



## Research paper

## Property-based assessment of soil mineralogy using mineralogy charts

Oksana Paykov<sup>a,1</sup>, Harmonie Hawley<sup>b,\*</sup><sup>a</sup> Department of Civil and Environmental Engineering, California State University, Fullerton, 800 N. State College Blvd., Fullerton, CA 92831, United States<sup>b</sup> Department of Civil and Environmental Engineering, University of Texas at Tyler, Tyler, TX 75799, United States

## ARTICLE INFO

## Article history:

Received 15 January 2013

Received in revised form 1 December 2014

Accepted 2 December 2014

Available online 15 December 2014

## Keywords:

Soil mineralogy

Specific surface area

Liquid limit

Mineral quantification

## ABSTRACT

It is essential to determine soil mineralogy as soils containing high amounts of smectites pose a hazard to geotechnical structures and increase susceptibility to soil erosion and landslides. The everyday use of analytical techniques in geotechnical engineering practice is considered expensive and time consuming. Prior studies suggest that physico-chemical properties of soil can be used to estimate the soil mineralogy. The current study evaluated specific surface area and liquid limit as possible parameters to estimate soil mineralogy. Mineralogy charts are introduced to estimate the percentage of montmorillonite, kaolinite, and illite in a sample. The degree of accuracy is highly dependent on the method used to determine the soil properties. Mineralogy Chart<sub>SSA</sub> yielded as accurate results as artificial neural network based models. Prediction of soil mineralogy based on liquid limit of the soil yielded a wide range of correlation coefficients between the measured and calculated values.

© 2014 Elsevier B.V. All rights reserved.

## 1. Introduction

Expansive soils, which contain large amounts of smectites, pose a hazard to geotechnical structures due to dramatic swelling and cause billions of dollars of damage in the United States each year (Krohn and Slosson, 1980; Chiappone et al., 2004; Yuxselen-Aksoy and Kaya, 2010). The expansion of clays and the associated uplift results in considerable damage to the shallow foundations of light structures, roads, and buried utilities (Ozer et al., 2012). In addition, slopes containing high amounts of smectites have been found to be susceptible to erosion. Ben-Hur and Wakindiki (2004) suggested that mineralogical composition of soil should be considered during erosion modeling. At about 5% clay content the behavior of soil is dominated by clay properties, particularly swelling properties if montmorillonite is present (City of Galveston, Texas, 2013).

Several stabilizing agents have been widely applied to modify the properties of expansive soils, including lime, cement, and fly ash. Lime increases the optimum water content, shrinkage limit and strength, and reduces the swelling potential, liquid limit (LL), plasticity index, and maximum dry density of the soil (Eren and Filiz, 2009). The addition of cement reduces the swelling potential, plasticity index, and liquid limit (Eren and Filiz, 2009). Studies suggest that the best outcome of these stabilization techniques is achieved when the mineralogical composition of soil is taken into account. According to Pedarla et al. (2011) clay mineralogy plays an active and important role in the

chemical reactions between soil and additives. Dash and Hussain (2012) found that a wide range in quantity of lime is required to achieve the maximum increase in unconfined compressive strength of soil depending on the mineralogical composition of soil. Stavridakis (2005) determined the outcome of the stabilization technique by the addition of cement is a function of portion and mineral type.

Soil mineralogy is commonly determined by X-ray diffraction, scanning electron microscopy, and infrared spectroscopy. In geotechnical engineering practice, these practices are usually restricted to research applications because of the specialized equipment and resultant high cost (Cerato and Lutenecker, 2002; Chiappone et al., 2004; Chittoori et al., 2008; Chittoori and Puppala, 2011). Each of these methods has other limitations related to availability of appropriate standards, sample preparation, time required, or other complications (Drever, 1973; Brindley, 1980; Laird and Dowdy, 1994; Mitchell and Soga, 2005). While X-ray diffraction is the most widely used method for identification of fine-grained soil minerals, there are uncertainties in quantitative determination of the amounts of different minerals in a soil on the basis of simple comparison of diffraction peak heights (Kinter and Diamond, 1956; Kolka et al., 1994; Mitchell and Soga, 2005).

Electron microscopy studies require prolonged and sophisticated sample preparation and the use of multivariate calibrations (Righi and Elsass, 1996; Sudduth and Hummel, 1996; Chang et al., 2001; Waiser et al., 2007).

According to Mitchell and Soga (2005) the presence of minerals can be determined by a combination of several simple tests, including the quantification of organic matter and free oxides, in addition to X-ray diffraction. However, to accurately estimate the mineralogical composition, the number of different analyses needed is equal to the number of mineral species present (Mitchell and Soga, 2005). Chittoori and

\* Corresponding author. Tel.: +1 903 565 5711; fax: +1 903 566 7337.

E-mail addresses: [opaykov@csu.fullerton.edu](mailto:opaykov@csu.fullerton.edu) (O. Paykov), [hhawley@uttyler.edu](mailto:hhawley@uttyler.edu) (H. Hawley).<sup>1</sup> Tel.: +1 949 331 3009.

**Table 1**  
Published values for SSA, CEC, and LL of pure minerals.

Mineral	SSA (m <sup>2</sup> /g)	CEC (meq/100 g)	LL (%)
Montmorillonite	747	146	482
Kaolinite	55	6	72
Illite	100	25	90

Puppala (2011) developed a methodology to quantify the presence of montmorillonite, kaolinite, and illite in soil using soil properties, including specific surface area (SSA), cation exchange capacity (CEC), and total potassium (TP) of the soil. To determine the dominant clay mineral and its quantity present in the sample, Chittoori and Puppala (2011) developed a mineral interaction program that utilizes the input data (SSA, CEC, TP) to produce an outcome in terms of the percentage of montmorillonite, kaolinite, and illite in a sample. This study further evaluates soil properties (SSA, CEC, and LL) as possible parameters to use to determine the soil mineralogy. In addition, the study introduces mineralogy charts that can be used to determine the percentage of montmorillonite, kaolinite, illite, and quartz in a sample.

## 2. Procedure

Twenty five (25) samples were prepared by mixing sodium montmorillonite, kaolinite, illite, and quartz in various proportions based on the dry weight of each mineral. The minerals were purchased from Ward's Natural Science. Based on X-ray diffraction studies from the manufacturer, the purity of sodium montmorillonite, kaolinite, and illite was 90% montmorillonite, 85% kaolinite, and 80% illite, respectively. The impurities were mainly composed of quartz and feldspar. The quartz was supplied in powdered form (particle size smaller than 5 µm). Methylene blue (purity = 82%) was obtained in powdered form from Sigma-Aldrich Co. LLC (Saint Louis, MO).

Methylene blue (MB) stain test was performed to determine the blue value ( $V_B$ ) of the soil sample. It was performed according to the French standard (NF P 94-068). The blue value of soil was then used to calculate the SSA and CEC of the soil sample.

The exact procedure for the MB stain test was adapted from Chiappone et al. (2004) and described in Paykov and Hawley (2013). Briefly, all materials were oven-dried at 105 °C for 24 h, then 5 g of the oven-dried sample was dispersed in 500 ml of distilled water, and stirred until it was fully dispersed. This was followed by sequential additions of 1 ml of methylene blue solution (10 g/L). Five minutes were given to achieve solution equilibrium after each addition. One drop of suspension was placed on a filter paper (Ahlstrom: Grade 615-21, Diameter 15 cm) after each addition of 1 ml of methylene blue solution.

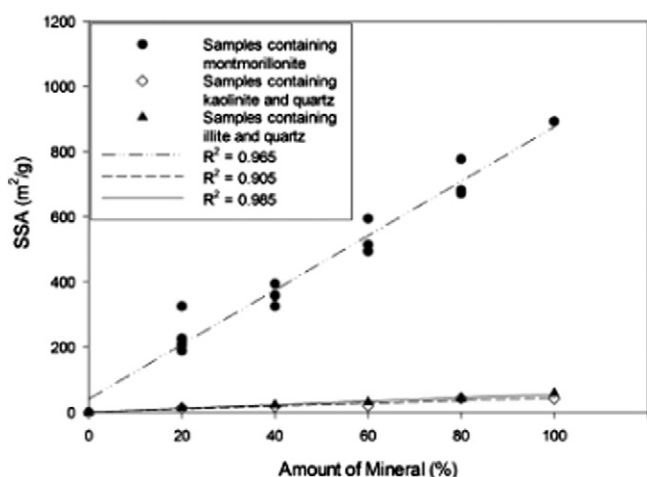


Fig. 1. Relationship between soil mineralogical composition and SSA.

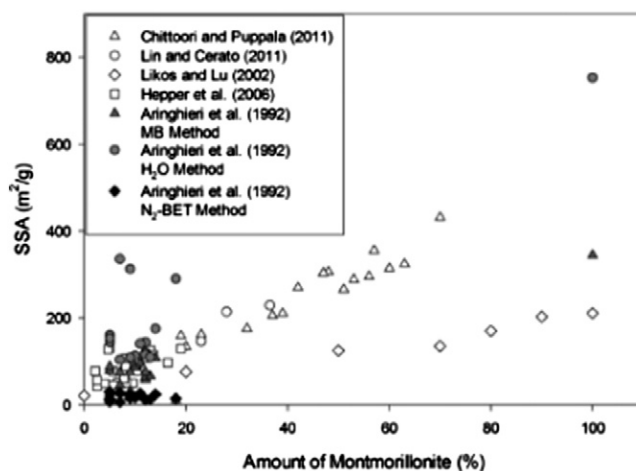


Fig. 2. Relationship between the amount of montmorillonite present in a sample and SSA based on published data.

If one dark stain was observed, an additional 1 ml of methylene blue solution was added to the soil solution. The dark blue stain indicates that MB molecules have been fully adsorbed onto the soil surface. Additions of MB solution were performed until a light blue halo around the dark blue stain was observed. The light blue halo around the dark blue stain indicates that the soil surface is fully covered by MB molecules and excess MB remains in solution producing the light blue halo around the dark blue stain. If the light blue halo persisted for more than 5 min, the volume of methylene blue solution required to achieve a halo was used to calculate the blue value of the soil (Eq. (1)).

$$V_B = (100CV)/W \quad (1)$$

where  $V$  is the volume (in cm<sup>3</sup>) of the methylene blue solution,  $C$  is concentration of the methylene blue solution, and  $W$  is the dry weight (in g) of the soil.

The SSA of soil was determined using Eq. (2).

$$SSA = (V_B * N * A) / (100 * MW_{MB}) \quad (2)$$

where  $N$  is Avogadro's number and is equal to  $6.02 \times 10^{23}$ ,  $A$  is the surface area of one methylene blue molecule and is equal to  $130 \text{ Å}^2$ ,

**Table 2**  
 $R^2$  values for the relationship between percentage of montmorillonite and SSAs.

Samples containing montmorillonite	Samples containing kaolinite and quartz	Samples containing illite and quartz	Soil type	Test performed	Source
$R^2 = 0.96$	$R^2 = 0.98$	$R^2 = 0.99$	Mineral mixtures	MB stain	Current study
$R^2 = 0.90$	N.A.	N.A.	Natural soil	EGME	Chittoori and Puppala (2011)
$R^2 = 0.91$	N.A.	N.A.	Natural soil	EGME	Lin and Cerato (2011)
$R^2 = 0.27$	N.A.	N.A.	Natural soil	EGME	Hepper et al. (2006)
$R^2 = 0.84$	N.A.	N.A.	Mineral mixtures	H <sub>2</sub> O adsorption	Likos and Lu (2002)
$R^2 = 0.97$	N.A.	N.A.	Natural soil	MB method	Aringhieri et al. (1992)
$R^2 = 0.78$	N.A.	N.A.	Natural soil	H <sub>2</sub> O adsorption	Aringhieri et al. (1992)
$R^2 = 0.0039$	N.A.	N.A.	Natural soil	BET-N <sub>2</sub> adsorption	Aringhieri et al. (1992)

Download English Version:

<https://daneshyari.com/en/article/1694637>

Download Persian Version:

<https://daneshyari.com/article/1694637>

[Daneshyari.com](https://daneshyari.com)