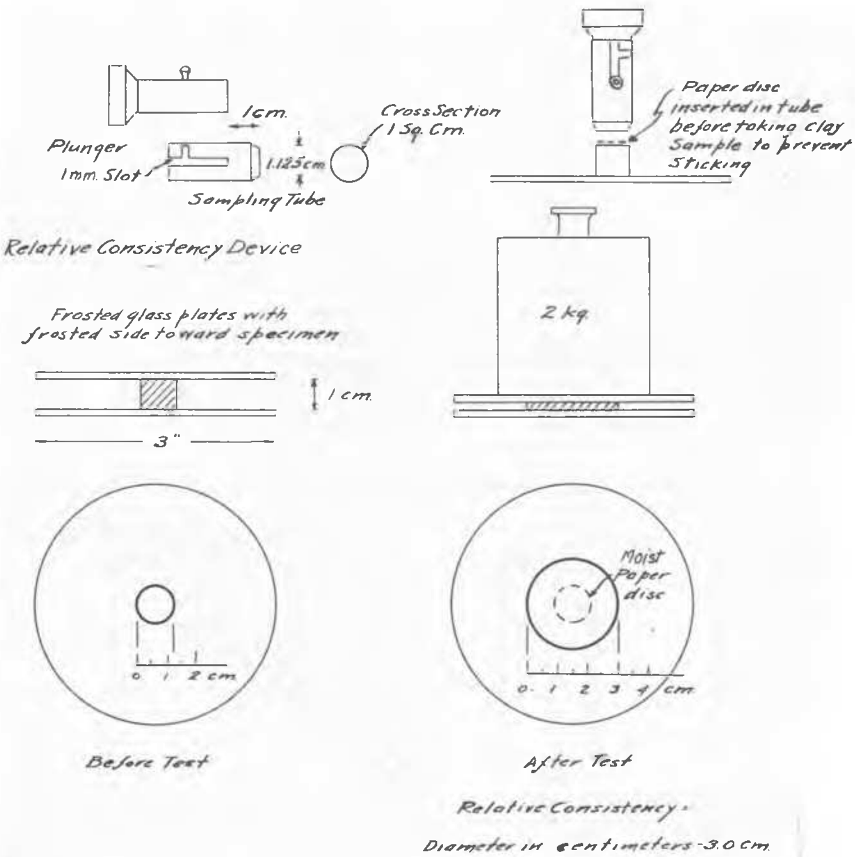
A-13 A NEW METHOD FOR DETERMINING THE RELATIVE CONSISTENCY OF SOILS

Donald M. Burmister, Department of Civil Engineering, Columbia University, New York City

A simplified squeeze test is used for determining the relative consistency of plastic soils, which, with the usual routine tests, makes possible a more complete classification of soils as to their physical characteristics. It may be used as a control and check test on the physical properties of soils for both laboratory and field use. A most important use is that of giving more immediate information during boring operations on the essential properties of the soil, which can be correlated more specifically later with the laboratory tests. Probably most important of all, the test will yield a measure of the true consistency of the soil immediately upon its removal from the ground and therefore it will be possible to obtain a measure of the swelling or other changes that always take place in the undistributed sample before being tested in the laboratory.



Method of Test
Fig. 1

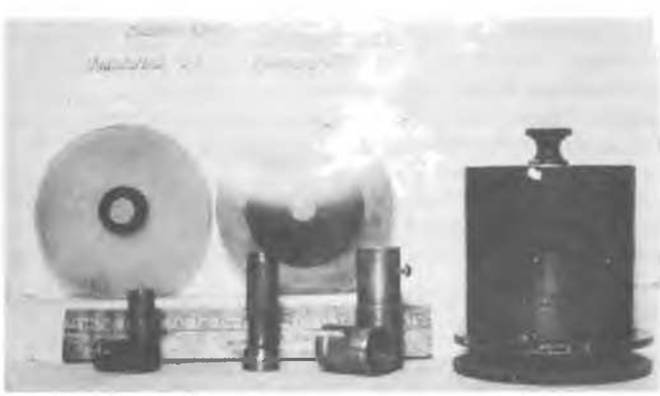


Fig. 5
The Relative Consistency Test Illustrates the Degree of Structure Possessed by the Precipitate of Hudson River Silt from the Hydrometer Test

The consistency of the soil is one of its most important physical properties and is of great engineering significance. The shear strength of plastic clays, which do not appreciably increase in strength under rapid loading, is the best measure of consistency. The relative consistency test is of the nature of a squeeze test (Shearing Resistance of Soils. Dr. Jurgenson, Boston Soc. of Civil Engineers, July, 1934, Vol. XXII, No. 3) or a cube test (Determination of Consistency of Soils by Means of Penetration Tests. Professor Terzaghi. Public Roads. Vol. 7, No. 10, 1921, page 210) for shear strength, and is made by squeezing a specimen of the clay, having a cross sectional area of one sq. cm. (Dia. 1.12 cm.) and a height of one cm. between two frosted glass plates under an applied load of two kilograms. The load is allowed to come to rest in about 5 seconds. The device for cutting the specimen and the method of making the test are illustrated in Fig. 1 and 5. The diameter of the squeezed soil pat in centimeters is taken as the relative consistency.

A comparison of the liquid and plastic limits with the corresponding values of the relative consistency bring out a number of important facts. The significance of these routine soil tests has been discussed by Professors Terzaghi (Simplified Soil Tests for Subgrades and Their Physical Significance. Public Roads, Vol. 7, Oct., 1926, page 153) and Casagrande (Research on the Atterberg Limits of Soils. Public Roads, Vol. 13, Oct., 1932, page 121).

The results in Table I show that the relative consistency of plastic soils at these two limits is practically constant, although the individual moisture contents vary widely. In general for plastic soils the relative consistency at the liquid limit is between 3.2 and 3.4 and at the plastic limit between 1.2 and 1.4. The non-plastic nature of the silts is revealed at once by a value of about 1.6, while the intermediate character of the peat is indicated by a value of about 2.4.

TABLE I

Comparison of the Liquid and Plastic Limits of Soils
With the Corresponding Values of the Relative Consistency

Sample		Liquid Limit	R.C. cm.	Plastic Limit	R.C. cm.
50	Hudson River Silt	56.5	3.2	28.0	1.2 (more clay)
	" " "	46.2	2.8	35.3	1.9 (more silt)
51	Yellowish silt	41.3	1.9	none	
52	Loess (clayey)	32.2	3.0	25.6	1.7
60	Dark gray clay	46.3	3.4	22.2	1.6
62	Very light gray clay	44.8	3.4	24.3	1.2
232	Gray clay	83.5	3.0	48.0	1.2
234	" "	103.5	3.3	44.7	1.3
292	" "	111.8	3.6	50.9	1.4
294	" "	110.0	3.1	50.3	1.4
342	" "	100.0	3.1	29.0	1.2
343	" "	91.6	3.0	39.6	1.3
344	" "	127.8	3.2	68.5	1.7
528	" "	78.9	3.4	37.9	1.2
345	Silt	24.9	1.6	none	
346	Silty clay	34.5	1.7	28.5	1.5
347	" "	44.6	2.1	33.5	1.3
295	Peat	441.0	2.4	none	
393	"	702.0	2.4	none	
391	Clay & Organic Matter	112.8	3.2	68.2	1.4
231	" " "	213.0	3.1	108.0	2.0
291	" " "	147.5	2.6	93.5	1.7

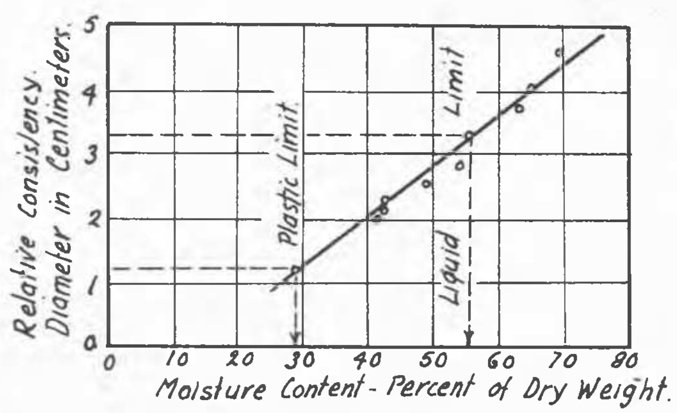


Fig. 2
The Variation of Consistency with Moisture
Content for Hudson River Silt

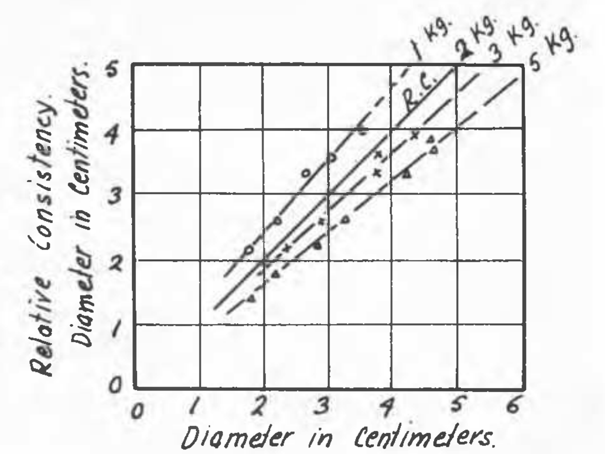


Fig. 4
The Relation Between Relative Consistency
And the Magnitude of the Applied Load

The variation of consistency with moisture content is an important consideration. The fact that a linear relationship exists for this test is significant, as illustrated for the Hudson River Silt in Fig. 2, because, if the liquid and plastic limits are known for a given soil, then the consistency line may be defined for remolded samples by locating these two points.

It is also essential to know what effects variations in certain conditions of the test may produce. The curves in Fig. 3 and 4 show that the results follow a simple linear law where a different diameter of specimen is used and where different loads are applied. This is of practical value because for stiff clays the five kilogram load may be used in order to obtain measureable values of the relative consistency.

One of the most important soil properties, for which to obtain a measure, is structure. Professor Casagrande (Structure of Clay in Foundation Engineering, Boston Soc. of Civil Engineers, Col. 19, 1932, page 180) has discussed the significance and importance of structure of clays and the effect of disturbance. The relative consistency test affords a simple and satisfactory measure of structure by observing the increase in diameter (which represents a decrease in shear strength) of remolded clay over that of the undisturbed material. To illustrate this a number of undisturbed samples of clays and silts were tested and the results are given in Table II.

TABLE II

The Comparison of the Relative Consistency of Undisturbed And Remolded Clays as a Measure of Structure

Sample		Moisture Content %	Relative Consistency Undisturbed	Remolded
112	Gray Clay	77.7	2.4	3.2
171	" "	131.0	2.5	2.9
174	" "	112.5	2.9	3.4
202	" "	109.0	3.6	4.4
207	" "	112.8	2.9	3.5
232	" "	118.5	2.9	3.7
234	" "	113.8	2.6	3.8
294	" "	107.0	2.4	3.1
343	" "	106.8	2.6	3.4
528a	" "	71.0	1.8	2.5
528b	" "	51.0	1.1	1.6 (load 2 Kg.)
			1.6	2.3 (load 5 Kg.)
116	Red Clay	36.7	1.2	1.4
347	Silty Clay	44.3	1.8	
467	Silt	23.3	1.8	1.8
394	"	22.6	1.8	1.9
295	Peat	222.0	1.8	2.3

Tests on Soil Samples After the Hydrometer Analysis:

Sample	Moisture Content	Relative Consistency Undisturbed	Remolded	
Hudson River Silt (more clayey)	65.5	1.4	4.7	With sodium silicate
		1.7	4.5	Without sodium
(more silty) •	80.0	2.0	5.0	With sodium
528	103.4	2.0	5.5	With sodium

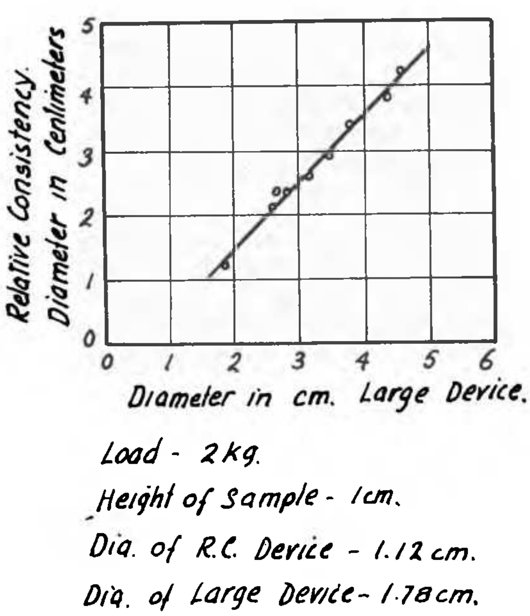


Fig. 3
The Relation between Relative Consistency and the Diameter of Specimen for constant height of Specimen and Constant Load

The results show that structure is of far greater importance at the higher moisture content that is, low consolidation pressure, and hence the effect of disturbance is greater and more serious. Such a test illustrates, as probably no other simple test the significance of structure and the marked effect of disturbance from any cause. This is illustrated in Fig. 5 by tests on the precipitate from the hydrometer test for a Hudson River Silt, which shows that structure is even developed in a very short time by all fine materials settling in quiet water.

These facts are illustrated in another way in Fig. 6. The consistency line is defined for two clays by the liquid and plastic limits. The relative consistencies of the undisturbed and remolded samples are then plotted in relation to the consistency line. A horizontal line drawn through the point for the undisturbed test to an intersection with the consistency line now defines approximately the moisture content of a remolded clay, which would have the same consistency and hence shear strength as the undisturbed sample possessing considerable structure. A badly disturbed clay would have to be consolidated approximately to the lower moisture content before it would again develop shear strength equal to that of the undisturbed state.

More exact and specific information on the engineering properties of clays must be obtained from the standard consolidation and shear tests. But it is of great interest and of practical value to partially correlate the relative consistency test with:

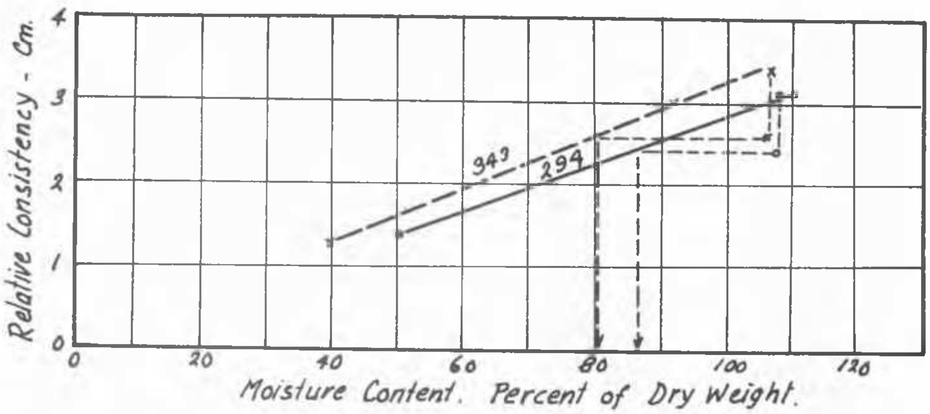


Fig. 6
Consistency and Structure of Clays
And the Effect of Remolding

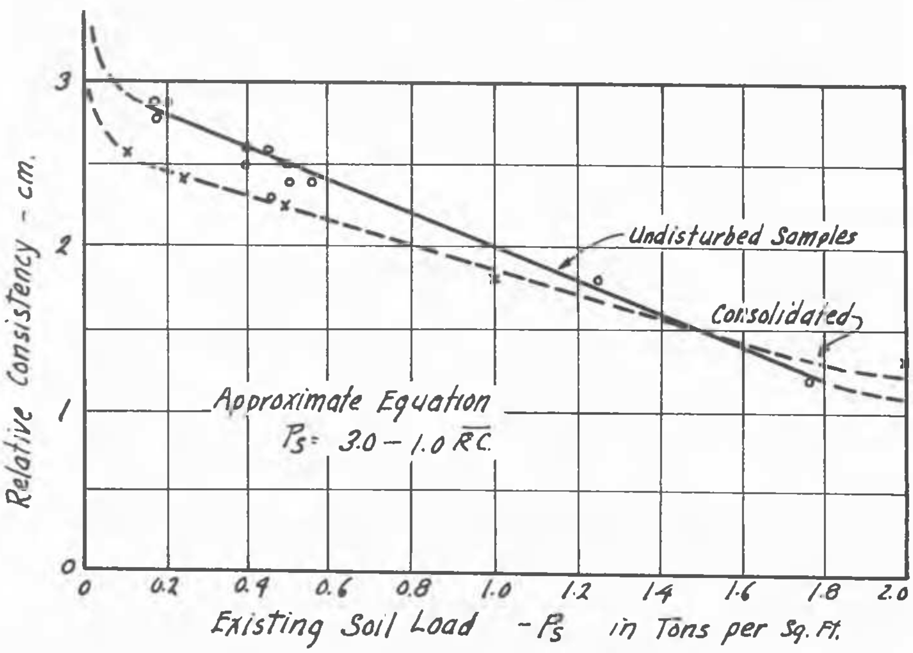


Fig. 7
The Relation between the Existing Soil Load
And the Relative Consistency.

1. The pre-consolidation load as defined by Professor Casagrande (New Facts in Soil Mechanics from the Research Laboratory. Eng. News-Record, Sept. 5, 1935, page 320) that is, the existing soil load.

2. The shear strength of the soil, which is a function of this existing soil load.

In order to evaluate these important factors, consolidation tests and shear tests were made upon undisturbed and remolded samples of soils. The results of these tests are plotted in Fig. 7 and 8 with the relative consistency as the argument.

The curve for the undisturbed samples in Fig. 7 show that there is a significant linear relationship between the relative consistency and the existing soil load over the range tested and for the materials tested. The curve for the remolded samples, which were consolidated from the same initial moisture content to the pressures indicated shows that a disturbed clay would not have to be consolidated quite to the lower moisture content indicated in Fig. 6. Furthermore these two curves bring out a fact of utmost importance. The undisturbed samples had actually swelled to a considerable degree due to relief of ground pressure and to the presence of gas, and hence, there was some decrease in shear strength which could not be evaluated while the sample from consolidation test did not have time to change appreciably. This leads to a most important conclusion, namely, a truer value of the consistency of the undisturbed soil may be obtained by means of Relative Consistency test immediately after the sample has been removed from the ground and before it has had time to swell appreciably. Any change in consistency would then be indicated at the time of test. It may be concluded that lightly consolidated clays will show the effect of swelling, disturbance and remolding to a greater degree and structure will be of far greater importance. These factors show the importance of obtaining some measure by a simple test of the consistency of all clays immediately on the site during boring operations, and especially for all those samples which are used for general classification purposes only and are not subjected to the consolidation or shear tests because of lack of time or expense. It is believed that the relative consistency is sufficiently accurate and sensitive to afford a satisfactory test for such purposes. The test values are significant to about 0.2 cm.

The curve in Fig. 8 shows that a significant relationship exists between the shear strength and the corresponding relative consistency. The slope of the curve indicates that shear strength and hence consistency varies as about the 5th power of the final diameter of the soil pat after squeezing. This final diameter corresponds to a certain thickness for the particular clay, at which, after a certain amount of plastic flow, equilibrium under constant load is possible. This curve can, at least, be used for purposes of more immediate classification of clays right on the job. For the very stiff clays the five kilogram load will yield measurable values.

The simplicity of the test and the valuable information which it affords, makes it suitable for both laboratory and field use. It is believed that the test curves show the relative consistency

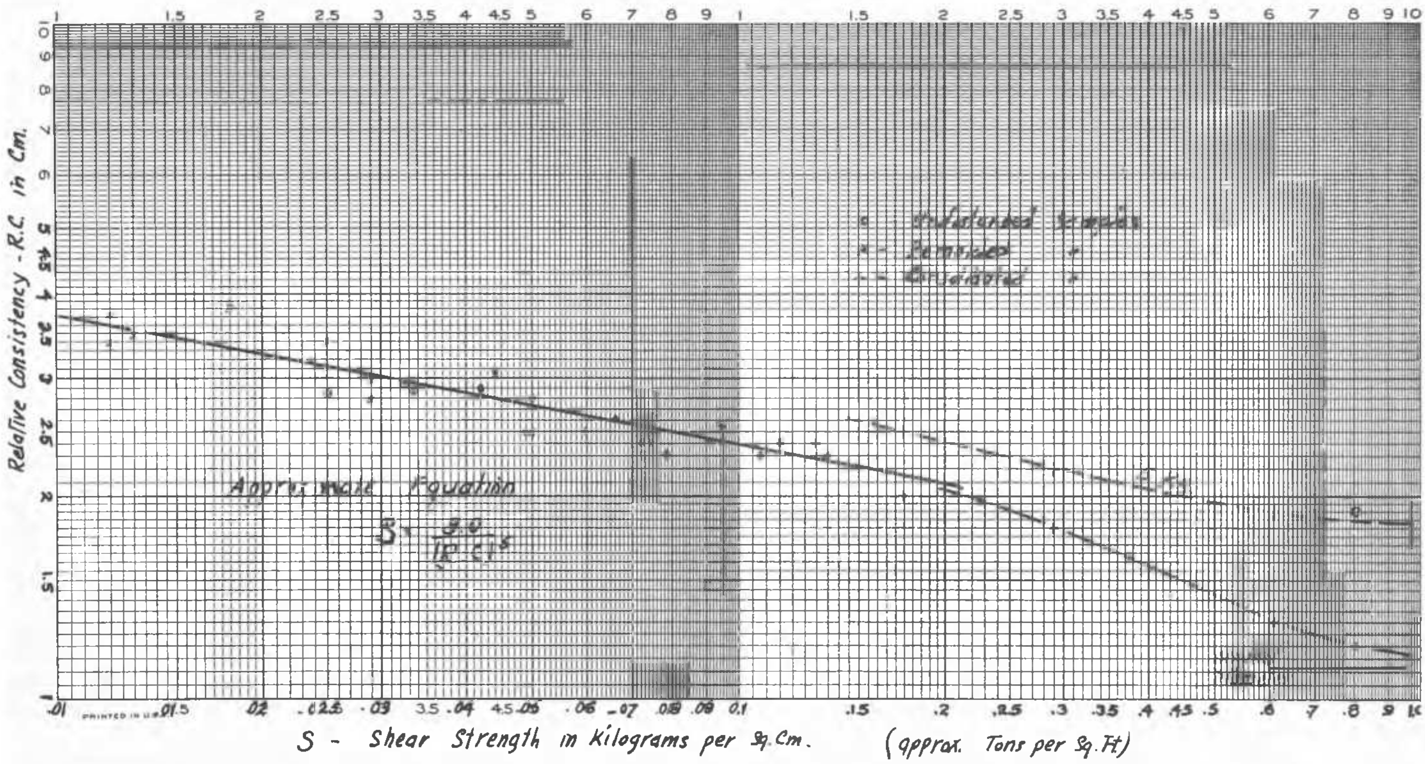


FIG. 8 Approximate Relation between Relative Consistency and Shear Strength of Clays.

test to be sufficiently reliable and sensitive so that the results may have general application. A slightly larger apparatus with an integral loading device is being perfected.

In conclusion the following advantages may be listed:

1. The test affords information for a more complete classification of soils.
2. It yields more immediate information on the character of the soil and its essential physical properties right on the job.
3. It affords a measure of the true consistency of undisturbed samples and of the change that occurs up to the time when tested.

ACKNOWLEDGEMENTS

The writer is greatly indebted to Daniel E. Moran and Carlton S. Proctor, Consulting Engineers, New York City, for the opportunity of making this investigation, and to George W. Glick of Moran and Proctor for valuable suggestions.