EVALUATION OF THE SPEEDY MOISTURE TESTER

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ABSTRACT: A commercially available device for rapid determination of soil and aggregate moisture contents over a wide range of moisture conditions was tested in comparison with the conventional oven-dry method. Variations to be expected in both techniques are discussed; values obtained by the two methods compared favorably. A calibration curve was developed which extends the device's usefulness through a moisture content of 52 percent and simplifies testing procedures at all soil moisture contents. The device is rugged enough for normal construction use, and much quicker than conventional methods. Due to smaller sample size, however, sampling methods are quite critical for coarse materials.

KEY WORDS: soil moisture, moisture control, soil testing, oven drying, testing equipment, test methods.

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In an effort to develop more rapid methods for determining moisture contents of soils and aggregates, the Research Laboratory Division was requested to investigate a commercial soil moisture measuring device known as the "Speedy Moisture Tester." Developed in England and marketed here by the Alpha-Lux Company of New York, it operates on the principle that a given quantity of moisture will react with calcium carbide to produce a specific volume of an acetylene gas. The gas is then confined in a pressure vessel, where a gage is calibrated to indicate percentage moisture content, based on the sample's wet weight. Interest in the possible application of this equipment to highway construction had been expressed by the Soils Division and the Office of Construction.

Testing and use of this equipment by several groups, with varying degrees of success, has resulted in several modifications. The Bureau of Public Roads* reported favorably on a later, larger model, capable of testing 26-g samples. They concluded, in part, that the device had proved to be sturdy, dependable, reasonably accurate, and fast and easy to operate.

The Research Laboratory Division conducted systematic laboratory tests of both the smaller and larger capacity Moisture Testers (6 and 26 g). Results for the smaller model were unsatisfactory, so all work concentrated on evaluating the larger model. The tests compared the Speedy method with conventional oven-drying procedures for determining moisture content. Sampling errors and errors due to nonhomogeneity of soil-water mixtures were minimized by careful control of test methods. The equipment also underwent limited field testing.

Description and Operation

The Moisture Tester is a hollow aluminum vessel approximately 14-in. long with a maximum diameter of 6 in., having a pressure gage on one end and a cap with a clamping arrangement on the other. Empty, the device weighs about 3.7 lb. The instrument and its auxiliary equipment--

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*Blystone, J. R., Pelzner, A., and Steffens, G. P. "Moisture Content Determination by the Calcium Carbide Gas Pressure Method." Public Roads, Vol. 31, No. 8 (June 1961), pp. 177-81.

carrying case, scale for weighing samples, small ladle for measuring the amount of chemical (calcium carbide) added, steel balls for breaking soil samples, cleaning brush, and a chart for converting moisture readings to the dry weight basis--are shown in Figure 1. The supply of calcium carbide must be stored in airtight containers.

The general procedure for using the apparatus is as follows:

1. Place the two 1-1/2 in. steel balls and two ladles of calcium carbide into the large chamber.

2. Weigh a 26-g sample of the soil to be tested into the cap of the cylinder (Fig. 2). Insert the cap into the cylinder and seal by tightening the clamp.

3. Rotate the cylinder in a horizontal position (Fig. 3) for 10 sec, so that the steel balls rotate around the inside circumference of the chamber. Allow to rest for 20 sec. The 30 sec required for shaking and resting is designated the "shake-rest" cycle. Repeat this cycle for 3 min or for two consecutive, identical readings. During this operation, the steel balls must not fall on the cap or the surface leading to the pressure gage, as this could damage the instrument.

4. Read soil moisture content directly from the gage (Fig. 4). This value is based on the wet weight of the soil, but may be converted to dry weight basis by use of the chart shown above the Tester in Figure 4.

5. Remove soil and carbide from the pressure chamber and thoroughly brush out the cylinder and cap.

Use of the standard 26-g Tester is limited to samples having moisture contents under 25 percent on the dry weight basis. A special 13-g weight is provided so that soil sample size can be halved. In this case, the gage reading must be doubled to obtain the desired moisture content. Halving the sample size extends the capacity of the Moisture Tester to samples containing approximately 50-percent moisture on the dry weight basis.

Laboratory Testing

The laboratory evaluation had two phases. In the first, each of several soil types was tested at a single moisture content to check the possible effect of soil characteristics on results. The range of moisture contents for all of the samples was between 4.5 and 12.7 percent, based on dry weight of the soil.

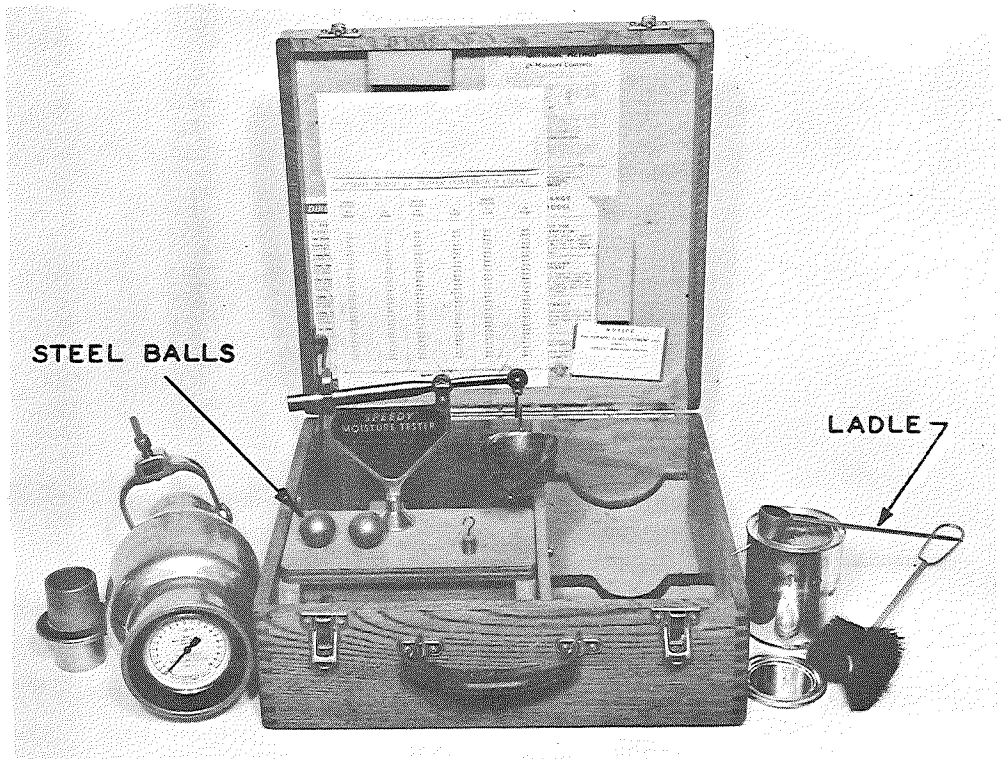


Figure 1 (left). The Speedy Moisture Tester and auxiliary equipment.

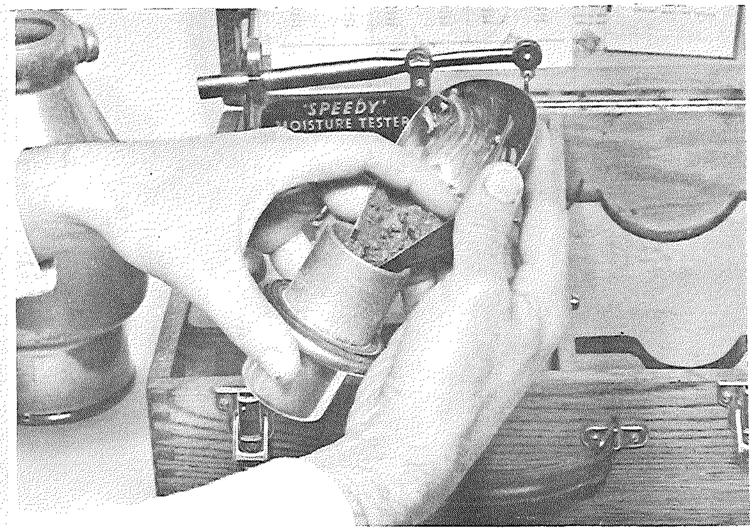


Figure 2 (above). Placing soil in cup of cylinder.

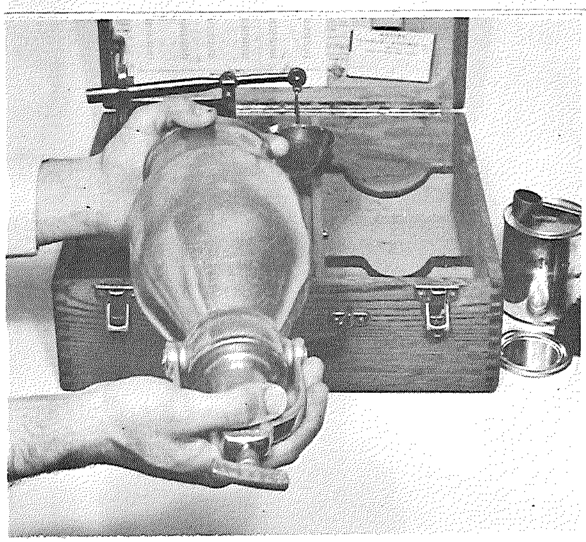
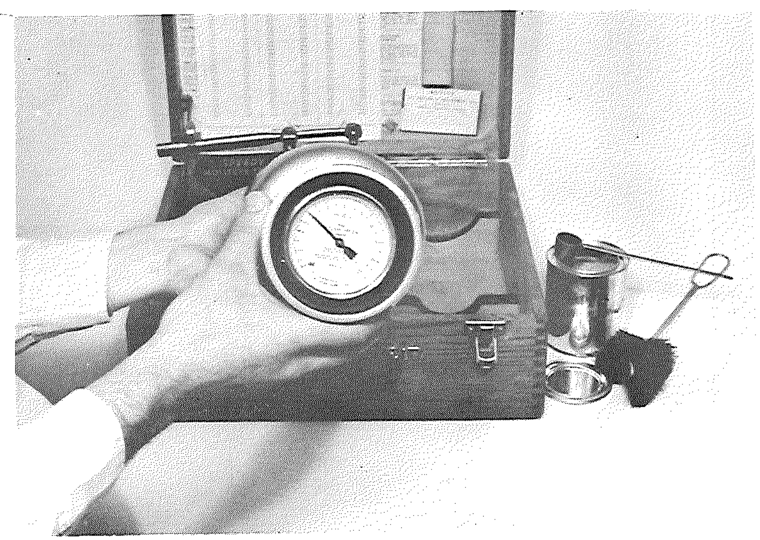


Figure 3 (left). Position for conducting shake-rest cycle.

Figure 4 (right). Dial indicator showing moisture content of soil on wet basis.



In these tests, one 10-lb batch each of six different soil types was mixed with water and allowed to cure overnight in a moist cabinet. Ten samples were taken from each 10-lb batch, and each sample was then divided, with moisture content of one part (26 g) to be measured by the Speedy Tester, and the remainder by the oven-dry method. The resulting 10 paired values (Speedy vs. oven-dry) for each soil sample were compared to examine moisture content determination by the two methods.

Figure 5 and Table 1 indicate good agreement between average moisture contents of each group of 10 samples as determined by the separate methods, but for each method there were variations of individual moisture contents within groups. For a specific group, the variations between the two methods may be compared in terms of their standard deviations. However, because the Speedy method was to be evaluated over a wide range of moisture contents, the standard deviation alone does not give the complete picture. By computing the "coefficient of variation" (the standard deviation divided by the average moisture content of the sample group, and multiplied by 100 to obtain percent), it is possible to relate the magnitude of variability to the magnitude of a particular group's moisture content. The coefficients of variability (Table 1) indicate the Speedy method to be almost equal or less variable than the oven-dry method.

Figure 6 shows the scattering of individual moisture values and mean averages for the two methods when plotted around a line of equal values. Also shown is the 95-percent confidence limit to be expected when predicting oven-dry values from those obtained with the Tester. This figure indicates that the two methods compare within ± 1.5 percent in 95 percent of the tests.

Results from this phase of the testing show the Speedy method to be consistently as reliable as the oven-dry method in measuring moisture content of soils and aggregate.

A second phase of the laboratory testing was to determine whether the Speedy method was applicable over the extreme moisture content ranges likely under field testing conditions. The Bureau of Public Roads found in its 1961 tests that a calibration curve was necessary if higher moisture contents were to be measured accurately, and developed one covering a range from 0 to 42 percent. With this curve, Tester readings could be converted directly to percent moisture on the dry weight basis. The Bureau suggested that the curve might not be applicable generally, and recommended that each Tester user develop his own calibration curve if check tests against their curve indicated such a need.

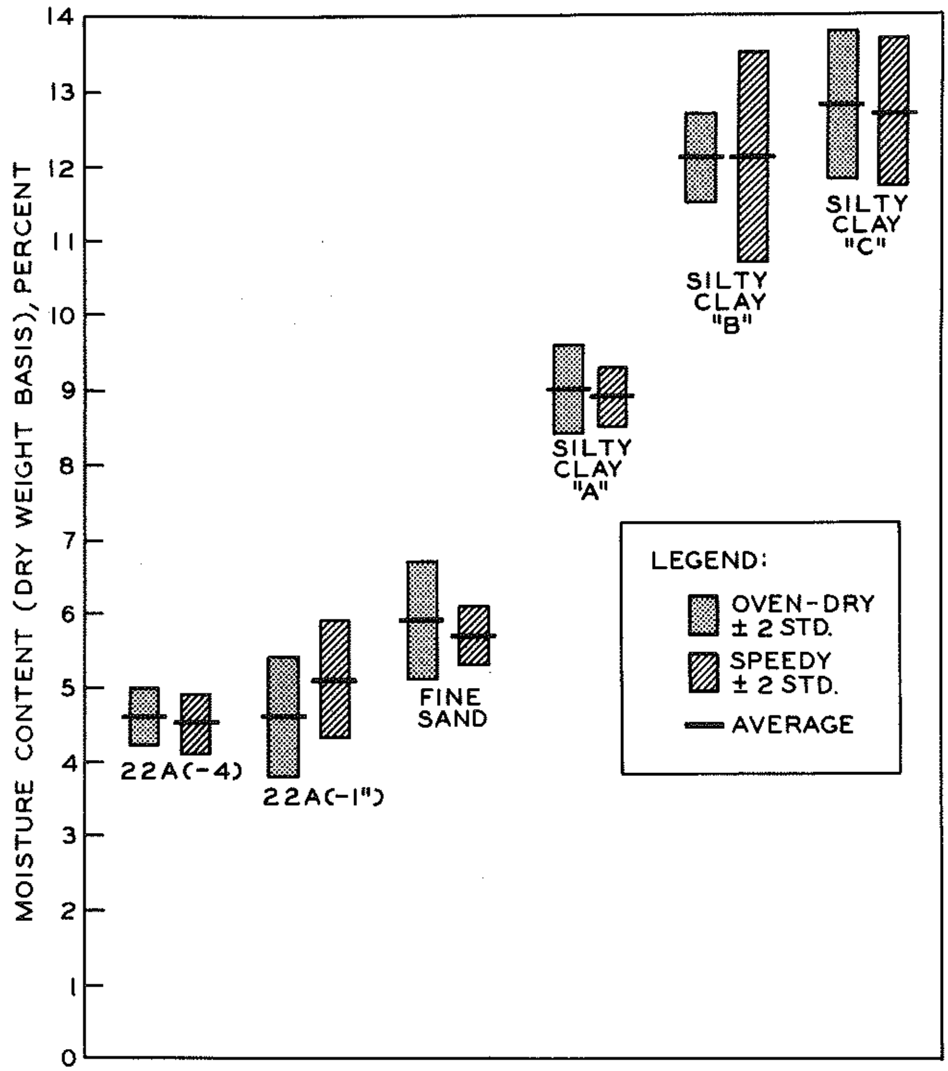


Figure 5. Variation and average of moisture contents of 10 samples each of six soils used in comparing the two test methods.

TABLE 1
COMPARISON OF OVEN-DRY AND
SPEEDY METHODS OF MOISTURE DETERMINATION
Ten Samples Tested for Each Value

Soil Type	Average Moisture Content, percent		Standard Deviation		Coefficient of Variation	
	Oven-Dry	Speedy	Oven-Dry	Speedy	Oven-Dry	Speedy
22A (-4)	4.6	4.5	0.2	0.2	4.4	4.5
22A (-1 in.)	4.6	5.1	0.4	0.4	8.7	7.8
Fine Sand	5.9	5.7	0.4	0.2	6.8	3.5
Silty Clay A	9.0	8.9	0.3	0.2	3.3	2.2
Silty Clay B	12.1	12.1	0.3	0.7	2.5	5.8
Silty Clay C	12.8	12.7	0.5	0.5	3.9	3.9

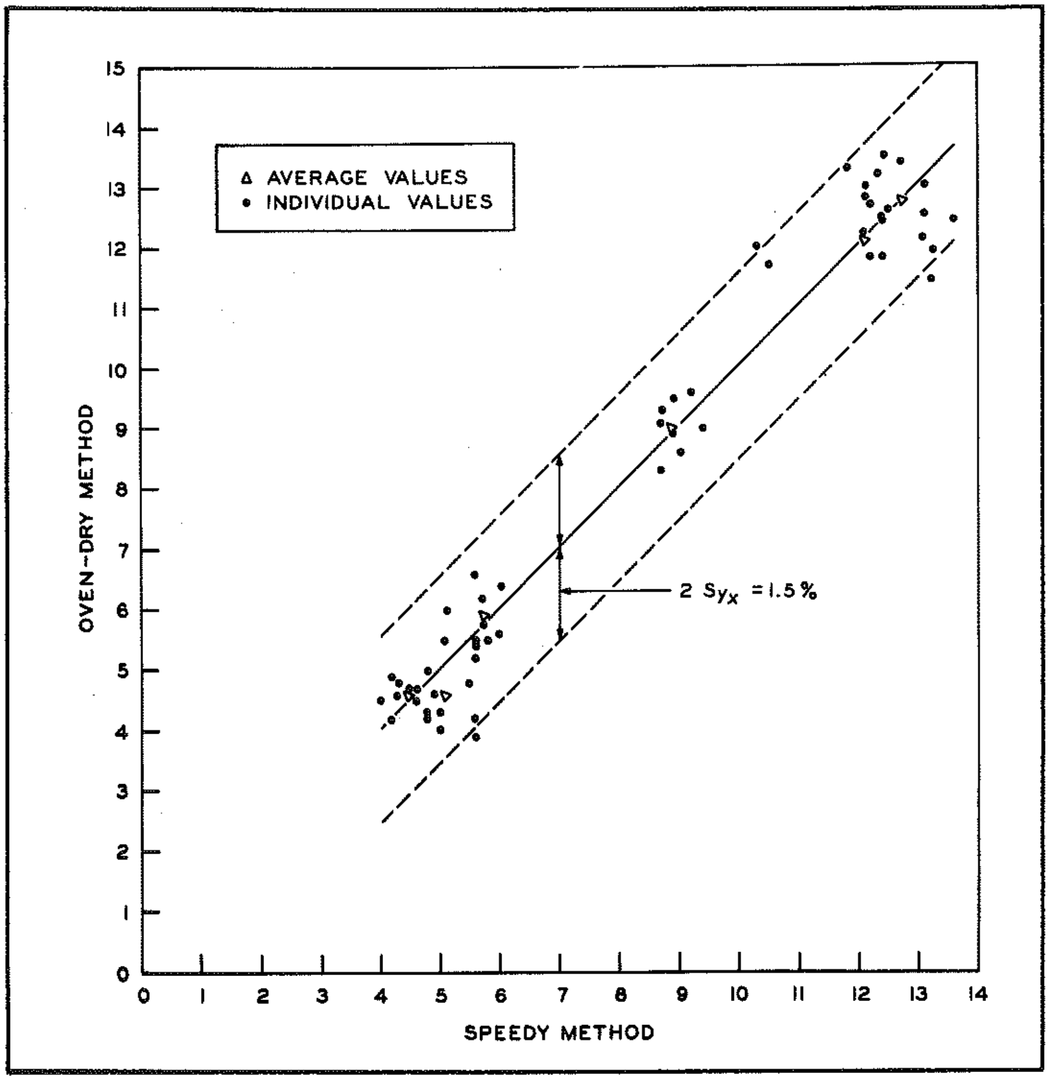


Figure 6. Comparison of average and individual values of moisture content (percent of dry weight) for the two test methods.

Two soil materials, Ontonagon clay and 24 A gravel, representing extremes in Michigan grain size, were used to develop a calibration curve, The gravel was tested at approximately 3-, 6-, and 9-percent moisture contents. At 9-percent moisture the gravel was at or near saturation. The clay was tested at approximately 10-, 20-, 30-, and 50-percent moisture contents. Twenty paired samples were prepared at each moisture content and allowed to cure in a moist atmosphere for a minimum of three days, during which they were mixed periodically to assure even distribution of moisture. To reduce variations in moisture contents between samples used for comparative tests, the samples were selected and carefully paired as follows. A representative sample from each batch was selected, from which one operator removed enough soil for the Speedy test while another removed that required for corresponding oven drying. In these tests, weight of the oven-dried samples was standardized at 100 g, to eliminate any variation that might be caused by sample size. The Tester samples were either 26 or 13 g, depending on their moisture content.

The Bureau of Public Roads found that Tester moisture readings could vary with the temperature generated by the reaction between the carbide and water. The heat produced by this reaction is directly proportional to the amount of water contained in the sample. Thus, results at higher moisture contents were significantly affected. This problem was overcome by allowing the cylinder to cool to a point where temperature no longer influenced this pressure reading. For moisture contents up to 30 percent, a 3-min shake-rest cycle was satisfactory, and above 30-percent moisture, a 5-min cycle.

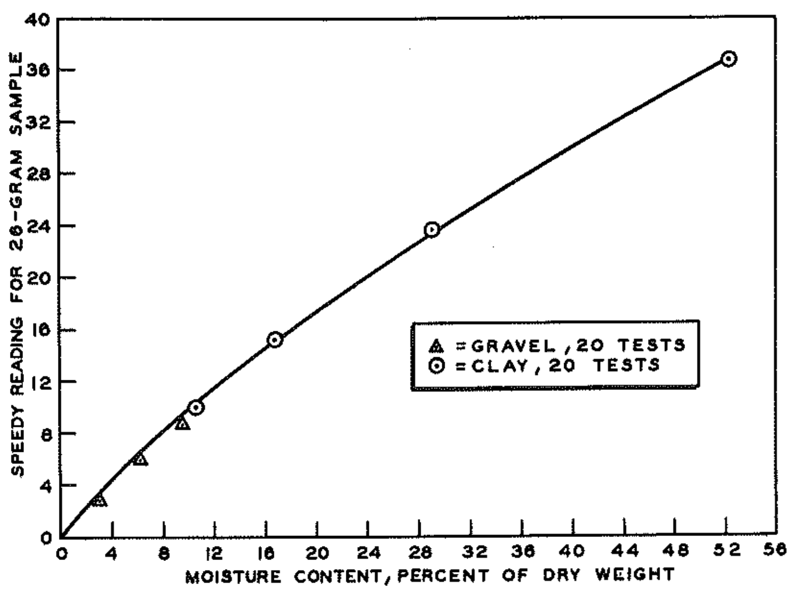


Figure 7. Calibration curve for Speedy vs. oven dry methods in percent dry weight.

Early in this series of tests, it became apparent that a calibration curve was necessary to obtain satisfactory agreement between the Tester and oven-dry methods when moisture contents exceeded 10 to 15 percent. Using the average value of 20 tests per point, over the complete range of moisture for these tests, the calibration curve shown in Figure 7 was developed. It was found that this curve coincided with the one developed by the Bureau for the soils they tested.

Comparative individual and average values obtained by the two methods of testing are shown in Figures 8 and 9 and Table 2. Figure 8 shows the variations in moisture content of each group of 20 samples throughout the moisture content range of this test. These data indicate close agreement between the average moisture content values obtained by each method, usually within 0.1 percent. They also show that some variation in individual test values is to be found at each moisture level, but generally there is no great difference in variation between the two test methods.

TABLE 2
COMPARISON OF OVEN-DRY AND
SPEEDY METHODS OF MOISTURE DETERMINATION
Twenty Samples Tested for Each Value

Soil Type	Average Moisture Content, percent		Range of Moisture Content, percent		Standard Deviation		Coefficient of Variation	
	Oven-Dry	Speedy	Oven-Dry	Speedy	Oven-Dry	Speedy	Oven-Dry	Speedy
Gravel	2.9	2.8	0.6	0.7	0.18	0.21	6.3	7.6
	6.1	6.2	1.8	2.8	0.48	0.63	7.8	10.2
	9.6	9.2	3.2	2.1	0.78	0.89	8.2	9.7
Clay	10.6	10.7	0.3	0.5	0.08	0.19	0.8	1.8
	16.8	17.0	2.2	2.5	0.48	0.62	2.8	3.6
	29.1	29.2	1.4	2.6	0.33	0.86	1.1	2.9
	52.3	52.2	6.6	11.3	1.39	3.02	2.7	5.8

Figure 9 shows individual test values obtained by plotting the Tester against the oven-dry method around a line of equal values. These data show uniform distribution of test values around the line of equality and a relatively small range in values. The greatest differences are found at the higher moisture content where the range in values was 11.3 percent. Based on the higher moisture content for these samples, however, the range compares favorably, on a percentage basis, with those of the lower moisture content samples. This is also shown by the coefficient of variation values in Table 2. It should be noted, however, that with the exception of one odd value which could be due to experimental error, the oven-dry moisture determinations compared quite closely at the higher moisture content while the Moisture Tester varied its maximum amount at this point.

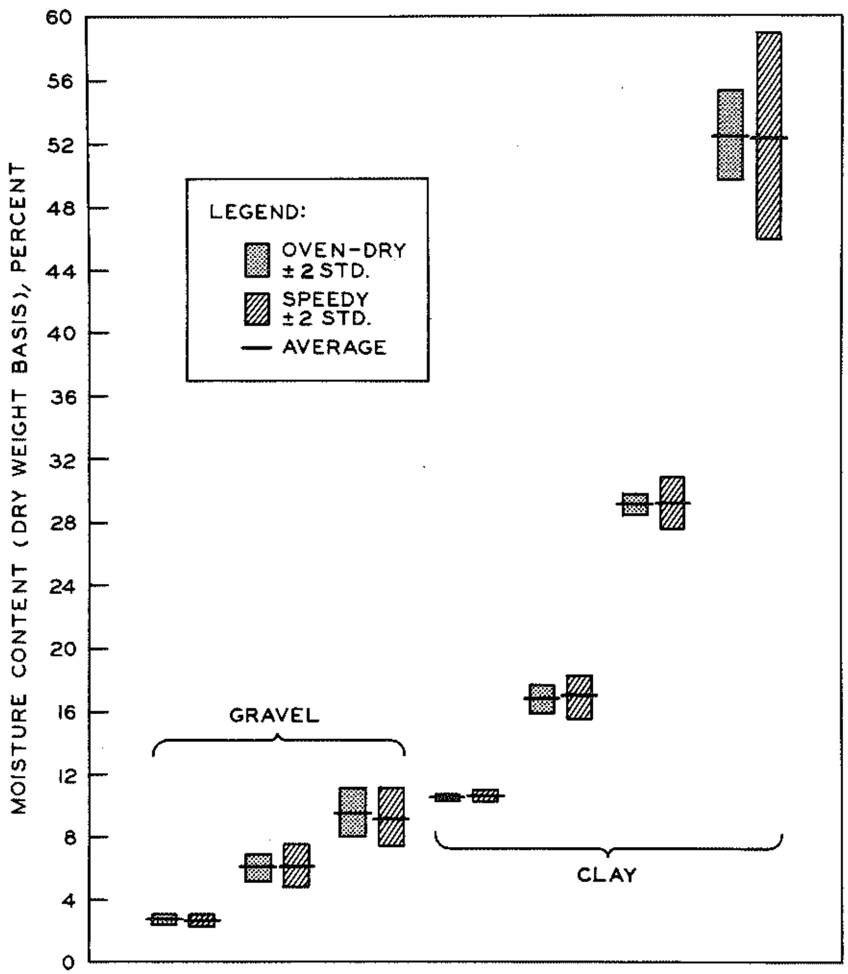


Figure 8. Variation and average of moisture contents of 20 samples each of gravel and clay (at different moisture contents) for the two test methods.

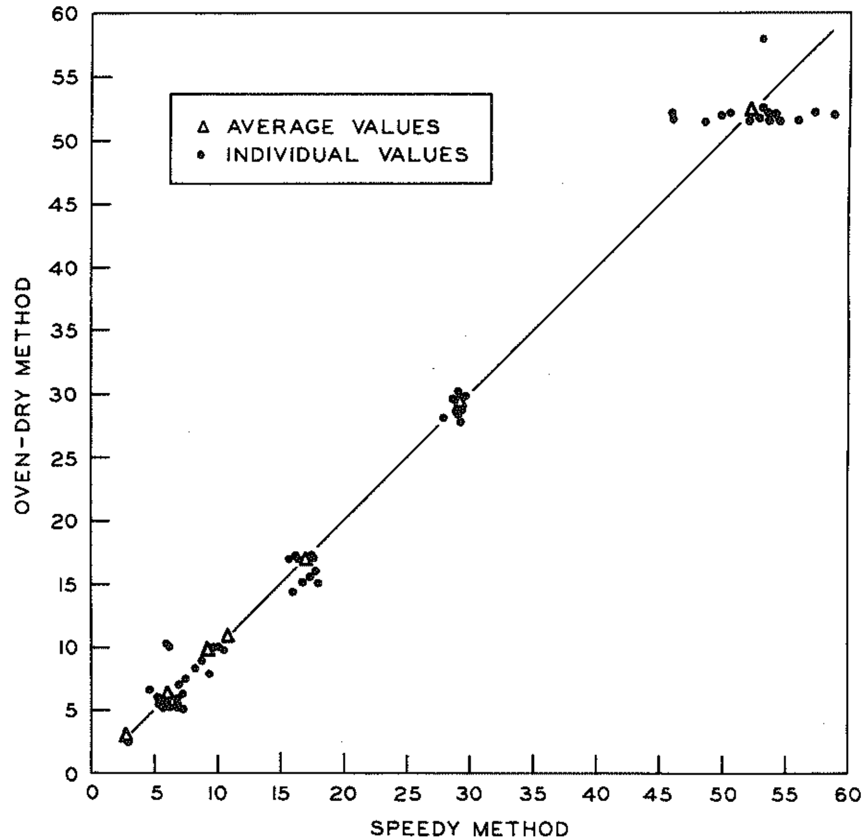


Figure 9. Comparison of average and individual values of moisture content (percent of dry weight) for gravel and clay using the two test methods.

The standard deviations (Table 2) indicate very little difference between values of the two methods when the moisture content does not exceed 17 percent. Variation in the Speedy method ranges up to 0.15 percent of moisture content greater than the corresponding range for the oven-dry method. The coefficient of variation, which reflects the magnitude of the moisture content level, is a better measure of the relative variability of the two methods. Figure 10 indicates a graphical relationship between the coefficient of variation data of Table 2, showing that the coefficient of variation for both methods fluctuates as the moisture level changes, and that generally this fluctuation is similar for both methods. This figure also shows that the coefficient of variation is greater for gravel than for clay.

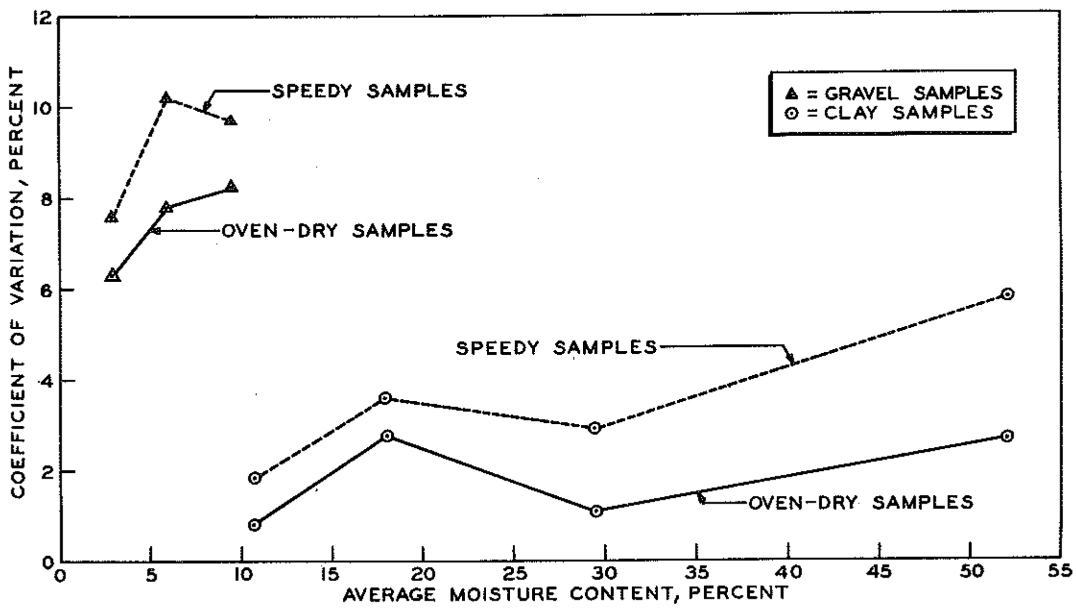


Figure 10. Variation of individual tests from their average at different moisture levels, expressed as coefficient of variation.

The indications derived from these data are that the sources of variation in moisture content are the same for both the Speedy and the oven-dry methods, and are probably due to the nonhomogeneity of the soil-water mixtures and to differences in sample sizes. These differences may result in samples less representative of the whole mass. Because the Speedy samples are smaller than those used for the oven-dry method, they are more susceptible to sampling error. At the 30- and 50-percent moisture levels, sample sizes for the Speedy tests were only 13 g. Variation in sampling also would be greater for the larger sized material (gravel) and this also is reflected in the tabulated and plotted data.

In addition to laboratory evaluation tests, the Research Laboratory has used the Tester method for routine moisture control of experimental field and laboratory projects. In all this work the method has proved reliable and the equipment entirely suited to rugged, routine use. Use of various chemical admixtures with the soil and aggregates did not appear to diminish the accuracy of results.

Conclusions

As a result of the tests described here, the following conclusions have been reached concerning suitability of the Speedy Moisture Tester for measuring moisture content of soils and aggregates:

1. Under carefully controlled test conditions, the Speedy Method proved to be reliable and accurate for measuring moisture contents of aggregates and clays ranging in moisture content from 0 to 50 percent, respectively.

2. Under field testing conditions, however, there is increased chance of sampling error when using the Speedy method because of the small sample size (26 g) used, as compared with 100 g or more with conventional methods. This is particularly true when testing coarse aggregates, where the ratio of coarse-to-fine material can significantly influence moisture content. For this reason, single Speedy tests with coarse material should be made with extreme care, and only when accurate computations are not required. For accuracy as required for the Rainhart and T-99 compaction tests, it is suggested that the average of several Speedy values be used.

3. To improve the Tester for testing coarse aggregates, studies will be made in an effort to develop a special calibration curve adjusted for use with the minus-4 portion of coarse materials. Also, the simplicity of the Speedy device should permit the manufacturer to increase its capacity to handle 100-g samples, thereby reducing the chance of sampling error.

4. Calibration of all Moisture Testers should be required before their use in accurate field and laboratory work. Routinely, the pressure gage should be checked periodically.

5. Field and laboratory tests indicate the Speedy to be rugged and practical for field use. This method is at least three times faster than the conventional "cook-out" method of moisture determination, and much simpler to perform.

6. The Speedy method may be used successfully with soils and aggregates containing such admixtures as cement, asphalts, sodium chloride, and calcium chloride.

7. The Research Laboratory plans to continue use of the Speedy method for all laboratory and field work where quick soil moisture information is needed.