Transportation Geotechnics 2 (2015) 65–77

Contents lists available at ScienceDirect

Transportation Geotechnics

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

Correlation of compaction characteristics of natural soils with modified plastic limit

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ARTICLE INFO

Article history:
Received 13 May 2014
Revised 26 August 2014
Accepted 5 September 2014
Available online 16 September 2014

Keywords:
Compaction
Earth fills
Embankments
Ground improvement
Plastic limit

ABSTRACT

Compaction characteristics of soils being very important from field application point of view, any attempt to develop correlation equation to predict the same should be rational and universally applicable. It has been reported in the literature that the plastic limit of soils bear a good correlation with their compaction characteristics. In this study, attempts have been made to use modified plastic limit to account for the proportion of fraction less than 425 μm as a parameter to correlate with the compaction characteristics of natural soils. The proposed correlation between the compaction characteristics of natural soils with their modified plastic are going to be handy tool for construction engineers in quickly assessing their suitability for compaction related purposes.

Introduction

In many situations in civil engineering practice, geotechnical engineers are confronted to handle large volumes of soil, where the soil itself is used as a constructional material. The importance of compaction as a practical means of achieving the desired strength, compressibility and permeability characteristics of soils has been appreciated since the time early earth structures were built. Compaction of soil has applications in almost every field of civil engineering involving soil. So, for a civil engineer, it is very essential to know the compaction characteristics of natural soils, and thereby assess their suitability. Also, such kind of projects requires large quantities of soils, and it is difficult to obtain such large volume of soil with the desired compaction characteristics from a single borrow source. In such situations, to decide upon the suitability of soils obtained from various borrow sources, one has to obtain compaction characteristics such as maximum dry unit weight (γ_{dmax}) and optimum moisture content (OMC) from a laboratory compaction test. But laboratory compaction test requires sufficient time and effort. So, for preliminary assessment of the suitability of soils required for any such project, it is desirable to develop correlations of engineering properties with simple physical properties, namely Atterberg limits, which are obtained through simple tests known as index tests. Correlations making use of the Atterberg limits are fairly common in soil mechanics literature, and can be quite useful (Wesley, 2003).

One of the first attempts to relate compaction characteristics with index properties was by Jumikis (1946). He developed a correlation equation to estimate optimum moisture content with liquid limit and plasticity index. Later continuous attempts have been made by various researchers to predict compaction characteristics with simple physical and index properties. Rohan and Graham (1948) tried to relate optimum moisture content with

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http://dx.doi.org/10.1016/j.trgeo.2014.09.002
2214-3912/

gradation, specific gravity and shrinkage limit; Turnbull (1948) with gradation; Davidson and Gardiner (1949) with gradation and plasticity index. Ring et al. (1962) developed correlation equations to predict maximum dry density and optimum moisture content relating with liquid limit, plastic limit, plasticity index, approximated average particle diameter (D′50), content of particles finer than 0.001 mm (F0.001), and fineness average (FA). Ramiah et al. (1970) tried to correlate compaction characteristics with liquid limit alone as the parameter. Korifiatis and Manikopoulos (1982) tried to give correlation equation to predict maximum dry density relating particle size distribution. Boltz et al. (1998) related optimum moisture content with liquid limit of soils. Sivrikaya et al. (2008) tried to develop multi-linear regression model relating the compaction characteristics as a function of gravel content, sand content, fine-grained content, i.e., clay plus silt content, plasticity index, liquid limit and plastic limit. Recently, Di Matteo et al. (2009) while trying to develop regression models to predict compaction characteristics (OMC and MDD) have observed that the most significant variables influencing OMC and MDD were specific gravity, liquid limit and plastic limit. They developed relationship to predict OMC in terms of liquid limit and specific gravity; and MDD in terms of OMC predicted and plasticity index. It has also been reported in the literature indicating qualitatively that plastic limit of soils would bear a good correlation with the compaction characteristics of soils (Leroueil et al., 1992; Howell et al., 1997). Later, few researchers have made attempts to propose correlation of compaction characteristics with plastic limit (Nagaraj, 2000; Gurtug and Sridharan, 2002; Sridharan and Nagaraj, 2005). This aspect was supported by the findings of Sivrikaya (2008). He reported that optimum moisture content has a considerably good correlation with plastic limit in comparison with liquid limit and plasticity index. However, it should be noted that some of these studies were confined to correlation of compaction characteristics with plastic limit using soils having fractions less than 425 μm (No. 200 sieve size) (Nagaraj, 2000; Sridharan and Nagaraj, 2005); some studies using natural soils having fractions less than 425 μm by more than 98% by weight of the soils used for compaction (Gurtug and Sridharan, 2002); and few other studies using natural soils having soil fractions of all sizes and correlating with index properties including plastic limit (Leroueil et al., 1992; Howell et al., 1997; Boltz et al., 1998; Sivrikaya, 2008 to name a few) without taking into account the effect of amount of fraction greater than 425 μm (which is a variable for natural soils)and its influence on the compaction characteristics. However, for a geotechnical engineer, it is essential to predict the compaction characteristics of natural soils, which do have soil fractions greater than 425 μm, and has to be accounted for while using the index properties to develop a relation with the compaction characteristics.

As per standards (ASTM D 4318-95a), the plastic limit is determined using the soil fraction passing through 425 μm, whereas the compaction characteristics are obtained from the laboratory compaction test determined using soil fraction less than 19 mm. It is mentioned in ASTM D 4318-95a that the relative contribution of this portion (425 μm) of the soil to the properties of the sample as a whole must be considered when using the test to evaluate properties of a soil.

In this paper an attempt has been made to correlate compaction characteristics of natural soils at Proctor's energy level with plastic limit, which is modified to take into account the proportion of fines less than 425 μm present in the natural soils.

Experimental program

Forty two natural soils from various geological locations having liquid limits ranging from 24% to 115% and plastic limits ranging from 17% to 45% are used in this study. The soils were characterized for their physical properties according to ASTM Standards, and the results are summarized in Table 1.

The compaction test was done for the forty two soils using the Standard Proctor effort (ASTM D 698). The soil samples for compaction test were prepared by mixing desired amount of water, then transferred into polythene covers and left in it for at least 20 h to ensure moisture equilibration. For each soil, a minimum of six trials was done with varying initial water content to obtain the compaction curve. Table 2a summarizes the compaction characteristics of soils.

It has to be noted that, the correlation of compaction characteristics presented by Nagaraj (2000), Sridharan and Nagaraj (2005) is for soils having fraction less than 425 μm. As a first step in trying to develop correlation of compaction characteristics with natural soils, it was felt by the authors to verify the correlation equations with the present set of soils. For this purpose, fifteen soils out of the forty-two soils used in this study were selected and Proctor compaction tests were conducted using soil passing through 425 μm.

It is suggested in ASTM D 4318-95a, that since the plasticity tests are performed only on that portion of a soil, which passes 425 μm (No. 40 sieve), the relative contribution of this portion of the soil to the properties of the sample as a whole must be considered when using these tests to evaluate properties of a soil. Hence, plastic limit being used as a correlation parameter in this study to predict compaction characteristics of the natural soil as a whole, it has been modified to account for the proportion of soil fraction <425 μm present in the soil. However, this way of accounting for the amount of fines <425 μm present in the soil was not considered in any of the previous studies while developing the correlation equations between compaction characteristics and plastic limit of the soil (Gurtug and Sridharan, 2002; Sivrikaya, 2008).

Further, to study the influence of soil fraction >425 μm present in natural soils on the compaction characteristics, compaction tests were carried out for five soils (Soil nos.10, 17, 21, 24 and 39) with the soil fraction passing through 425 μm mixed with 10% and 20% (by weight basis) sand fraction having particle size >425 μm obtained by sieving a locally available natural river sand with a 425 μm sieve. This sand fraction retained on 425 μm is termed as Coarse Fraction (CF) in the further discussion.