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Application Brief

TROXLER MODEL 3660

CoreReader™
Laboratory Nuclear Density Device
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Introduction

The Troxler Model 3660 CoreReader is a new technology developed by Troxler to directly measure the density and bulk specific gravity of laboratory and field specimens. The reliability of current methods to accurately measure bulk specific gravity is suspect due to increasing interconnected air voids associated with coarse and open graded mixes. This results in over-approximations of density and, consequently, under-approximations of air voids; a major cause of premature pavement distress and permeability-related problems. The CoreReader performs actual measurement based on the material properties of the compacted specimen; therefore the need for any volume estimations or approximations is eliminated.

Traditional Methods

All current methods approximate specimen density as a ratio of specimen mass to volume. Mass determinations are fairly reliable when current state-of-the-art balances and scales are properly used. Inaccuracies in density determinations arise primarily from poor accuracy in the laboratory approximations of specimen volume.
Specimen volumes are approximated by two methods:
1. Dimensional analysis
2. Water displacement method

1. Dimensional Analysis
Dimensional analysis incorporates gross dimensional measurements into the formula for the volume of a cylinder [V = (pi) (radius)^2 (height)]. Measurements of height and diameter are generally made with calipers or micrometers at several locations. The volume is estimated by inserting the average height and radius into the volume formula. Some laboratories even use mold diameter and specimen height measurements from gyratory compactor output for the dimensional analysis. The major problem with the dimensional analysis method is that it assumes a perfectly smooth surface, thereby ignoring surface irregularities. Operator error associated with the measurements of height and diameter may also affect the accuracy and precision of the dimensional analysis method.
2. Water Displacement Method
The Greek mathematician Archimedes introduced the water displacement method of volumetric approximation over 2000 years ago. The Archimedes Principle approximates the volume of a solid by measuring the volume of water displaced by the submerged solid thereby accounting for surface irregularities.

The saturated surface dry (SSD) method (AASHTO T166) utilizes the Archimedes Principle for approximation of the volume of a compacted asphalt specimen. However, the reliability of the water displacement method decreases with increasing depth of the surface irregularities and the presence of interconnected voids that are open to the surface of the specimen. The result is that the volume of the asphalt specimen is under-estimated thereby over-estimating its density. Ironically, dimensional analysis yields a more accurate density approximation for open graded mixtures with high interconnected air void contents than the SSD method.

To overcome the limitations of the SSD method caused by the surface voids, the paraffin and Para film methods (AASHTO T275) were adopted. Both these materials are difficult to handle; and, if improperly applied will cause errors in the results. High user dependence, bridging of the surface voids and tears in the Para film have also rendered that method undesirable. No method, which attempts to seal the specimen in an impermeable material, can totally eliminate user dependence, bridging of surface irregularities and tearing of the surface seal. In fact, accuracy of any density estimation that is based on approximating volumes of a solid with irregularly shaped surfaces is always questionable.

Troxler Technology

Direct measurement is a quantum leap in technology for the determination of bulk specific gravity. Determinations are no longer estimations or approximations, but actual measurements based on the material properties of the compacted specimen. This new technology eliminates the need for the water bath and the expense associated with coatings and wrappings that attempt to improve the reliability of an archaic technology. Since Superpave has brought systematic improvements to asphalt mix design, test methods utilizing higher technology tools for measuring volumetric properties should be implemented to maximize the benefits sought from Superpave mix design.

Direct measurement of the specific gravity of asphalt specimens eliminates the need for mass to volume ratio estimations and the unreliability of volume approximations that are inherent in current dimensional analysis and water displacement methods. The accuracy and precision gained by direct measurement ensures reliability of the specimen density and air void content of pavement cores and laboratory prepared specimens.

For many decades, Troxler has manufactured gauges that utilize gamma ray methods for the determination of the pavement density. The gamma ray method for density measurement is based on the scattering and absorption properties of gamma rays with matter. When a gamma ray source of primary energy in the Compton range is placed near a material, and an energy selective gamma ray detector is used for gamma ray counting, the scattered and unscattered gamma rays with energies in the Compton range can be counted exclusively. With proper calibration, the gamma ray count is directly converted to the density or bulk specific gravity of the material.

The CoreReader allows very little room for operator error. There are no volume estimations or approximations necessary. Because the bulk specific gravity is a direct measurement of material properties, the CoreReader is more accurate than any method currently in use. A properly calibrated CoreReader will provide fast, reliable, user-independent results.

Another benefit of the CoreReader is that the results are extremely repeatable. The concerns of multi-user and multi-laboratory differences may be alleviated by the CoreReader because estimations and approximations of specimen volumes are no longer necessary. The potential for operator error is minimized with the CoreReader.

In an independent study by the Highway Materials Lab at North Carolina State University, data were collected on 108 different specimens. Among the data collected were repeated specific gravity measurements with the CoreReader at different measurement intervals. The average standard deviation of all 108 specimens comparing 4-minute and 8-minute counts was 0.0018. The test results also indicate that the CoreReader is more precise than other methods currently used because of the increased sensitivity to volumetric differences. (2001 AAPT, Malpass, Khosla)

The non-destructive density determination of laboratory prepared and cored pavement specimens allow for performance tests to be conducted on the same specimens used in the density determinations. The researcher does not have to prepare as many sample replicates to measure both volumetric and mechanical properties. In addition to timesavings, more reliable correlation between densities and moduli of specimens may be achieved.

Operation

Bulk specific gravity measurements can be obtained in as little as 5 minutes. There is no weighing, no wrapping, no sealing, no polymer bag, no vacuum device, no submerging, no drying, and no manual calculation required. In fact, a single person can perform the specific gravity determinations while performing other laboratory tasks. A busy laboratory could realize substantial savings in wages and man-hours.

The CoreReader can handle any specimen that is cool enough for personnel handling. Therefore, it is not necessary to cool the sample to determine air void content of QC specimens.

The specimen is placed into the CoreReader specimen chamber and the operator presses the {START} button on the keypad. The menu prompts the user to enter the specimen height. Once this information has been entered, the CoreReader measures the specimen specific gravity. The CoreReader will display the specimen bulk specific gravity (Gmb), specimen density, percent of theoretical maximum specific gravity (%Gmm) and specimen air void content (Va). If the user does not enter Gmm when prompted, then only the Gmb and density will be displayed. Though the CoreReader is a self-contained device, stored data may be downloaded to a computer data file via the CoreReader's serial port.

Data Storage and Output

This equipment is capable of storing up to twenty (20) project identification numbers under which measurement data is stored. If the *Auto store* feature is enabled, all measurements will be stored under the active project ID. The operator can store the readings individually if not using *Auto store*. Approximately 500 data records can be stored in all. The data that is stored can be viewed on the display, downloaded to a computer or other serial device or

erased. Data can also be automatically output to a computer or serial printer in real-time if the *PC output* option is enabled.

Features

An external beeper is available to indicate when a measurement is complete. This beeper can be enabled or disabled by the operator. The CoreReader stores the last 4 standard counts and averages them for comparison to the current standard count. If the standard count doesn't meet the predefined criteria, an error message is displayed. Standards are available for viewing at any time. Up to 500 measurement records can be stored in the CoreReader's memory. These records are stored under Project ID numbers and can be viewed, downloaded or erased by the operator. To confirm the accuracy of the CoreReader calibration, the operator can perform a confirmation using calibration standard cylinders provided with the unit. Any of the three modes can be confirmed individually or together. This will allow for greater confidence while using the CoreReader.

Keypad

The Model 3660 keypad consists of 19 keys. Above the keypad is a 4 line by 20 character Liquid Crystal Display screen.

Power Consumption

The 12-volt DC adapter plugs into a 110-volt wall supply and operates on maximum power of 26 Watts. The electricity used is 35% less than a 40-Watt light bulb. To maintain stability of the detection system, Troxler recommends that the power switch be left on, even when the unit is not in use. The average daily power cost for the CoreReader is around 5 cents (US) when left on 24 hours per day. For comparison, with some current methods, costs per test can be as high as 50 cents.

Determination of Precision

An interlaboratory study for repeatability and reproducibility was conducted over a six-month period.
Three sets of six specimens were prepared using a gyratory compactor to test the repeatability
and reproducibility of the three operation modes of the instrument. Twelve different gamma-ray instruments were installed at the laboratories participating in the study. The eighteen specimens were then boxed and circulated among each laboratory for height and G_{mb} determination. Each laboratory was instructed to have two operators measure the specimen heights and G_{mb}. Before measurements were performed, calibration quality was checked and, if necessary, the proper mode was re-calibrated. Each laboratory used their own vernier caliper for height measurements. Six evenly spaced height measurements were made on each sample (this procedure can provide heights with 0.1 mm precision). The first set of specimens was for testing the instrument operation mode I (150mm Lab), the G_{mb} of each specimen was measured twice by each operator. For the other two modes (150mm field and 100mm), the G_{mb} of each specimen was measured once by each operator. The G_{mb} measurements in mode I showed high repeatability (0.004 at 1-sigma) and reproducibility

(0.0065 at 1-sigma). For the other two modes, the G_{mb} measurements of specimens taller than 35 mm also showed high repeatability (0.006 at 1-sigma) and reproducibility (0.007 at 1-sigma). For specimen with heights less than 35mm, the precision of the Gmb measurement is determined by the precision of the height measurement. The precision for gamma-ray method was better than that for AASHTO T-166 [ASTM D2726] (r is 0.0124 and R is 0.0269) and AASHTO T-275 [ASTM D1188] (r is 0.028 and R is 0.034).

Summary

The Troxler Model 3660 CoreReader is the most innovative and high tech device available for measuring bulk specific gravity of laboratory prepared and cored pavement specimens. The CoreReader is technologically superior to current methods of specific gravity determinations. The Archimedes Principle of volumetric approximation, which current methods are based on, can provide only an estimation of the density of a compacted asphalt specimen and the dimensional analysis method does not account for surface irregularities of the compacted specimen. The CoreReader eliminates the need for any volume estimations or approximations. The CoreReader provides a direct density measurement of the compacted specimen, quickly, inexpensively and reliably.

Measurement Precision
Model 3660 CoreReader

Repeatability (Single Laboratory)	0.006 Sp. Grav. {0.3744pcf (6 kg/m3)}
Reproduceability (Multi laboratory)	0.009 Sp. Grav. {0.5616pcf (9 kg/m3)}