

Fundamental Studies on Soil-Profiles in the Aspect of Road Stabilization. II

Clay Mineralogy by Electrochemical Titrations of the Clay Fractions at Different Depths

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With 5 Figures

Inhaltsübersicht

Potentiometrische und konduktometrische Messungen an sauren Tonen der Provenienz von Tehra zeigen u. a. mit zunehmender geologischer Tiefe einen mineralogischen Wechsel.

Introduction

The stability of the subgrade in road construction has been considered to be an important factor for the stabilization of roads carrying heavy vehicular traffic. In our previous communication we have discussed how the information on the soil-profile is of great value for the designing and construction of the stable roads. It was elicited from the P. W. D. department that the constructed roads near the village Tehra, 14 miles away from Agra, on the Agra Gwalior Road, was a problem to the engineers, because due to the heavy load of vehicular traffic they experienced frequent failure of construction, more particularly during the rainy season. In our previous communication we have discussed the results of mechanical analysis from which it was evidenced that the percentage of clay was considerably greater at depths from 13''—36'' than from 0—12''. The percentage of sand at these depths were comparatively less than the short depth profiles. It was suggested that the increase of moisture content and lack of percolation during the rainy season in the clayey subgrade below 13'' depth of the profile may be responsible for a serious regression due to which the roads were frequently damaged. The effect of swelling and shrinkage of the clayey subgrade may also be responsible. In this paper the results on the electrometric titration of the clay fractions obtained from the different profiles have been presented and discussed. An attempt has been made to throw some light on the similarities and dissimilarities of these fractions which may be due to the slight changes in the character and structure of the clay minerals at the different depths of the soil profile at Tehra.

Experimental

The soil was sieved through a mesh to remove the coarser particles. 25 gms of the sieved material was treated with 0.5 N—HCl to remove free carbonates. The mixture was washed by repeated decantations with water and thorough shaking in a mechanical shaker. The washed sediment was treated with 6% H₂O₂ to oxidise the organic matter and allowed to settle for 24 hours. The residue is washed thoroughly till free from chloride ions.

The residue was then dispersed in 1000 c. c. distilled water in the presence of 10 c. c. N—NaOH and was shaken for 12 hours in an electrically driven shaker. The suspension was transferred to a jar and kept overnight. This was Na-clay which was pipetted out after 24 hours and evaporated to dryness. The dry residue was treated with 0.5 N—HCl and washed thoroughly till free from chloride ions. The H-clay thus obtained was dispersed in water by mechanical shaking for 8 hours and then allowed to settle for 24 hours. The supernatant fraction was collected as H-clay.

To carry out the titration the bottle titration technique was employed for potentiometric and conductometric titrations. A fixed volume (20 c. c.) of the aqueous suspension containing known amount of the H-clay, was taken in each of a set of 20—25 pyrex bottles provided with ground glass stoppers. Increasing amounts of the titrant were added to these bottles, and total volume was kept constant at 30 c. c. by adding water. They were then kept in a CO₂ free atmosphere by sealing them with wax, for about 24 hours, so that equilibrium conditions might be attained.

At the end of the period the specific conductance and pH of the contents of each bottle were measured. For conductometric measurements a Leads and Northrup drum type bridge was used together with a Muihead audio frequency oscillator as a source of A. C. And pH measurements were carried out using glass electrode against a saturated calomel reference electrode. Cambridge pH meter was used for reading the pH of the suspension directly.

The specific conductivities were plotted against the milliequivalents of NaOH added at every step. Similarly pH values were also plotted and the points of equivalence by the conductometric titrations were compared with the points of inflections in the pH curves.

Observation and Discussion

Table 1
Analysis of Clay Fractions

Depth		0—6"	7"—12"	13"—18"	19"—24"	25"—30"	31"—36"
SiO ₂	%	35.215	26.07	42.750	38.27	35.625	44.230
Al ₂ O ₃	%	16.520	15.75	25.625	22.40	25.133	20.326
Fe ₂ O ₃	%	9.040	7.90	11.885	10.02	10.492	9.874
SiO ₂ /R ₂ O ₃		2.470	1.97	2.040	2.08	1.770	2.5300
SiO ₂ /Al ₂ O ₃		3.260	2.54	2.560	2.62	2.170	3.330
SiO ₂ /Fe ₂ O ₃		10.380	8.80	9.580	10.18	9.330	11.9400

In table I, it will be seen that the variation of percentage of Al₂O₃ is appreciably high in profile from 13"—36". Comparing the variations in Al₂O₃ with the percentage of clay at different depths of the Tehra soil

Table 2
Mechanical Analysis

Depth	0''—6''	7''—13''	13''—18''	19''—24''	25''—30''	31''—36''
Clay %	9.36	4.48	18.66	22.34	25.90	20.60
Silt %	19.84	30.08	23.34	26.96	25.86	19.90
Sand %	70.08	65.44	68.00	50.70	48.24	59.48

(Table II) it may be concluded that the higher moisture conditions from 13''—36'' due to the higher percentage of clay may be responsible for the hydrolysis of the clay fractions, and hence for the slight alterations in clay minerals too. It may, therefore, be anticipated that these clay fractions obtained from the different profiles would show slight variations due to Aluminium and iron in the inflexions of the potentiometric titration and similar results may be observed in the conductometric titrations also.

In fig. 1 it will be seen that there are two sharp inflexions in the potentiometric curve for the clay titration 0—12'' profile. The same is evidenced by the points of equivalence in the conductometric titration curve. These sharp points suggest that the dissociable H-ions of the acid clay were neutralised. The ratio between the base uptake at these points is approximately 1 : 5 from the typical neutralisation curves for H-Kaolinite given by MARSHALL and KRINBILL¹); MUKERJEE, MITRA and MITRA²) the clay mineral appears to be Kaolinite.

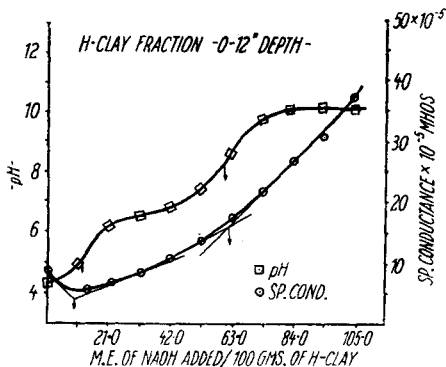


Fig. 1

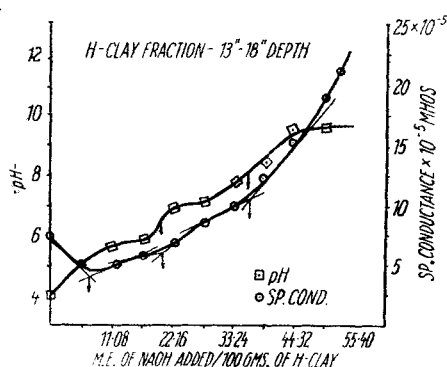


Fig. 2

¹) C. E. MARSHALL and C. A. KRINBILL, The Clays as Colloidal Electrolytes, *J. physic. Chem.* **46**, 1077 (1942).

²) J. N. MUKHERJEE, R. P. MITRA and D. K. MITRA, Electrochemical Properties of Clay Minerals and the Differentiation of Hydrogen Clays and Bentonites by Electrochemical Methods, I, *J. physic. Chem.* **47**, 543 (1943).

Potentiometric and conductometric titration curves in the profile of 13''–18'' give three inflections and three conductometric points of equivalence. The base uptake ratio at these points are 1 : 3.16 (fig. 2). Comparing the typical curves given by GRIM³) this ratio evidences the formation of H-montmorillonite (Indian bentonite) types of clay mineral at this depth of the profile. There are two points of inflection in the potentiometric titration curve for the clay fraction obtained from 19''–24'' and these are also supported by the points of equivalence in the conductometric titration curve. The base uptake ratio at these points are 1 : 6 (fig. 3). There are three inflection points in the potentiometric titration

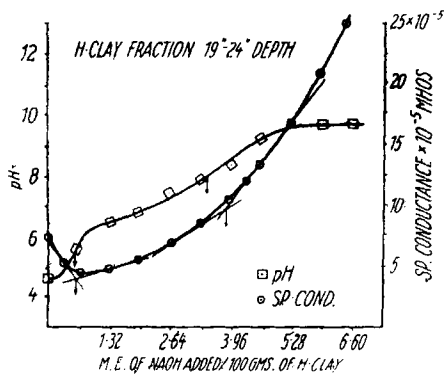


Fig. 3

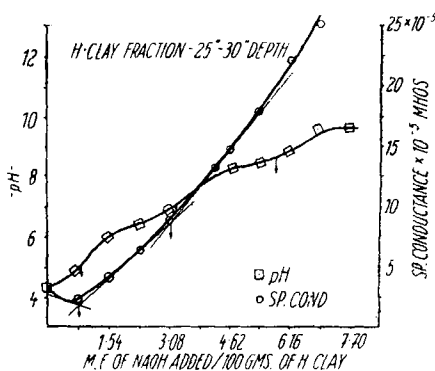


Fig. 4

curve for the clay fraction obtained from the profile 25''–30'' and the base uptake ratio is as 1 : 4 : 8. But there are only two points of equivalence in the conductometric titration curve in which the base uptake ratio is as 1 : 4 (fig. 4). This again reflects the nature of the H-montmorillonite (Wyoming bentonite) after MARSHALL and KRINBILL (loc. cit.) and MITRA, BAGCHI and RAY⁴).

The clay fraction in the profile 31''–36'' gives very weak inflection points and irregular points of equivalence in the conductometric titration curve showing that these points are not exactly due the dissociable hydrogen but are also due to the exchangeable Aluminium and iron. It appears that at this depth there has been much degradation of the clay minerals with the result that hydrated Alumina and iron may have been formed in considerable proportion.

³) R. E. GRIM, "Clay Mineralogy" Ed. 1953, pp. 130–131.

⁴) R. P. MITRA, S. N. BAGCHI and S. P. RAY, Electrochemical Properties of Clay minerals and the Differentiation of H-clays and Bentonites by Electrochemical Methods, II, J. physic. Chem. **47**, 549 (1943).

The two inflection points in 0–12" profile come at pH 5.2 and 8.5 respectively. Those in the profiles 13"–18" appears at pH 5.0, 6.3 and 8.0. In the profile 19"–24" the inflection are found to occur at 5.4 and 8.0; in the profile 25"–30" at pH 5.0, 7.0 and 8.5 while in the profile 31"–36" the inflections appear at pH 4.9 and 6.4. Comparing these figures with those of the typical clay minerals worked by the foregoing authors (loc. cit.) it is interesting to observe that there is a fair correspondence of the base uptake properties of H-Kaolinite and the hydrogen clay of the top profile 0–12" at Tehra and of H-montmorillonite and hydrogen clay fractions obtained from the depths 13"–30". The slight discrepancies of the pH values at the points of inflection from the standard curves of Kaolinites and montmorillonites appear to be due to the changes in the composition of the clay fractions with respect to the proportion of aluminium and iron.

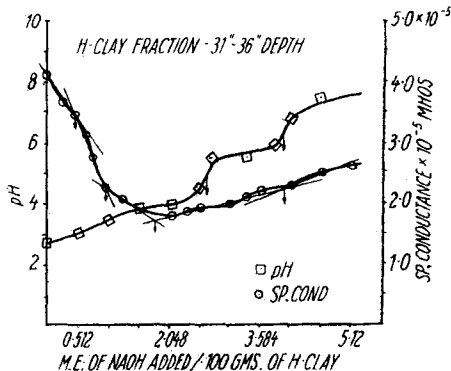


Fig. 5

The foregoing observations suggest that the changeability of clay minerals which have been observed in the profiles of Tehra soil, may also be a contributing factor to change the physical properties of different layers which may affect the stabilisation of roads in the long run. The study of profiles in the aspect of clay mineralogy for regression effects and soil stabilisation cannot, therefore, be over emphasised.

Summary

In continuation of our fundamental studies on soil profiles at Tehra (Agra Gwalior Road) in the aspect of road stabilisation, it was deemed necessary to study further the character of the clay fractions at different depths of the profiles by titrating the acid clay against a standard solution of NaOH by potentiometric and conductometric methods.

Close coincidence of the base equivalents at the points of inflection in the E. M. F. (pH) titration curves and the corresponding equivalence points in the conductometric titrations shows that the base uptake properties of the clay fractions of the layer from 0–12" were identical, but differed appreciably from the base uptake capacity of the clay fractions obtained from the profiles of depths 13"–30". From these curves it has been further concluded that the clay fractions obtained from the layers

0–12'', 13''–18'', 19''–24'', 25''–30'' and 31''–36'' suffered more or less mineralogical changes.

The points of inflection in the titration curves have been discussed in the light of the exchangeable hydrogen and aluminium in the clay fractions obtained from the samples at different depths of the profiles of Tehra soil.

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