SYMPOSIUM ON NUCLEAR METHODS FOR MEASURING SOIL DENSITY AND MOISTURE

INTRODUCTION

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As an introduction to the papers presented at this symposium it is in order to say a few words on their general nature. The papers are reports, either of work in calibrating nuclear instruments, or of work in checking an existing calibration. This problem, which at first may appear simple, can appear more complex on second thought. Normally, density tests, whether of soil or of moisture content, are based on fairly direct methods. Reports of such tests usually strike a background of familiarity with all concerned since everyone understands the types of measurements involved and it is usually unnecessary to examine closely the conventional test methods. In this presentation, we shall see these conventional methods used in comparison with another, and newer, method.

Even if the conventional tests, such as the sand-cone and oven drying tests, were 100 per cent accurate, there would be other problems created by such a comparison. Unfortunately, conventional tests are not 100 per cent accurate and this complicates the problem. For example, in the sand-cone test[2] adopted by the Society in 1958 the various weight measurements, volume of apparatus determinations, and so on, are specified to an accuracy of about 1 per cent. Some of the resulting errors tend to cancel—but there is uncertainty. In addition there is a problem in seating the apparatus which is complicated, in my experience, by the fact that the usual base plate deviates from a plane. Furthermore, if the same identical sand is repeatedly calibrated with the same apparatus, there will always be different values of the sand's bulk density; this is basic to the method. These sources of error in the sand-cone method have their counterparts in the nuclear "backscatter" methods. There is the same problem in seating the apparatus; there are different count values from the repeatedly tested spot; and the various arbitrary measuring accuracies in the sand-cone method are similarly present in the applied voltage, timing cycle, and other components of the nuclear method.

Aside from sources of error, which are present in any measurement, it would appear in order to consider just what is being measured. Comparisons of nuclear and conventional test methods would be of most significance in tests of a completely uniform soil-moisture system; however, it is generally believed that this precise condition is not achieved and that there usually are significant variations in soil-moisture systems resulting from point-to-point differences in gradation, moisture content, effective or realized compactive effort, and other factors. This is particularly true in rou-

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[2] Method of Test for Density of Soil in Place by the Sand-Cone Method (D 1556 – 58 T), 1958 Book of ASTM Standards, Part 4.

tine soil construction. Conventional sand-cone, rubber balloon, and other volume-weight measuring density tests give an *average* density of the material removed in digging the test hole or other directly measured volume. The nuclear method, however, gives a *weighted* value from a somewhat indeterminate volume —indeterminate both laterally and vertically. Compounding this, the nuclear method assigns the most significance to the material nearest the instrument and the least significance to that farthest removed. Furthermore, the degree of significance realized at the various distances is to some degree determined by the densities at these, at intervening, and at other distances.

The point in all of this is that there are a number of variables involved in conventional test methods, and when these methods are used in comparison with a different method, such as the nuclear, with characteristics peculiar to itself, a gamut or range of differences must be expected. In some respects, too, such a check, with bases in differing principles, is analogous to comparing apples and oranges. If, however, duplication of test results within some selected range is desired, it should be possible to calibrate the one against the other and to use this calibration in routine work, at least insofar as the preselected conditions of calibration are observed in using the calibration curve.

In looking at the data presented in the symposium papers it may be helpful to keep these and the following thoughts in mind:

1. Comparisons of soil *wet* densities by nuclear and conventional methods are the most direct. They may also be of the least interest. In an oversimplification, the nuclear test gives wet density more or less directly; the conventional test involves only a volume and a weight determination. All authors compare wet densities.

2. In comparing water content by the two techniques, a less direct comparison is necessary. The nuclear method measures water *density* in pounds per cubic foot; conventional methods give moisture as a *percentage* of soil dry weight. To compare these two values, one must be converted to the units of the other on the assumption of known soil density—in other words, on the general assumption that a density test is accurate. Some of the papers compare moisture tests on the assumption that one soil density test is correct, others on the opposite assumption. Mr. Burn and Mr. Shook may have minimized some of these problems by working with the averages of large samples.