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DETERMINATION OF LIQUID LIMIT OF SOILS BY DYE ADSORPTION

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A study of the adsorption of basic dyes on clay minerals indicates that the orientation of the adsorbed dye molecule depends both on the type of the clay mineral and on the adsorbate itself (6–9). For a soil containing a particular clay mineral in various proportions, the amount of adsorption varies linearly with the clay mineral content. Since the value of liquid limit varies linearly with the clay fraction in a soil, a plot of the quantity of dye adsorbed on a soil against the liquid limit should exhibit linearity.

Dinesh Mohan (2), and recently Davidson and Scheeler (1) and Hauth and Davidson (5), have found a correlation between the liquid limit and clay content of a soil. Gaskin and Samson (4) and Fairbairn and Robertson (3) attempted to correlate the liquid limit and plastic limit values with the amount of methylene blue adsorbed on a few soils. The correlation coefficients varied from 0.48 to 0.89.

In this paper an attempt is made to assess the application of the dye adsorption method for the determination of the liquid limits of three sets of Indian soils: alluvial; black cotton; and samples of soils from a test site with an area of 100 × 200 feet. Two types of basic dyes, malachite green and methylene blue, were used in the investigation as adsorbates.

EXPERIMENTAL

Soils passing through B. S. test sieve No. 36 were used both for liquid limit and dye adsorption determinations. The liquid limit values were obtained according to B.S. Specification No. 1377-1948, using an A.S.T.M.-type grooving tool. For estimating the quantity of dye adsorbed, one gram of the soil was treated with a 0.2 per cent solution of malachite green or methylene blue until there was a slight excess of unadsorbed dye. The contents were stirred continuously for about 15 minutes and allowed to stand for 1 hour. The unadsorbed dye was removed by filtration and washing, and was estimated by a microptic colorimeter.

The 35 samples selected for this investigation consisted of: alluvial soils (10 samples); black cotton soils (10 samples); and soils from a test site (including 5 samples at different depths) (15 samples).

DISCUSSION

Of the two dyes studied, methylene blue is adsorbed to a greater extent than malachite green. Figure 1 presents the variation of liquid limit values with dye adsorption for a few alluvial soils. A linear relationship is obtained for both malachite green and methylene blue as adsorbates. Two alluvial soils having malachite green adsorption values of 0.0346 g./g. and 0.0346 g./g., and methylene blue adsorption values of 0.0485 g./g. and 0.0478 g./g., with liquid limit values of 47.60 and 40.00, respectively, were found to be aberrant and are not shown in figure 1. Although high-adsorption values of these soils indicate that they do not contain the same type of clay mineral as the other alluvial soils studied, they find a better fit on the curve of black cotton soils. The best line drawn by eye, eliminating the two aberrant values, shows that for malachite green adsorbate the equation can be expressed as

$$y = 3730x - 37.75$$

and for methylene blue, as

$$y = 1800x - 8.00$$

where x and y represent, respectively, amount of dye adsorbed (g./g.) and liquid limit (per cent). The correlation coefficient for the plot of malachite green adsorption *vs.* liquid limit is found to be 0.989, while for methylene blue adsorption *vs.* liquid limit it is 0.977. The correlation coefficients fall to 0.644 and 0.717 for malachite green and methylene blue, respectively, if the two aberrant values are also taken into account.

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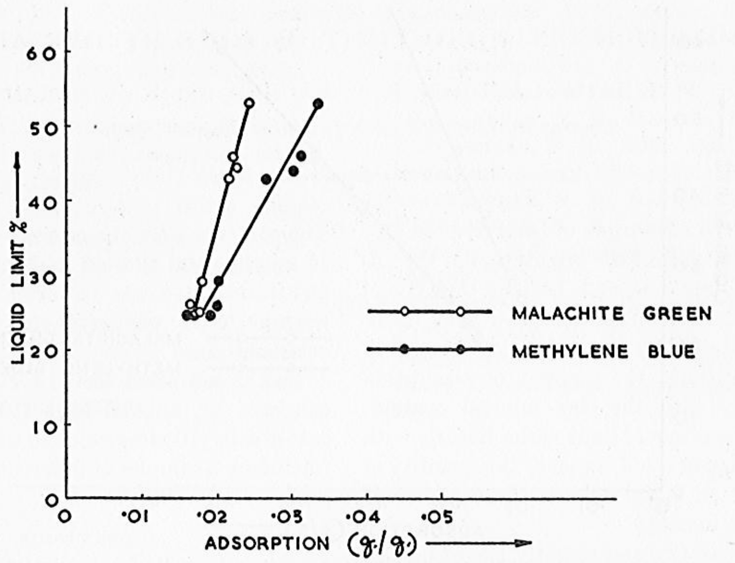

FIG. 1. Variation of liquid limit with dye adsorption for alluvial soils

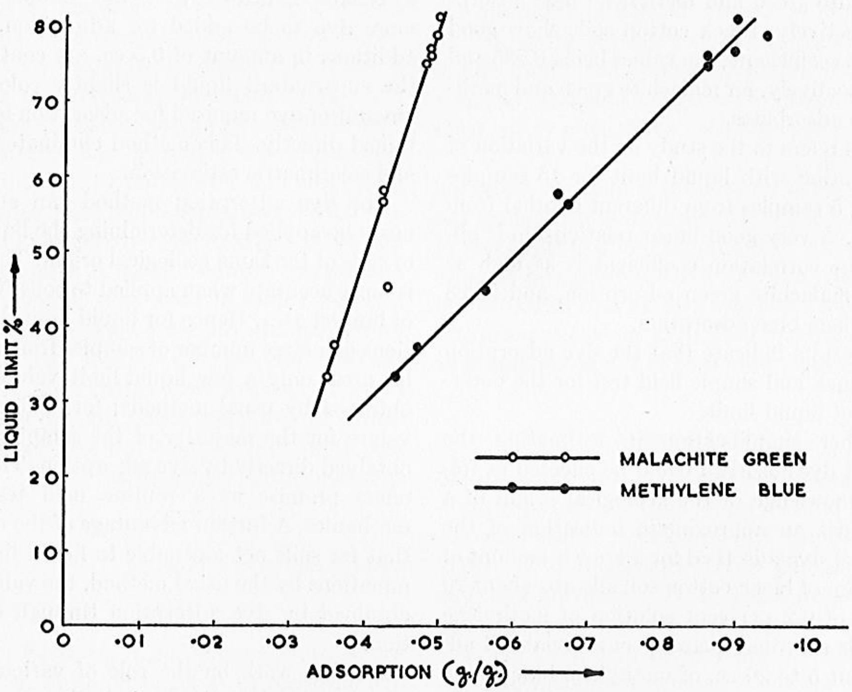

FIG. 2. Variation of liquid limit with dye adsorption for black cotton soils

Since the cation-exchange capacity values of black cotton soils are, in general, higher than those of alluvial soils, black cotton soils adsorb dyes to a greater extent than alluvial soils. A linear relationship exists between dye adsorption and liquid limit (fig. 2). The relationship follows the equation

$$y = 3077x - 74.5$$

and

$$y = 965.7x - 9.1$$

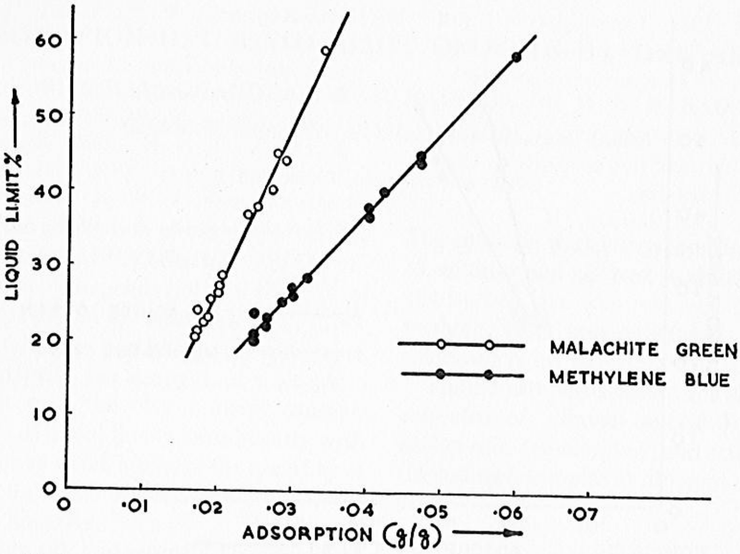

FIG. 3. Variation of liquid limit with dye adsorption for soils from a selected site

for malachite green and methylene blue adsorption, respectively. Black cotton soils show good correlation coefficients, the values being 0.935 and 0.994, respectively, for malachite green and methylene blue adsorbates.

Figure 3 refers to the study on the variation of dye adsorption with liquid limit for 15 samples (including 5 samples from different depths) from a test site. A very good linear relationship is obtained. The correlation coefficient is as high as 0.992 for malachite green adsorption, and 0.998 for methylene blue adsorption.

These results indicate that the dye adsorption offers a quick and simple field test for the determination of liquid limit.

A further simplification in estimating the amount of dye adsorbed could be effected as follows. A knowledge of the geological origin of a soil provides an approximate indication of the quantity of dye adsorbed for a known amount of soil. A gram of black cotton soil adsorbs about 20 to 50 cc. of 0.2 per cent solution of methylene blue, while an equal quantity of alluvial soil adsorbs about 5 to 20 cc. of methylene blue of the same concentration. The quantity of dye adsorbed on either of the above soils could be arrived at as follows. For example, in the case of black cotton soils, 20, 30, 40, and 50 cc. of 0.2 per cent methylene blue is added separately into four beakers, each containing a gram of soil. The contents are first shaken for about 15 minutes and then left for 1 hour. A clear supernatant liquid in a beaker indicates that the sample requires more dye to be added for adsorption. Further additions in amount of 0.5 cc. are continued till the supernatant liquid is slightly colored. The amount of dye required for adsorption is thus obtained directly. This method eliminates washing and colorimetric estimation.

The dye adsorption method can advantageously be applied for determining the liquid limits of soils of the same geological origin. The method is more accurate when applied to soils from a site of limited area. Hence for liquid limit determinations of a large number of samples from a particular area, only a few liquid limit values need be obtained by usual methods; for calibration, the values for the majority of the samples could be obtained directly by dye adsorption. The method offers promise as a routine field test in soil mechanics. A further advantage of the method is, that for soils not amenable to liquid limit determinations by the usual method, the values can be obtained by dye adsorption through extrapolation.

Further work on the role of various cations, clay fractions, crystal imperfections, and organic matter in the determination of liquid limit by dye adsorption is in progress.

REFERENCES

(1) DAVIDSON, D. T., AND SCHEELER, J. B. 1961 Cation-exchange capacity of loess and its relation to engineering properties. *Iowa State Univ. Eng. Expt. Sta. Bull.* 192: 96–118.

(2) Dinesh Mohan 1957 Consolidation and strength characteristics of Indian black cotton soils. *Proc. 4th Intern. Conf. Soil Mech., London*, 1: 74–76.

(3) Fairbairn, P. E., and Robertson, R. H. S. 1957 Liquid limit and dye adsorption. *Clay Mineral Bull.* 3: 129–136.

(4) Gaskin, A. G., and Samson, H. R. 1951 Ceramic and refractory clays of South Australia. *Bull. Geol. Surv. S. Australia* 28: 1–91.

(5) Hauth, W. E., and Davidson, D. T. 1961 Clay fractions in engineering soils; identification by D.T.A. *Iowa State Univ. Eng. Expt. Sta. Bull.* 192: 167–183.

(6) Ramachandran, V. S., Garg, S. P., and Kacker, K. P. 1961 Mechanism of thermal decomposition of organo-montmorillonites. *Chem. and Ind.* 23: 790–792.

(7) Ramachandran, V. S., Kacker, K. P., and Patwardhan, N. K. 1961 Basic dyestuffs in clay mineralogy. *Nature* 191: 696.

(8) Ramachandran, V. S., Kacker, K. P., and Patwardhan, N. K. 1962 Adsorption of dyes by clay minerals. *Am. Mineral* 47: 165–169.

(9) Ramachandran, V. S., Kacker, K. P., and Patwardhan, N. K. 1962 Differential thermal studies of dye clay complexes. *8th Intern. Ceram. Congr., Copenhagen*, pp. 293–299.

Indian – French

1+1+1+1+1 1+1+1+1

5+4= 9.

self 4=