Applied Clay Science 101 (2014) 68–72

Contents lists available at ScienceDirect

Applied Clay Science

journal homepage: www.elsevier.com/locate/clay

Estimating compaction parameters of clayey soils from sediment volume test

Ali Hakan Ören *

Department of Civil Engineering, Dokuz Eylül University, 35160 Buca, Izmir, Turkey

ARTICLE INFO

Article history:
Received 22 February 2012
Received in revised form 7 July 2014
Accepted 12 July 2014
Available online 2 August 2014

Keywords:
Clays
Compaction
Fine-grained soils
Liquid limit
Plastic limit
Sediment volume

ABSTRACT

Predicting the compaction parameters, in terms of maximum dry unit weight and optimum water content, from index properties of fine-grained soils has been of interest for the last few decades. Although various index properties, such as liquid limit, plastic limit and clay contents, have been used for the prediction, it was revealed that plastic limits of fine-grained soils correlate well with the compaction parameters. As an alternative method, this paper proposes sediment volume test to estimate the compaction parameters. In order to show its relevance, compaction and sediment volume tests were performed on nine fine-grained soils. The final sediment volumes (FSVs) of soils were determined from sediment volume tests. Then, the correlations between compaction parameters and FSVs were investigated. It is found from this experimental investigation that there is a good relationship between the compaction characteristics namely maximum dry unit weight (γ_{dmax}) and optimum water content (w_{opt}) and the FSV, indicating that this method can be used as an alternate way of predicting the same.

1. Introduction

Compaction is widely used in many geotechnical engineering applications to improve soil densification. The volume of air voids in the soil decreases as a result of compaction. This leads to an increase in the shear strength, and a decrease in the consolidation and the permeability of soils (Holtz and Kovacs, 1981).

The compaction parameters, maximum dry unit weight (γ_{dmax}) and optimum water content (w_{opt}), are important in most of the practical situations needing densification of soils, such as highway and railway subgrades and foundation soils. These parameters should also be taken into account during landfill design and construction to achieve low hydraulic conductivity for the liner material.

Despite simplicity of compaction test, it is a time consuming and labor intensive process. The test needs more soil, proper mixing of sample with water during its preparation prior to test and proper carrying out the test to transfer the rated energy. Prediction of compaction parameters from other tests has been of interest for a long time, since compaction tests are required for almost all earthwork applications.

There are many studies reported in the literature that estimate the compaction parameters of soils from index properties (Al-Khafaji, 1987, 1993; Blotz et al., 1998; Günaydın, 2009; Gurtug and Sridharan, 2002; Sridharan and Nagaraj, 2005). Al-Khafaji (1987) investigated the compaction characteristics of 88 local soils and reported that the compaction parameters were correlated well with the liquid limit (w_L) and clay content (C) as given by the following equations:

$$w_{opt} = 0.5 + 0.26(w_L + C) \quad (1)$$

$$\gamma_{dmax} = 2.31 - 0.84w_L - 0.81C \quad (2)$$

where, w_{opt} is the optimum water content and γ_{dmax} is the maximum dry unit weight. Subsequently, Al-Khafaji (1993) proposed new equations to estimate the w_{opt} and γ_{dmax} of the same soils as a function of liquid limit and plastic limit (w_P):

$$w_{opt} = 0.24w_L + 0.63w_P - 3.13 \quad (3)$$

$$\gamma_{dmax} = 2.44 - 0.02w_P - 0.008w_L. \quad (4)$$

Blotz et al. (1998) used liquid limit to predict the w_{opt} and γ_{dmax} of 22 clayey soils. They reported that the typical errors were about ±2% for w_{opt} and ±6% on γ_{dmax}.

Sridharan and Nagaraj (2005) proposed a method to predict compaction parameters in terms of index properties of fine-grained soils. In addition to their 10 data, they gathered 54 data from different sources for the prediction. Based on their findings, compaction parameters could be correlated well with the plastic limit rather

* Tel.: +90 232 412 7966; fax: +90 232 453 1192.
E-mail address: ali.oren@deu.edu.tr.

http://dx.doi.org/10.1016/j.clay.2014.07.019
0169-1317/

than liquid limit. They proposed the following equations to predict the compaction parameters:

$$w_{opt} = 0.92\, w_P \tag{5}$$

$$\gamma_{dmax} = 0.23\,(93.3 - w_P). \tag{6}$$

In the subsequent study, Gurtug and Sridharan (2002) increased the number of fine-grained soil from 64 to 86 and reexamined the correlation between compaction parameters and plastic limit. They found the same equation while predicting the w_{opt} (i.e. Eq. (5)). In addition, they proposed the following correlation equation to predict the γ_{dmax}:

$$\gamma_{dmax} = 0.98\,\gamma_{dwp} \tag{7}$$

where, γ_{dwp} is the dry unit weight at the plastic limit water content.

Similarly, Günaydın (2009) performed a simple regression analysis on 126 soils to estimate the compaction parameters. It was reported that the coefficients of determinations were 0.82 and 0.73 for w_{opt} and γ_{dmax}, respectively, when liquid limit was used as an independent parameter. The coefficients were rather low when plastic limit was the independent parameter in the analysis. Günaydın (2009) also ran multiple regression analysis on the samples and concluded that the best predictions could be made when liquid and plastic limits were both used in the analysis.

All of these equations show that compaction parameters can be estimated using plastic limit or both liquid and plastic limits. Though the parameters liquid and plastic limits used in the previous studies to correlate compaction characteristics are easily determinable, still it was felt desirable to find an alternate and yet simple procedure to predict the compaction characteristics.

Sediment volume test has been proposed to make an assessment on identification and classification of soils (Prakash and Sridharan, 2010). There are also numerous studies that report the estimation of mineralogy, liquid limit and consolidation parameters of fine-grained clayey soils from sediment volume test (Ören and Kaya, 2003; Prakash and Sridharan, 2002, 2004; Sridharan and Prakash, 1999; Yukselen-Aksoy et al., 2008). However, there is no study reported in the literature estimating the compaction parameters from final sediment volumes (FSVs) of the soils. In this study an attempt has been made to develop a correlation for predicting the compaction characteristics through sediment volume of soils.

2. Materials and methods

2.1. Materials

Eight natural soils were gathered from different parts of western Turkey. In addition to the eight soils, commercial kaolin (soil #2) was supplied from Kale Maden A.Ş., Çanakkale/Turkey. The compaction and sediment volume tests were conducted on the total of 9 clayey soils. The soils were air dried before the tests. Then, all soils were crumbled in a rock crusher to obtain sand sized particles passing through No 4 sieve (less than 4.75 mm). It is already known that the sediment volume of soil is susceptible to pore fluid compositions. Since compaction tests were performed with distilled water, sediment volume tests for nine soils were carried out with the same liquid. However, it was not possible to determine the FSV of soil #9 with distilled water as the settling was not complete even at the end of two months after the start of the test. To enhance the rate of settling, Prakash and Sridharan (2002) suggested conducting the sediment volume tests with 0.025 M NaCl solution. They reported that the equilibrium sediment volume of clays in distilled water was almost the same with those in 0.025 M NaCl solution. Thus, the sediment volume test for soil #9 was performed with 0.025 M NaCl solution instead of distilled water.

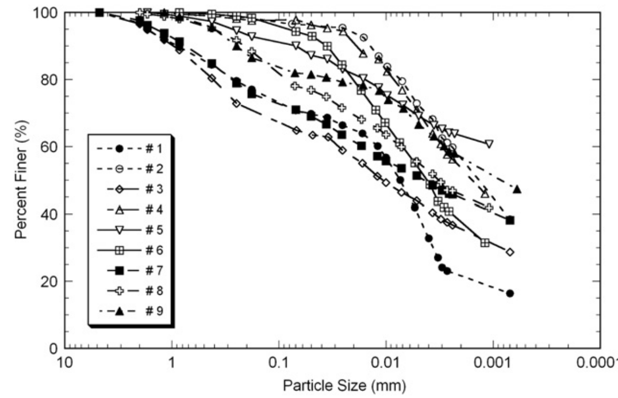

Fig. 1. The particle size distributions of soils used in the present study.

2.2. Methods

The particle size distributions of all soils were determined from sieve and hydrometer analysis by following the ASTM D422 (2007) (Fig. 1). Specific gravity and plastic limit were determined in accordance with ASTM D854 (2010) and ASTM D4318 (2010), respectively. The liquid limits of soils were determined by the fall cone test method as described in BSI-BS 1377 (1990). Index properties of soils used in this study are summarized in Table 1.

The compaction tests were conducted on air dried soil samples. Requisite amount of water was added to the samples with a spray bottle and they were thoroughly mixed to prevent the formation of clods. Then, the mixtures were kept in sealed plastic bags for one day. Finally, the samples were compacted using standard Proctor effort as specified in ASTM D698 (2012). The samples were compacted in a 4-inch compaction mold (i.e. 101.6 mm in diameter and 116.4 mm in height). The compaction curve was obtained by drawing third-order polynomial curves through the measured data (Howell et al., 1997). The peak point on the compaction curve refers to the γ_{dmax} and the corresponding water content to the γ_{dmax} is the w_{opt}.

The sediment volume tests used in this study were performed using a soil fraction obtained by passing through No. 40 (425 μm). The natural soils may include some organics which may be removed when dried at greater temperatures (i.e. 105 °C). This may affect the settling behaviors. Thus, all samples used in the present study were dried at a lower temperature in an oven (i.e. 60 °C) for one week. The sediment volume tests were conducted in 100 ml graduated cylinders (Prakash and Sridharan, 2004). The cylinders were filled up to the 80 ml level and 10 g of dry samples was slowly poured into the cylinder. The soils were poured in small increments and the soil samples were allowed to wet, hydrate and settle to the bottom of the graduated cylinder for

Table 1
Index properties of soils used in the present study.

Soil number	Specific gravity, G_s	Liquid limit, w_L (%)	Plastic limit, w_P (%)	Plasticity index, I_P (%)	Grain size distribution (%)		
					Sand	Silt	Clay
1	2.68	33.4	17.5	15.9	29.6	49.2	21.2
2	2.61	39.0	23.1	15.9	3.4	39.9	56.7
3	2.63	50.3	24.9	25.4	35.1	29.4	35.5
4	2.67	53.2	26.1	27.1	3.7	42.6	53.7
5	2.71	55.0	24.0	31.0	11.9	24.7	63.4
6	2.78	57.6	26.8	30.8	6.4	56.2	37.4
7	2.63	59.0	29.1	32.9	31.6	23.2	45.2
8	2.66	68.8	35.9	32.9	22.1	32.6	45.3
9	2.50	92.4	42.3	50.1	20.1	23.6	56.3