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APPLICATION BRIEF

The Importance of the Application of Necessary Moisture Correction Factors to Field Compaction Tests Made With Nuclear Moisture Gauges

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A report addressing the use of the moisture correction when using any nuclear moisture gauge, focusing on the 3411B.

Introduction

It has become increasingly evident that many nuclear gauge users are neglecting an important "fact of life" in the compaction testing of soils. That is, they are not making an appropriate correction to moisture measurements when certain interfering constituents are encountered in the soils they are testing. These constituents will not only cause an error in the percent moisture measured by the gauge, but will also result in an erroneous dry density determination and, of course, affect the percent relative compaction end result.

Troxler Technology

The problem revolves around the basic fact that a nuclear gauge, operating in the moisture mode, is primarily measuring hydrogen and to a very much lesser degree, other elements (e.g. silicon, calcium, oxygen, etc.) which normally remain fairly constant in natural soils and therefore are accommodated in gauge calibration. In a simplified review, the radiation principal involved consists of "fast" high energy neutrons coming from the source in the gauge and impacting hydrogen atoms. Through these impacts, the fast neutron will lose energy by way of the elastic collision process and be moderated to a low energy or "slow" neutron state. It takes, on average, about nineteen collisions with hydrogen atoms to reduce or moderate a fast neutron to the slow neutron energy level. Some of the moderated neutrons will be scattered in space, but some will also work their way back to a detector tube in the gauge which will only respond to the moderated slow neutrons. Of course, since the usual major component in soil containing hydrogen is water, then the counts per minute (cpm) registered by the detector tube reflects the moisture content in the soil. It also follows that the more water there is in the soil, the greater will be the number of hydrogen atoms available to moderate the neutrons, therefore, the cpm at the detector will increase proportionately.

The above described process is a very accurate way of measuring the moisture content of soils providing there are not other constituents present in the soil to interfere with the operation. However, in natural soils there can be two basic interference conditions which are identified as follows:

<u>Type I Condition:</u>

First, and perhaps most common, is the case where the soil contains bound water, molecular hydrogen, water of hydration, adsorbed water or hydrocarbons. Compaction testing involves only free water (e.g. that which can be driven off by low temperature oven drying) and the other types of nonfree hydrogen must not be involved. However, as can be seen in the previous paragraph, the gauge is basically reading hydrogen and it cannot discriminate between free water hydrogen and the other types just named. Therefore, it is obvious that a gauge operating on soils containing hydrogenous materials (other than free water) will show a higher moisture content than is actually present in terms of free water as indicated by an oven dry test. Examples of hydrogenous materials often found in soils are given as follows:

1. Gypsum – for every molecule of calcium sulfate there are two molecules of attached water.
2. Lime – contains a hydroxyl.
3. Mica – usually contains considerable molecular hydrogen.
4. Clay – almost any clay, especially those of the montmorillonite and illitic class, contain adsorbed (not absorbed) water which is not normally removed by oven drying and sometimes other types of hydrogen are also included in combination.
5. Organics – contains hydrocarbons.

Type II Condition:
The other type of interference comes from soils which contain elements or compounds which will capture or absorb slow neutrons before they can get to the detector tube and be counted. In this case the gauge will read a lower moisture content than is actually present in the form of free water. Examples of these kinds of materials, sometimes found in soils, are given as follows:

1. Usually rather rare mineral types – cadmium, lithium, boron. In California, boron is found in large amounts in the region of the borax mines in the southern deserts.
2. High salt content – often found in interior desert salt flats and tidal basins along the coast.
3. High iron oxide content – must be above 35% - 40% to be an effective absorber.

Gauge Operation

The correction procedure to be used with the Troxler 3411B

It is recommended that when a user first comes on a project and he is not familiar with the moisture characteristics of the soil he should perform a quick moisture comparison (e.g. hot plate or Speedie moisture) with the gauge percent moisture. This is done by taking a representative sample from under the gauge after the gauge determination. If there is a significant moisture differential between the two tests (usually considered greater than 2%), then it is recommended that at least four comparisons be performed in each general soil type (i.e. if there is a significant soil classification change on the project) at random locations. These samples should be taken to a laboratory and subjected to low temperature oven drying (OD). However, if another moisture test is a standard for the project, then use it.

After the OD moisture contents are determined, calculate a K factor for each sample using the following equation (see page 4-6 in the 3400B Series Instruction Manual) and observing the algebraic sign convention for the K value (+ or -).

$$K= \left(\frac{\%M\ (True^*)\ -\ \%M\ (Gauge)}{\%M\ (Gauge) + 100} \right) \times 1000$$

*True means oven dry or other standard test for soil moisture.

Average the four or more K factors within each general soil type. Then dial the appropriate average factor for the soil type being tested in the 3411B with the rotary switches at the bottom of the front panel under the label “Moisture Correction”. If the K factor has a minus sign it means that the gauge moisture is greater than the OD moisture and a bound hydrogen (Type I) condition exists in the soil. Conversely a plus sign means that the gauge moisture is less than that for the OD moisture and elements causing the neutron capture exist in the soil (Type II). Set the sign switch to the left of the moisture correction switches to the appropriate sign.

Analysis of the K Factor

After a K factor is dialed in with the rotary switches on the 3411B, then with each test on the soil, the microprocessor within the instrument undergoes a series of rather complex calculations. These nearly instantaneous computations start with the adjustment of the dry density (DD) to a corrected value. In turn this corrected DD is subtracted from the basic wet density (WD) measured by the gauge to obtain the volumetric expression of moisture content (M) in either pounds per cubic foot (pcf) or kilograms per cubic meter (kg/m^3), depending on whether the English or Metric system is used. Finally, the corrected percent moisture by dry weight of soil (%M) is calculated by dividing the corrected M by the corrected DD. This correction process in the gauge can be eliminated by simply turning the moisture correction switches back to zero.

By analyzing the K factor's relationships to gauge moisture and wet density, it is possible to develop a concept of the effect of the factor in changing a dry density to its correct value. The K factor will not only vary with the difference between true and gauge moisture, but also with the moisture level encountered in the soil (gauge moisture). The higher the moisture content, the less range there will be in the K factor for differences between true and gauge moisture. The reason for this is that the bound hydrogen represents a smaller proportion of the total moisture.

The relationship of the K factor in changing the dry density becomes somewhat more complex. In this case the gauge moisture is not only a variable, but the K factor will also vary in relation to the wet density encountered. The change in dry density is not highly sensitive to the K factor. It takes between 10 and 15 K units to change the density 1 pcf. This is why it is normally satisfactory to take the average of K factors from a number of moisture comparisons on a project to establish a value to be used in the gauge.

Summary

While this presentation was written around the Troxler Model 3411B and the K factor, any nuclear gauge (regardless of make or model) is subject to errors in moisture measurements when interfering constituents are encountered in the soil. The radiation principals involved are the same for all gauges, but the particular technique for making a moisture correction depends on the make and model being used. This information is usually found in the instruction literature that comes with the particular instrument.

The important advantage of the 3411B procedure is that it is independent of the dry densities of the soils involved in the moisture comparison tests from which the K factor is calculated. The method normally used with other gauges is a function of dry density and is only valid for the particular density of the soil in the test from which the moisture correction value is determined.

It may seem tedious and time consuming for a new 3411B user to perform the moisture comparisons and necessary K factor calculations on each new project. However, after the engineer gains experience with the soils in his area of operations, he will develop a "feel" for when the use of the K factor is necessary and when it is not. It is also often possible to develop K factors for certain localities for use on a routine basis in future tests.

In the end, it should be apparent that the proper application of a moisture correction is important when a nuclear gauge is being used for compaction control. It can make the difference between a failing and a passing test.

12/81 By Daniel R. Howe, Western Branch Manager
Note: This report, originally written in 1981, contains valuable information that is still appropriate with today's Troxler Models 3430, 3440 and 3450 gauges.