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Further Correlation of Consistency Limits of Iowa Loess with Clay Content

By J. B. SHEELER and D. T. DAVIDSON

Mixing and manipulation of soil and water cause consistency changes at various moisture contents. These changes reveal important characteristics of the soil even though the condition of the soil-water system is not the same as that found in nature. The characteristics of consistency have been correlated with engineering behavior of soil. Together with mechanical analysis, these relationships provide a basis for the identification and engineering classification of a soil and aid in judging its suitability for engineering structures.

Soil-water mixtures exist in the various states of matter from a true liquid to a solid, depending upon the amount of water in relation to the amount of soil. In 1911 the Swedish scientist, A. Atterberg, suggested two simple tests for determining the moisture content at the upper and lower limits of the moisture range in which a soil has the properties of a plastic solid. These tests for liquid limit and plastic limit are in widespread use today. The numerical difference between these two limits is called the plasticity index of the soil. This property has become essential to the judgment of the character and quality of an engineering soil. The plasticity index is a measure of the cohesive properties of a soil and indicates the degree of surface activity and bonding properties of the clay minerals present.

The Atterberg limits are three of the many routine engineering tests being used to study the engineering properties of Iowa loess. Previous work (1, 2, 3, and 4) has shown a linear correlation between the Atterberg limits and clay content of soils from southwestern Iowa. This paper further elaborates on these correlations by including loess samples from the entire state. The state of Iowa has been divided arbitrarily into five different areas in order to facilitate the study of the properties of the loess. These areas are indicated on the map of Iowa in Figure 1; in addition, individual sampling sites are also shown.

The 223 samples of Wisconsin age loess used in this correlation study were taken at various depths from the sites shown in Figure 1. A-horizon samples have been excluded as well as samples containing more than 5 percent sand. A-horizon samples contained considerable organic matter and the samples containing more than 5 percent sand were from the basal portion of the loess sections. These samples tended to have erratic liquid and plastic limit values. Results from such samples were therefore considered unreliable and were not plotted.

The correlations were made by plotting the Atterberg limits against the clay contents* as shown in Figures 2, 3, and 4. The lines in Figures 2 and 4 were placed by eye, whereas the line in Figure 3 was computed from the equations for the lines in Figures 2 and 4.

Linear correlations between the variables have been shown to hold for southwestern Iowa and were expected for the other areas. Subsequent plotting proved this true and equations for the best straight line through the points from each area were determined by the method of least squares. Since the plasticity index is by definition the liquid limit minus the plastic limit, and the liquid limit and the plasticity index plots show the best relationships to clay content, the equations for the plastic limit plots were derived from those found for the liquid limit and the plasticity index.

The results of the above computations are shown in Table 1. The equation of a straight line is $y = m x + b$, where "m" is the slope

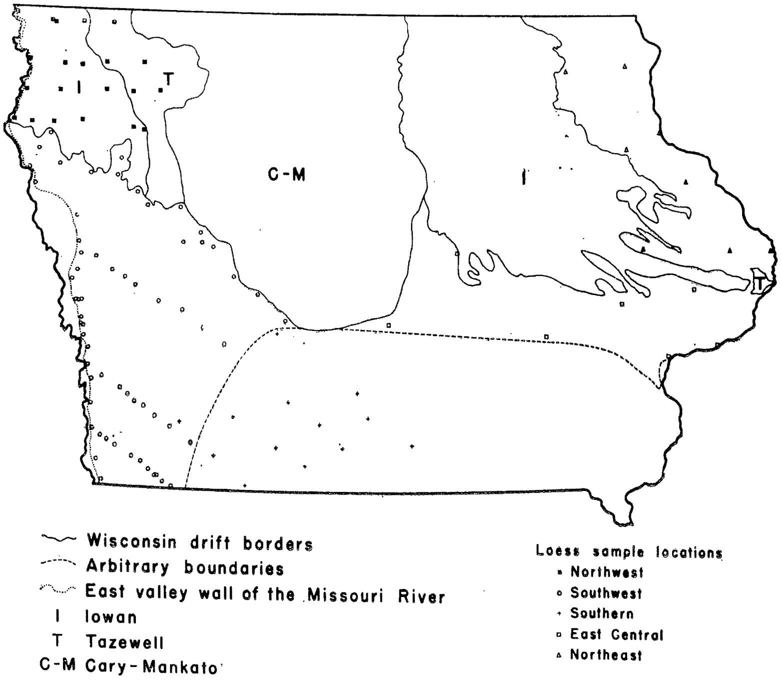

Figure 1. Loess sample locations in Iowa.

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*The term "clay content" refers to all material with an equivalent spherical diameter of 5 microns or less, which is the standard engineering definition of clay.

Table 1

Comparison of Constants in the Atterberg Limit Equations

	Atterberg Limits = m x + b					
	Liquid Limit		Plastic Limit		Plasticity Index	
Sample Area	Slope m	Constant b	Slope m	Constant b	Slope m	Constant b
Southwest	0.79	16.9	—0.22	29.1	1.01	—12.2
East-central	0.95	11.3	—0.09	20.2	1.04	— 8.9
Northeast	0.93	10.0	—0.01	22.1	0.94	—12.1
Northwest	0.98	6.3	0.22	18.7	0.76	—12.4
Southern	0.99	5.2	0.25	13.2	0.74	— 8.0
Overall*	0.91	10.9	—0.04	24.7	0.95	—13.8

*Equations derived from lines drawn by eye through the entire mass of points.

of the line and "b" is the intercept. Here "y" represents the Atterberg limit and "x" represents the clay content.

The liquid limit equations are all essentially parallel with the exception of the one for southwest Iowa loess. This exception is believed to be due to a much higher carbonate content in the loess of this area, especially near the Missouri River where the clay content is low. Higher than normal liquid limits result which tends to reduce the slope of the line. However this is offset by the plastic

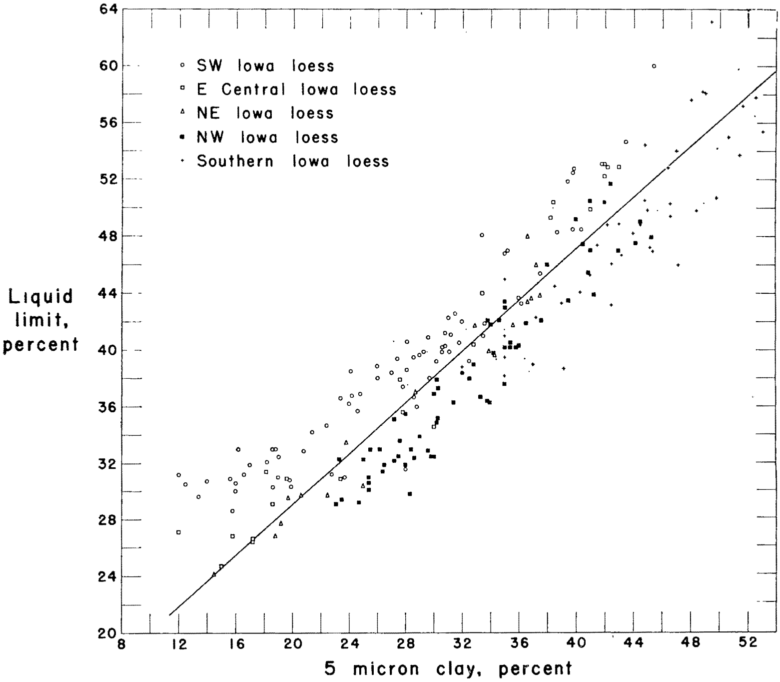

Figure 2. Liquid limits plotted as a function of 5 micron clay content.

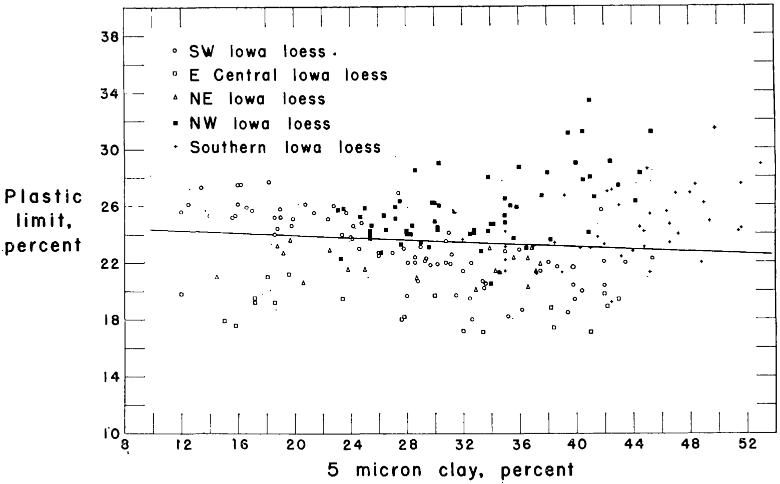

Figure 3. Plastic limits plotted as a function of 5 micron clay content.

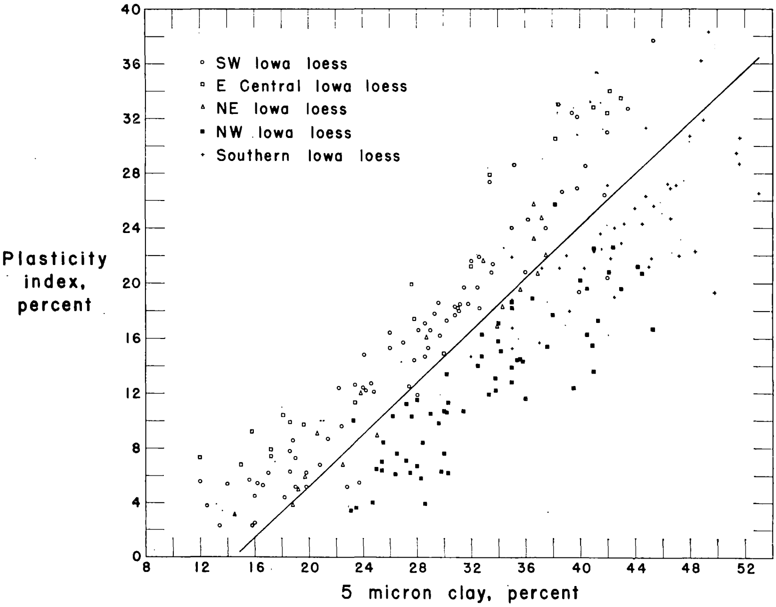

Figure 4. Plasticity indices plotted as a function of 5 micron clay content.

limit equation and the resulting plasticity index equation exhibits a slope that is consistent with those for east-central and northeast Iowa.

The slopes of the plastic limit lines for northwest and southern Iowa loess are drastically different from those found in the other three areas. The discrepancy was found to be due to poor operator technique. All Atterberg limits for these two areas were run by the same operator. The liquid limit results can be duplicated easily by different operators since it is mainly a mechanical test, but the plastic limit requires human judgment and is therefore more subject to error.

Table 2 shows a comparison of plastic limits obtained by three different operators. The results of operator C agree quite well with those of operator A on the loess from southwest, east-central and northeast Iowa. Operator B obtained results that appear to be much too high, especially in the higher clay content loess, for northwest and southern Iowa. It has been concluded from this comparison that the plastic limit results of operator B are unreliable, probably due to insufficient training in the performance of this test.

A decrease in the plastic limit values that becomes larger with increasing clay content is indicated by the above comparison for the northwest and southern areas. Such a decrease would result in a flatter slope than is shown in Table 1 and would bring the plastic limit and plasticity index results closer in agreement with the results from the other areas.

Table 2
Comparison of Plastic Limit Results Obtained by Different Operators

Area	Sample No.	5-Micron Clay Content, percent	P. L. by Operators A and B, percent	P. L. by Operator C, percent	Decrease A to C or B to C	Increase A to C or B to C
Southwest	55-1	13.4	A27.3	C23.8	3.5	
	20-2-VI	19.8	A24.6	C24.4	0.2	
	25-1	27.8	A23.0	C22.9	0.1	
	44½-1	42.0	A20.4	C21.1		0.7
East-central	122-10	17.2	A19.5	C19.1	0.4	
	110-6	23.4	A19.5	C19.6		0.1
	110-2	41.0	A17.1	C19.3		2.2
Northeast	227-5	14.5	A21.0	C20.5	0.5	
	222-4	28.7	A20.9	C19.5	1.4	
	202-2	34.3	A21.4	C19.7	1.7	
Northwest	300-8	25.4	B23.7	C23.3	0.4	
	300-4	31.4	B25.6	C23.4	2.2	
	308-3	37.6	B26.7	C22.7	4.0	
	305-2	45.3	B31.2	C24.3	6.9	
Southern	513-4	39.0	B21.3	C20.2	1.1	
	508-2	46.6	B24.7	C18.9	5.8	
	509-2	49.0	B26.2	C20.0	6.2	
	512-2	51.6	B27.2	C24.8	2.4	

In conclusion, the straight line relationships of the Atterberg limits and the clay contents of the loess in the five areas of Iowa, together with the similarity of the slopes of these lines, offer further evidence of the uniformity of the clay minerology of the loess. The correlations also indicate that differences in the Atterberg limits of the loess in Iowa are primarily due to the amount of clay present.

ACKNOWLEDGMENT

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References

1. Davidson, D. T., and Handy, R. L. 1953. Studies of the clay fraction of southwestern Iowa loess. Clays and Clay Minerals. Natl. Ac. Sc. Natl. Res. Council, Pbl. 327.
2. ——— and Sheeler, J. B. 1952. Cation exchange capacity of loess and its relation to engineering properties. ASTM, Spc. Tech. Publ. 142, p. 1-19.
3. ——— and ———. 1952. Clay fraction in engineering soils: III. Influence of amount on properties. Hwy. Res. Bd. Proc. 31: 558-563.
4. Handy, R. L. 1956. Stabilization of Iowa loess with portland cement. Unpublished Ph.D. thesis, Iowa State College Library, Ames, Iowa.

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