TROXLER®
The Leader in Construction Testing Equipment

Troxler Electronic Laboratories, Inc. - Troxler International, Ltd.
3008 Cornwallis Road, P.O. Box 12057, Research Triangle Park, NC 27709 - USA
Telephone: 1.919.549.8661 Telefax: 1.919.549.0761 Web: troxlerlabs.com

Application Brief

TROXLER MODELS 3450, 3451 & 4640

Thin Layer Nuclear Density Gauge Technology

May 2007

Introduction

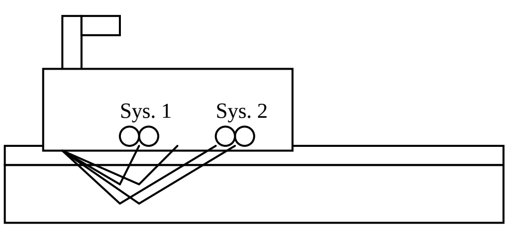
Troxler Electronic Laboratories, Inc. manufactures several models of nuclear moisture/density gauges for the testing of soils and asphalts. The model 4640B density gauge has the capability of measuring the density of asphalt layers with thicknesses from 1 inch to 4 inches without influence from the underlying material. The Model 3450 and 3451 gauges are capable of testing asphalt as well as soil in backscatter mode (approximately 4 inch depth), direct transmission mode (depth is determined by the user), as well as in thin-layer mode as described above.

Traditional Methods

Traditional surface moisture density gauges use a mode called nomograph mode to measure thin-layer densities. This mode requires the operator to know the density of the underlying material as well as the thickness of the overlay at the site of each measurement. These factors are used, along with the wet density determined by the gauge in backscatter mode, to calculate the overlay density. In many cases these factors can be difficult to determine.

Troxler Technology

The thin-layer mode measures density using two detection systems. Each system measures the bulk density of the material beneath the gauge. The systems themselves do not take overlay thickness into consideration; each is influenced by varying amounts in the differing strata within the measurement material. System 1 is influenced by the uppermost portion of the material in greater proportion than is system 2. Therefore, their bulk density results can be combined numerically to calculate the overlay density.



In general, system 1 is more greatly influenced by the uppermost portion of material than is system 2.

Thin-Layer Mode Equation

The thin-layer mode equation used to determine the overlay density is:

$$D_T = \frac{K_2(x) \times DG1 - K_1(x) \times DG2}{K_2(x) - K_1(x)}$$

D_T = overlay density

x = overlay thickness

DG1 = system 1 bulk density, gauge measurement

DG2 = system 2 bulk density, gauge measurement

$K_1(x)$ & $K_2(x)$ = values that quantify the influences of density of the overlay material & of the underlying material on the bulk density measured by the gauge.

Example 1 shows the result of a thin-layer density gauge used to test the density of a 1.5 inch overlay with a density of approximately 161.2 pcf over a base with a density of approximately 133 pcf.

Example #1:

$$161.073 = \frac{(0.240448 \times 159.872) - (0.057 \times 156.0061)}{(0.240448 - 0.057)}$$

The functional relationship between K_1 (x) and (x) and between K_2 (x) and (x) are constants that are calculated during the factory calibration. This is done by placing aluminum and magnesium plates of varying thicknesses over calibration blocks, taking measurements, and performing the curve fitting calculations. Once these calibration constants are entered into the gauge, the thin-layer gauge will measure thin-layer densities accurately provided that the proper overlay thickness is entered by the operator.

Standard Surface Gauges

Gauges such as the Model 3430 and the Model 3440 that do not have the thin-layer mode described above can be used in the nomograph mode to measure thin-layer densities. The method in which the nomograph calculates thin-layer density has some similarities to the thin-layer system but also some differences. The main difference between the two types of gauges is that the bottom layer density must be known in order to use the nomograph method but is not necessary in order to use the thin-layer gauge. Both types of gauges determine the overlay density by multiplying a gauge-determined bulk density by one weighing factor (K (x) which is dependent on the overlay thickness), multiplying another density value by a weighing factor (which is equal to the first weighing factor minus one), and subtracting the two values.

Nomograph Equation

The equation that is used to determine the overlay density in nomograph mode is:

$$D_T = \frac{WD - (D_B \times K(x))}{1 - K(x)}$$

D_T = overlay density

WD = wet density, gauge measurement

D_B = bottom layer density

K (x) = value that quantifies the influences of the density of the overlay and of the bottom layer on the resulting wet density

Example 2 shows the result of a standard surface density gauge used in nomograph mode. The 1.5 inch overlay has a density of 161.2 pcf and the underlying material has a density of approximately 133 pcf. The true bottom layer density was entered into the gauge.

Example #2:

$$162.91 \text{ pcf} = \frac{154.4 - (133 \times 0.28454)}{1 - 0.28454}$$

Example 3 and 4 also show the result of the standard surface density gauge used in the nomograph mode. The overlay density can vary greatly if the bottom layer density is miscalculated by only +/-10%; the following examples demonstrate this for the situation calculated above (bottom layer density of 133 pcf).

Example #3:

$$168.2 \text{ pcf} = \frac{154.4 - (119.7 \times 0.28454)}{1 - 0.28454}$$

Example #4:

$$157.8 \text{ pcf} = \frac{154.4 - (146.3 \times .28454)}{1 - 0.28454}$$

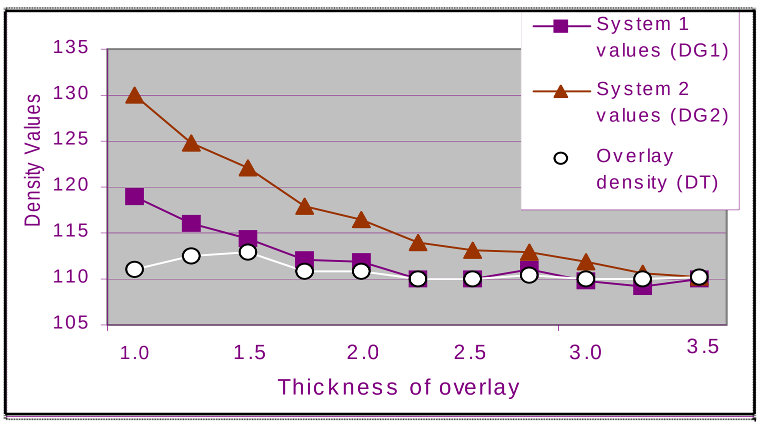
Benefits of a Thin-Layer Gauge

The fact that the bottom layer density cannot always be known or is not always consistent, and that the overlay thickness is not always consistent makes the nomograph method less practical to use. The two variables in this calculation (WD and D_B) can vary greatly. The readings can be greatly influenced if the overlay thickness changes or the true bottom layer density changes. Therefore the readings can be grossly in error.

The two variables in the equation for the thin-layer gauge density calculation are the actual counts from system 1 and system 2 (DG1 and DG2). The difference between these two values is much smaller than the difference between the two factors in the nomograph equation. Both of the system counts are bulk densities which are influenced by the top and bottom layers, though in different proportions, rather than one being a bulk density and one a factor programmed by the operator. (Note that in example equation #2 the difference between the WD and D_B densities is 22 pcf and in example #1 the difference between the DG1 and DG2 densities is 3.87 pcf.) When the factors are more similar the error will be much smaller if, for example, the thickness of the overlay were to vary unexpectedly. This does not mean that the non thin-layer gauges are more sensitive to changes in layer thickness. It simply means that if the values programmed into the gauge are in error (usually due to an unknown change in the pavement) it will have a more substantial effect on the measured thin-layer density than it will with the true thin-layer gauge. This is one example of a benefit of using a true thin-layer gauge.

Chart A displays how the thin-layer gauge reads the overlay density of a material with a density of 110.3 pcf over a material with a density of 160.8 pcf. The layer thicknesses vary from 1 inch to 3.5 inches. The two different system counts are shown as well as the resulting overlay density reading.

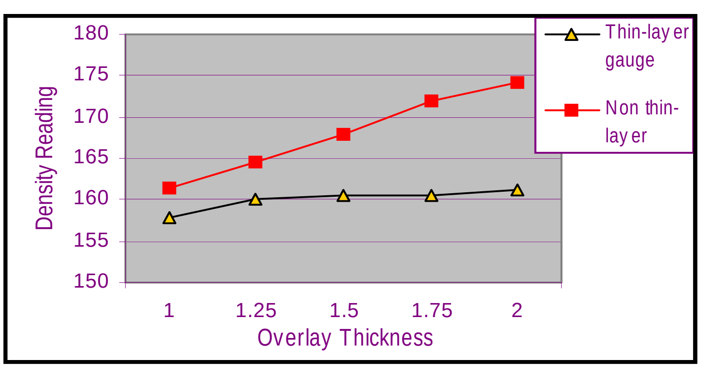
CHART A



The system 1 density measurement is more heavily influenced by the material that is closer to the surface, therefore it more closely matches the true overlay density. Both density measuring systems are influenced by the overlay and the underlying material and the densities that result are relatively similar.

As explained earlier, the thin-layer gauge will not react the same way as the standard surface density gauge (non thin-layer gauge) when the conditions change. The following chart represents the resulting density that is read by each of these types of gauges when the overlay thickness varies from 1.0 inch to 2.0 inches, but the thickness programmed into the gauge remains constant at 1.5 inches. The overlay has a density of approximately 161.2 pcf and the underlying material has a density of approximately 133 pcf.

CHART B



The overlay density read by the standard surface moisture/density gauge varies by as much as 12.7 pcf in this situation. The thin-layer gauge overlay density reading varies by only 3.5 pcf. Chart B also shows that the thin-layer gauge is much more accurate in the density measurement; the standard surface gauge never reads the correct density of the overlay.

The most important test that can be done to evaluate any instrument is a check of accuracy. The best method to test the Troxler thin-layer gauges for accuracy is to position the gauge properly on an overlay of a known density and thickness, enter the correct layer thickness into the gauge and take a measurement. The gauge should yield the asphalt equivalent density of the overlay material. As long as one remains within the recommended density range and overlay thicknesses while performing this test, this test is valid and fairly simple to perform. In order to be assured that the underlying material is not influencing the reading, another test can be performed. The test outlined above can be done twice; once with the overlay resting on a block of equal (or similar) density and once with the overlay resting on a block of differing density. The two results should be similar (within +/- 1 pcf).

Summary

The thin-layer gauge has definite advantages over the conventional method of measuring overlay density, referred to as nomograph. The bottom layer density does not have to be determined in order to use the thin-layer gauge. Slight changes in the overlay thickness will not greatly distort the thin-layer gauge density reading as it will the nomograph density reading. The information given in this application brief explains the reasons why these differences are true. Troxler Electronic Laboratories, Inc. is the only manufacturer of a true thin-layer gauge for the measurement of the density of asphalt layers from 1 to 4 inches thick. The accuracy and ease of use of this type of gauge makes it a necessity for anyone concerned with the quality control of asphalt pavements.