RELATION OF THE MECHANICAL ANALYSIS TO THE MOISTURE EQUIVALENT OF SOILS

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The soil physicist has been very much interested during the past decade in trying to find some constant that will be a measure of the physical properties of soils so that when comparing two or more soils, this so-called constant will express numerically the difference that may exist between such soils.

Comparatively little work has been done by use of the moisture-equivalent determination and since some writers have claimed that there is a direct relation between the mechanical analysis of a soil, for instance, and its moisture equivalent, it was thought desirable to present a preliminary report at this time showing some results that have been obtained in the laboratory of the division of soil technology of the University of California, and to endeavor to offer explanations of the results.

The moisture equivalent was determined by use of the centrifuge designed by Briggs, et al, (2, 3) and was operated at a speed of 2400 revolutions per minute for a period of 30 minutes. This machine exerts a force 1000 times that of gravity on the saturated soil contained in the centrifuge cups.

The mechanical analysis was made by the Bureau of Soils method (4, 6) and special care was exercised to insure that the separation into the seven groups was made as accurately as possible. The analysis was made on 12 different soil types in duplicate, ranging in texture from coarse sand to clay and in origin from residual to recent alluvial. All of the particles belonging to the same group were combined so that a composite sample for each of these seven groups would be obtained. The moisture equivalent for these composite groups of soil particles was then determined in duplicate and not calculated indirectly, as most previous investigators have done.

The results obtained from the moisture-equivalent determinations of these seven grades of soil particles are given in table 1.

Specific-gravity determinations were also made on these seven grades. The results obtained are given in table 2 and show a range from 2.64 to 2.69 and seem to indicate that the separation by the mechanical analysis gave seven grades of soil material that differed mainly in the size of the particles constituting any one group, and not in any marked variation in mineral content.

By noting the results obtained for the different-sized particles making up a soil, as given in table 1, it can readily be seen that textural grade has a definite influence on the moisture equivalent of the soils and that each grade has a definite capacity for holding moisture.

There are soils in the western part of the United States which contain a large proportion of particles ranging from 0.05 mm. to 2 mm. in size, with a relatively small amount of silt and clay. They are, however, capable of holding sufficient moisture for the successful maturity of crops such as grapes, in regions where the annual rainfall averages below 15 inches and no irrigation is resorted to.

TABLE 1
Results obtained in moisture-equivalent determinations

TEXTURAL GRADE	SIZE OF PARTICLES	MOISTURE EQUIVALENT
	mm.	per cent
Fine gravel.....	2.0 -1.0	1.18
Coarse sand.....	1.0 -0.5	1.44
Medium sand.....	0.50 -0.25	1.85
Fine sand.....	0.25 -0.10	2.34
Very fine sand.....	0.10 -0.05	4.62
Silt.....	0.05 -0.005	24.99
Clay.....	0.005-0.0001	61.03

TABLE 2
Results obtained in specific gravity determinations

TEXTURAL GRADE	SPECIFIC GRAVITY
Fine gravel.....	2.67
Coarse sand.....	2.64
Medium sand.....	2.64
Fine sand.....	2.69
Very fine sand.....	2.66
Silt.....	2.65
Clay.....	2.66

The above results indicate that if it is possible to use the mechanical analysis as an indirect method for the calculation of the moisture equivalent, the investigator must give to each textural grade a definite and distinct value and not disregard the sands, or group three or four grades into one.

Three synthetic soils were then made up from these grades of soil particles, following the average mechanical analysis for these three soils as given by the United States Bureau of Soils (8), and the moisture equivalent was determined for these synthetic soils by the usual method. Before determining the moisture equivalent, however, the soils were allowed to stand in a moistened condition for ten days to allow a thorough saturation and an adjustment in the structure of the soil mass. The mechanical analysis and the moisture equivalent of these synthetic soils are shown in table 3.

Various formulas have been proposed for the calculation of the moisture equivalent from the mechanical analysis, of which the following two have received the most prominence:

Briggs (5) proposed the values

$$0.02 \text{ sands} + 0.22 \text{ silt} + 1.05 \text{ clay} = \text{moisture equivalent},$$

and Alway and Russell (1)

$$0.14 \text{ sands} + 0.27 \text{ silt} + 0.53 \text{ clay} = \text{moisture equivalent}.$$

The results obtained up to this time in our laboratory agree more closely with the latter formula than with the former. By noting the results given in table 1 it will be found that the sands total 0.11, the silt 0.25 and the clay 0.61.

TABLE 3

Mechanical analysis and moisture equivalent of three synthetic soils

SOIL TYPE	FINE GRAVEL	COARSE SAND	MEDIUM SAND	FINE SAND	VERY FINE SAND	SILT	CLAY	MOISTURE EQUIVALENT
	<i>per cent</i>	<i>per cent</i>	<i>per cent</i>	<i>per cent</i>	<i>per cent</i>	<i>per cent</i>	<i>per cent</i>	<i>per cent</i>
Loam soil.....	2	5	5	15	17	40	16	21.02
Sandy loam.....	4	13	12	25	13	21	12	14.50
Fine sandy soil.....	1	4	10	57	17	7	4	6.65

TABLE 4

Determined moisture equivalent compared with calculated moisture equivalent

SOIL TYPE	MOISTURE EQUIVALENT		
	Determined	Calculated	Departure
Loam soil.....	21.02	20.86	-0.16
Sandy loam soil.....	14.50	14.01	-0.49
Fine sandy soil.....	6.65	6.32	-0.33

Taking the values for the moisture equivalent as determined for each separate and then calculating the moisture equivalent by using these values in conjunction with the mechanical analysis of the synthetic soils and comparing the result with the actual moisture equivalent of the synthetic soil, the value of a formula can be tested. The averages used for the various textural grades on the basis of the results given in table 1 were: fine gravel 0.010, coarse sand 0.015, medium sand 0.020, fine sand 0.020, very fine sand 0.045, silt 0.250, and clay 0.600.

The results of the determined moisture equivalent compared with the calculated moisture equivalent for the three synthetic soils are given in table 4.

If the sands are totaled the departure of the calculated moisture equivalent from the determined moisture equivalent is much greater than if definite values are given to each of the sand groups, as was done in the table.

The results given in table 4 show that the calculated moisture equivalent

is practically the same as the determined when separate values are given to the seven individual grades of texture, and not when determined by totaling the five grades of sand or disregarding the sands and just considering the silt and clay content of a soil.

A mechanical analysis was then made on 18 samples of soil, the moisture equivalent determined by use of the centrifuge as well as calculated, and the departure noted. The calculated moisture equivalents were in nine cases below the determined and in the others above. The departure of the calculated moisture equivalent from the determined ranged from -0.90 to $+2.94$.

On a similar set of samples (ten in number) the mechanical analysis and the moisture equivalents were determined by some advanced students in our laboratory. The departure of the calculated moisture equivalent from the determined was greater than that found in the previous set and ranged from -5.44 to $+5.31$.

For the third set of samples the mechanical analysis for 30 samples of soil were obtained from the report of the Bureau of Soils, The Soil Survey of the Ukiah Area, California. Duplicate samples of each of these soils were in our laboratory and the moisture equivalent was determined on them. The calculated moisture equivalent departed from the determined from -0.57 to $+7.28$.

There were several samples of special interest in that the mechanical analysis was practically the same, yet the determined moisture equivalent varied considerably. The results for some of these peculiar samples are given in table 5.

The mechanical analyses of the first two samples given in table 5 are almost identical, but the determined moisture equivalent of one is 30.80 and for the other 35.82. A similar condition exists for the other two samples noted in the same table.

Taking the average mechanical analysis of several representative soil classes as given by the Bureau of Soils (8) and calculating their moisture equivalent by using the values for the various textural grades as given in table 1, the results shown in table 6 were obtained.

Table 6 shows that from the average of a large number of mechanical analyses there is a direct relation between texture of the soil and its moisture equivalent.

Alway and Russell state (1) "If the mechanical analysis is to be used for the indirect determination of the moisture equivalent, it will be necessary at least in the case of some widely-differing soil types to employ several different formulas."

From the results given in this and previous publications it becomes evident that one formula will not hold in all cases, if that formula is calculated by means of least squares as was done by Briggs and McLane (2, 3) or by direct determination of the moisture equivalent for the various separates, as was tried in this laboratory.

One factor that has been overlooked by most investigators has been the influence of the shape of the soil particles on the moisture retentiveness of soils or on their moisture equivalent. Free states (7), "A very micaceous soil, for instance, has very different physical properties from one of the same mechanical analysis but composed of particles which are mainly spheres instead of disks." The results reported in this paper for the three synthetic soils show that the calculated moisture equivalent agrees very closely with the determined moisture equivalent, keeping in mind that the same sepa-

TABLE 5

Mechanical analysis and moisture equivalent of four special samples of soils

DESCRIPTION OF SAMPLE	MECHANICAL ANALYSIS							MOISTURE EQUIVALENT DETERMINED
	Fine gravel	Coarse sand	Medium sand	Fine sand	Very fine sand	Silt	Clay	
	per cent	per cent	per cent	per cent	per cent	per cent	per cent	
Residual surface soil (Climax clay adobe).....	2	2	1	6	9	33	47	30.80
Residual subsoil (Climax clay adobe).....	1	3	1	6	9	34	46	35.82
Recent alluvial surface soil (Yolo silty clay loam).....	1	3	2	8	14	47	25	25.97
Recent alluvial subsoil (Yolo silty clay loam).....	2	3	2	11	14	45	23	21.33

TABLE 6

Calculated moisture equivalents of seven soils

SOIL TYPE	MOISTURE EQUIVALENT CALCULATED
Coarse sand.....	6.38
Sandy loam.....	14.00
Fine sandy loam.....	15.04
Loam.....	20.85
Silt loam.....	25.91
Clay loam.....	26.11
Clay.....	34.82

rates were used for the derivation of the formula as were used in making the synthetic soils. When one, however, applies the results obtained to field soils varying widely in age and origin, the results are far from being in agreement.

It was thought at first by the writer that it would be possible to have one formula to be used for residual soils, another for "wind-laid," another for recent alluvial, etc.; which might take care of the shape of the soil particles. When one, however, sees how the surface soil of residual origin as given in table 5 has the same mechanical analysis as the subsoil of the same origin

and yet a considerably lower moisture equivalent, while on the other hand, a recent alluvial surface soil has the same mechanical analysis as its subsoil yet a considerably higher moisture equivalent, it is evident that any suggested formulas for calculating a constant such as the moisture equivalent from the mechanical analysis of soils are far from accurate.

The mechanical analysis just considers the amounts of the various-sized particles in a given soil, while the moisture equivalent as determined by means of the centrifuge gives a soil constant which is influenced not only by the size and amount of the different particles present in a soil, but also by the shape of the soil particles, amount of organic matter present, amount of soil colloids present, chemical composition of the soil, etc.

From the data given it is felt that while the moisture equivalent calculated from the mechanical analysis according to the formulas suggested gives approximate results, nevertheless they are far from accurate for scientific work, and it will be necessary to make an actual moisture-equivalent determination for satisfactory results.

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