

Application Brief
TROXLER MODEL 3451
Troxler Enhanced Roadreader™ Plus
Nuclear Moisture Density Gauge
May 2007

Introduction

The Troxler Enhanced RoadReader™ Plus, Model 3451, offers the combination of surface moisture and density measurements with thin layer density determination in a single nuclear gauge. In addition the 3451 provides many technical improvements and innovations insuring easier operation, greater reliability, and improved performance. Once powered on, this gauge is completely controlled by a personal digital assistant (PDA) handheld device. The Model 3451 also employs the use of GPS locations for locating measurements in the field. To the testing laboratory that works on both soils and asphalt, the Enhanced RoadReader™ Plus offers a significant opportunity for expanded measurements. The ASTM standard numbers D 6938 (replaced D 2922 and D 3017 as of November 2006), D 2950, and C 1040 are met or exceeded by this gauge. This application brief will introduce the 3451 and describe its operation, application, and features.

Measurement Technology

Traditional nuclear gauges use the interaction of gamma radiation with matter either through direct transmission or backscatter to measure density. In direct transmission position, the source rod extends through the base of the gauge into a hole which has been predrilled to the desired depth. Photons from the source travel through the material to reach the photon detectors in the gauge base. In backscatter position, the source rod is lowered to the first notch below the standard (STD) position. This positions the source and the photon detectors in the same plane. Shielding between the source and the detectors reduces the number of photons reaching the photon detectors by a direct path from the source, so photons must travel from the source into the test material where they collide with electrons and are scattered (or reflected). Those that reach the photon detectors are counted to determine the density of the material. Moisture is also measured through backscatter technology, however, it is the detection of thermalized neutrons that forms the relationship by which the moisture content of a material can be determined.

Traditionally there have been two general classes of surface nuclear gauges: standard surface moisture/density gauges and thin layer density gauges. The surface moisture density gauge, such as the Troxler Model 3440, utilizes a neutron source and detector to measure moisture and a gamma source and photon detector pair to determine density. The density source can be lowered into the soil to a maximum of 12 inches to provide a direct transmission measurement

through the media. Alternatively, the source can be set on the surface of the soil or full depth asphalt to provide a density determination through the backscatter of photons. The thin layer density gauge also determines density through the backscatter of photons. However, the thin layer density gauge can test the true density of a thin lift (1 to 4 inches) independently of the density of the underlying layer by using two sets of photon detectors, placing one detector set closer to the source than the other and thereby differentiating between the density of the thin layer overlay and the density of the underlying material. Prior to the advent of thin layer technology with the Troxler Model 4640, standard surface moisture/density gauges provided the only viable means of measuring the density of thin layers through the use of a nomograph mode. Using the nomograph, a backscatter measurement is taken. The gauge can then calculate the top layer density, provided the top layer thickness and bottom layer density are known. Although the nomograph will, in theory, provide a reasonable estimation of the top layer density, the results are highly dependent on the actual bottom layer density. Since the bottom layer is covered, density in the location of measurement is usually not precisely known, an estimated, or average, value must be used. This can produce erroneous surface density results.

Combining Surface Moisture/Density with Thin Layer Density

The Enhanced RoadReader™ Plus, Model 3451, through improvements in microcontroller capabilities and years of research optimizing gauge geometry, combines the functions of the 3400 and 4640 gauges. The 3451 provides the user with a tool for surface moisture, direct transmission and backscatter density, and thin lift density measurements. As a result, the testing lab, DOT, municipality, county, and contractor can perform soil, stone, base asphalt, and thin layer asphalt testing with a single gauge.

Gauge Operation

Modes of Operation

The 3451 offers three modes of operation: Soil, Asphalt, and Thin Layer. Although each mode takes measurements from the moisture and density systems, how the data is used and presented is different for each mode.

Soil Mode is designed for measurements of soils, stone, clay or any other material where both density and moisture contents are of interest. Typically, density measurements are made in direct transmission with the source lowered into the material (to a maximum of 12"). Although backscatter can also be used, direct transmission typically offers better precision. Among the information provided by the gauge with a soil mode measurement are: Dry Density, Wet Density, Moisture, Percent Moisture, Percent Proctor, Percent Air voids, and Void Ratio.

Asphalt mode is used on asphalt layers thicker than four inches. Typically, the source rod is in backscatter position, on top of the asphalt, but direct transmission may be used if a hole can be drilled into the asphalt. The asphalt mode displays the Wet Density, Percent Marshall, and Percent Voids.

Thin Layer mode is used to automatically determine the top layer density, with the user only having to enter the layer thickness. The source rod must be in the backscatter position while using this mode. In addition to the density of the top layer, the gauge displays Percent Marshall and Percent Voids. The thin layer mode also allows for averaging multiple readings.

Each mode offers certain offsets to correct for non-standard conditions. In soil mode, the user may apply an offset to the moisture to correct for the presence of chemically bound hydrogen or neutron absorbers (such as cadmium, boron, cement, gypsum, coal, or lime). All three modes permit a density offset to correct for material composition variances or for densities outside the calibration range. All modes also use a trench offset to correct for errors due to large vertical surfaces near the measurement area. Finally, Soil and Thin Layer modes provide a special calibration option to correct for material composition variances or, in the case of thin layer, surface voids.

Operational Interface

The Model 3451 is the first field density gauge to be completely controlled by a handheld PDA device once it is powered on. This PDA features user friendly software and expansive storage capabilities. The measurement data from each reading is automatically stored in the PDA after each test is performed. The operator can then enter notes if desired. This data is recorded under the active project number so it can be accessed at a later time. In addition, the measurement data is stored in the gauge as a backup in case the PDA is lost or damaged. DMS (data management software) is supplied with the Model 3451. This allows the user to view data that is downloaded from the PDA to the computer. When the data is downloaded it cannot be changed, therefore managers or DOTs can be sure that the data is reliable. In addition, the data can be sent to an Excel spreadsheet in order to be sorted or manipulated.

Batteries and Power Consumption

The 3451 operates from a set of Nickel Metal Hydride (NiMH) rechargeable batteries (pack of 5 C batteries). This combination provides up to 4 weeks of service life without charge, depending on gauge power configuration and use. Incremental charging will not damage the batteries. These batteries can be fully charged in only 2.5 hours. The gauge will shut down before the battery reaches a level where data would be effected or lost. In addition, after 5 hours of inactivity the gauge will shut down to conserve battery power.

Additional Features

An "all new" feature of the Model 3451 is an onboard global positioning system (GPS) receiver. Precise GPS coordinates are stored with each measurement record. The GPS receiver used in the Model 3451 has Wide Area Augmentation System (WAAS) capabilities, which provides accuracy to within three (3) meters (10 ft). To determine latitude and longitude, a GPS receiver must receive signals from at least three satellites. The receiver in this gauge is accurate to within 15 m (approx. 50 ft.) when receiving GPS data alone. The WAAS capabilities can increase the accuracy to within 3 m (10 ft.). The measurement display and stored record denotes the quality of the location fix as *DGPS fix* if WAAS information is available and *GPS fix* if it is not.

The PDA software employs the use of a Project Wizard that assists the user when beginning a new project. This prompts the user for the information necessary when setting up to begin readings on a new project site or when new material is measured. This information includes; measurement mode, units, count time, target value(s), offset(s) and finally project name. After this information is entered the operator is ready to begin performing measurements with the gauge and can feel secure that all of the gauge parameters are correct for this job site.

In addition to the standard statistical stability (Stat) and Drift tests, the gauge provides comprehensive diagnostics through the software for isolating internal problems. Validity of the standard count (a measurement taken on a standard block) is assured through a test comparison with the previous standard counts and through a comparison with the calibration standard count corrected for source decay. Some other useful features: the user is prompted by the software to perform a leak test every six months (or other set interval), battery voltages can be displayed at any time to estimate the remaining life and choice of automatic or manual depth indication.

Finally, attention has been paid to the need to insure that the gauge is water resistant. An o-ring seal is used between the base and the topshell to prevent water migration. The control unit has a gasket with a penetrating edge, and the serial connector is waterproof. The result is a gauge that is highly resistant to water penetration in even the worst conditions.

Summary

The Troxler Enhanced RoadReader™ Plus Model 3451 is the top-of-the-line nuclear gauge for the measurement of moisture and density of soils, stone, full depth asphalt and thin layer asphalt. It is designed to meet the demanding needs of the testing lab, DOT, municipality, county, or contractor who works on a wide variety of construction materials and who wants the highest precision in moisture/density measurements.

In addition to combining thin layer density measurements in a surface moisture/density gauge, the 3451 offers a variety of technological innovations including a handheld PDA device to control the gauge, GPS locations stored with each measurement record, automatic storage of all measurements in the PDA and in the gauge, Data Management software for downloading data to the computer and ensuring that it remains unaltered and nickel metal hydride (NiMH) batteries for longer gauge use and shorter recharge time.

For the user operating in the demanding environments of asphalt and soil, the Troxler Model 3451 is clearly the most innovative nuclear moisture/density gauge on the market.

Measurement Specifications: (U.S. Customary and Metric Units)

Direct Transmission Density, 150 mm (6in)	15 sec.	1 min.	4 min.	
Precision @ 2000 kg/m ³ (125PCF)	5.2	2.6	1.3	+/-kg/m ³
Composition Error @ 2000kg/m ³ (125PCF)	0.32	0.15	0.08	+/-PCF
Surface Error 1.25 mm, 100% void (0.05 inch, 100% void)	8.0	8.0	8.0	+/-kg/m ³
Backscatter Density (98%) 100 mm (4 in)	0.50	0.50	0.50	+/-PCF
Precision @ 2000kg/m ³ (125PCF)	18.0	18.0	18.0	-kg/m ³
Composition Error @ 2000kg/m ³ (125PCF)	1.1	1.1	1.1	-PCF
Surface Error 1.25 mm, 100% void (0.05 inch, 100% void)	16.0	8.0	4.0	+/-kg/m ³
Moisture Precision at 240 kg/m ³ (15PCF)	1.0	0.50	0.25	+/-PCF
Surface Error (1.25mm, 100%void)	14.0	14.0	14.0	+/-kg/m ³
Moisture Surface Error (1.25mm, 100%void)	0.87	0.87	0.87	+/-PCF
Precision at 240 kg/m ³ (15PCF)	80.0	80.0	80.0	-kg/m ³
Surface Error (1.25mm, 100%void)	5.0	5.0	5.0	-PCF
Moisture Precision at 240 kg/m ³ (15PCF)	11.0	5.5	2.8	+/-kg/m ³
Surface Error (1.25mm, 100%void)	0.69	0.34	0.17	+/-PCF
Moisture Surface Error (1.25mm, 100%void)	19.0	19.0	19.0	-kg/m ³
	1.2	1.2	1.2	-PCF

**Depth of Measurement at 250 kg/m³ – 215 mm
(at 15 PCF – 8.5 inches)**

Thin Layer Mode 2240 kg/m³ (140 pcf)	Thickness	kg/m³	pcf
Time (min.) 1.0	2.5 cm (1.0")	+/-16	+/-1.0
	5.0cm (2.0")	+/-10	+/-0.60
	6.3cm (2.5")	+/-8	+/-0.50
	10cm (4.0")	+/-8	+/-0.50
4.0	2.5 cm (1.0")	+/- 8	+/-0.50
	5.0 cm (2.0")	+/-5	+/-0.30
	6.3 cm (2.5")	+/-4	+/-0.25
	10cm (4.0")	+/-4	+/-0.25

Precision is defined as +/- one standard deviation in density readings. This number is calculated by the ratio of the standard deviation in the counting rate and slope of the calibration curve at a given density.