclear gauges will wish to have a means or method available to check locally the calibration of their nuclear units. Calibration schools are offered by some gauge manufacturers and occasionally by universities or other institutions. These present an excellent opportunity to gain proficiency in calibration, gauge operation and techniques at minimal cost.

B. Calibration for moisture content by comparison with conventional dried samples is recommended for its simplicity and adequate accuracy. Satisfactory secondary standards are to be preferred for calibrating large numbers of gauges. However, these present problems, primarily in stability, most gauge users will prefer to avoid.

II. Operational Checks - It is anticipated that the manufacturer's recommendations will normally be adequate.

III. Safety - The use of one or more film badges capable of measuring both gamma and neutron radiation is adequate and recommended for use by the gauge operator. Monitoring of the instrument is not necessary unless it exhibits indications of physical damage. Procedures that meet state and local radiological health standards should be followed.

IV. Training - A formal training program should be established. The assistance of the manufacturer is usually available for training and it is recommended that this assistance be utilized.

V. Repair Facilities - Many gauges are now designed to encourage the user to perform most repairs, frequently with the aid of a telephone call to the manufacturer. These repairs will usually require that the gauge be re-calibrated. Unless a large number of nuclear units is involved, older gauges or those not specifically intended to be repaired by the user are best returned to the manufacturer for repairs.

VI. Gauge Seating - Deviations no greater than 1/8 inch from a plane surface and the use of native fines for seating are recommended.

VII. Test Count - The trend in nuclear testing is toward shorter, more simplified tests taken at a greater number of locations in order to better sample density of the material tested. The manufacturer's knowledge of his gauge's operating characteristics will normally enable him to recommend a test duration and position which will produce the desired accuracy.

VIII. Density Test Configuration - The material to be tested will frequently govern the type of gauge configuration to be used. Where it is possible to drive or drill a hole without significant disturbance of the test material, the direct transmission test method offers greatest accuracy and close control of depth of measurement. For depths of less than approximately three inches or when it is not practicable or desirable to disturb the test material the air gap and backscatter methods are used with the air gap showing a slight superiority in accuracy.

SPECIFICATIONS

I. Materials Tested by Nuclear Method - Nuclear density-moisture gauges are used with nearly all types of construction materials requiring density control. The relatively lower level of usage with bituminous materials will almost certainly increase greatly within the next few years because of the many advantages of the nuclear method over conventional density control methods.

II. Specification Test Method - The great variation in densities found within many highway construction materials has indicated that the commonly used single test for acceptance or rejection is inadequate. This is especially true with soils since the problem is compounded

II. Specification Test Method (continued)

by the use and intermixing of soils having different density characteristics. Manufactured materials present less of a problem due to the improved uniformity of their physical characteristics. A semistatistical method of testing of soils similar to that used in California may offer a more desirable approach to that material while the test strip method as used in Virginia and West Virginia appears to offer a satisfactory solution to testing most granular and bituminous materials. Local conditions will frequently govern the density procedures used to determine acceptance and the methods mentioned here are suggested solely as possible alternatives to those who are dissatisfied with present density control and wish to investigate different approaches to the problem. It is recommended that the specific states be contacted for more information concerning their density control methods.

CONCLUSION

From the results of this questionnaire it can be seen that the nuclear method offers a very flexible approach to the control of the density and moisture content in highway and associated construction which can be tailored to the requirements of virtually any user. As with all testing a certain level of competence will be required of the operator but the requirements are no greater than for other methods of density testing.

Refinement of nuclear testing, which is already well accepted and whose accuracy is well established, will continue. However, because of the acceptance and general satisfaction with this test method as well as its present high level of development it is not recommended that potential users postpone acquisition and use of nuclear gauges from fear of obsolescence any more than they would hesitate to obtain any other type of test or construction equipment for that reason. Its advantages of speed, accuracy and economy warrant consideration of this test method for use by engineering firms, contractors, cities and counties as well as by state and federal agencies.

GROUP 2
Design and Construction of Transportation Facilities

John L. Beaton, Chairman
Materials and Research Engineer
California Division of Highways
Sacramento, California

HIGHWAY RESEARCH BOARD STAFF

W. G. Gunderman, Engineer of Materials and Construction

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Purdue University
Lafayette, Indiana

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