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Multi-faceted investigation and modeling of compaction parameters for road construction

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Abstract

Compaction parameters for road construction were multi-faceted investigated and modeled in this study. For this aim, aggregate samples were randomly taken from D-100/11 highway section in Düzce. Standard Procter tests, sieve analysis, unit weight in natural state (γ_n), unit weight in dry state (γ_d), water content (w), physical and mechanical properties of aggregate samples were determined by conducting experiments in laboratory. By using SPSS software programme statistical analyses were performed on the experimental test results. Different prediction models were developed for the prediction of maximum γ_d based on the compaction parameters and the particle diameter of aggregates. For the maximum γ_d the correlation coefficient was found perfect level between developed prediction model and the current compaction test results. In order to determine γ_d, γ_n and w of compacted aggregate samples in field, different prediction models were also developed based on the penetration test results. As a result, the entire relationship between compaction parameters and particle diameter of aggregates were detailed determined and it was also seen that the developed prediction models can be easy used for the prediction of the compaction test parameters.

Keywords: Soil compaction; Compaction parameters; Statistics; Prediction models

1. Introduction

Soil compaction is one of the most efficient and practical soil improvement techniques. Soil compaction is carried out at three main stages which are design, construction and compaction assessment. Assessment of compaction performance is the most important steps of these works. It is commonly carried out by different test methods such as sand-cone and nuclear gauge tests. These tests are intended to determine optimum water content and maximum dry unit weight. Therefore, determination of these parameters has to be done in an easy and reliable manner. Commonly, these parameters can be obtained from plate load test which is both costly and time consuming. Thus, engineers have had to use various guidelines charts and (PCA, 1984; AASHTO, 1993; IRC, 2002; AUSTROADS, 2004) numerical methods (Terzaghi, 1955; Bowles, 1996) for design of earth structure. These guidelines, charts and methods are highly complex. Engineer also needs shear strength parameters, sub-grade resilient modulus and soil elastic modulus for using the guidelines, charts and methods. Obtaining of these parameters is difficult as much as performing plate load test. Estimating of the deformation modulus and coefficient of sub-grade reaction of soils using soil properties is more practical than suggested guideline charts and methods.

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In the literature, a number of studies have been undertaken to evaluate the coefficient of sub-grade reaction (Terzaghi, 1955; Moossazadeh and Witczak, 1981; Horvath, 1983; Lin et al., 1988). However, deformation modulus studies are limited. Recently, Pantelidis (2008) studied based on numerical analysis using finite element software for the correlation of the Modulus of Elasticity (tangent modulus) with the deformation modulus (secant modulus). According to this, correlation related to the shear strength parameters of soils the radius of the rigid loading plate and the magnitude of applied pressure.

A laboratory test using a “Proctor” mold and applied unidirectional pressures was carried out using a sandy clay loam soil, but with samples of varying water content and aggregate sizes (0 to 2, 2 to 5, 5 to 10 and 0 to 10 mm).

The applied pressures were in a limited range 35 to 93 kPa and were applied as static loads for periods of less than 5 s. The resulting compaction was measured as bulk density and H/H_{i} is the initial height of the sample and H is the height after compaction. Tensile strength of the soil aggregates at the same water contents used above was determined. The ratio of the applied pressures to aggregate tensile strength was established. This ratio was then used to explain the differences in level of compaction obtained with the different sized aggregates and water contents (Willatt, 1984).

Soil compaction preferentially removes large soil pores called macro pores which are critical for water transport in soils. Soil cores were removed from replicated compacted and non-compacted field treatments and scanned using a medical X-ray computed tomography scanner. The compacted treatment for this study was found to increase the density of the soil by 8% and decrease the soil permeability by 69%. The number of macro pores and the relative area of macro pores were decreased by 69% and 64%, respectively. Differences between treatments for the porosity parameters were most pronounced in the upper 10 cm soil depth. A regression equation was developed which predicted soil permeability with CT-measured macro porosity and porosity. Efforts should be made to minimize soil compaction due to its harmful effects on soil pores and subsequent challenges for plant root growth and enhanced runoff of water and nutrients (Kim et al., 2010).

In recent years, estimation models obtained from statistical and artificial neural networks methods widely used in geotechnical engineering instead of performing difficult laboratory and field tests (Kahraman et al., 2007; Karakus et al., 2004; Yasar and Erdoğan, 2004; Najjar et al., 1996; Lee and Lee, 1996; Yuanyou et al., 1997; Yang and Zhang, 1998; Hurtado et al., 2001; Rafiq et al., 2001; Lee et al., 2003; Basma and Kallas, 2004; Gunaydın, 2008; Taskiran, 2010). Similar models were developed and evaluated for estimating of deformation modulus and coefficient of sub-grade reaction of compacted soils. Also, availability of these models was discussed for engineering applications. The applications of artificial neural networks (ANN) and simple–multiple regression analysis to predict deformation modulus and coefficient of sub-grade reaction of compacted soils from compaction parameters such as maximum dry density (MDD) and optimum moisture content (OMC), field dry density (FDD), and field moisture content (FMC). Regression analysis and artificial neural network estimation indicated that there are acceptable correlations between deformation modulus and coefficient of sub-grade reaction and these parameters (Dinçer, 2011).

In this study, the effect of compaction parameters onto the compaction test results was detailed investigated, statistical analyses were conducted by using the experimental test results. Prediction models were developed for the prediction of maximum γD based on the “w”, γN, penetration values, and particle diameter of aggregate. As a result, the entire relationship between compaction parameters and particle diameter of aggregates were detailed determined and it was also seen that the developed prediction models could be easy used for the prediction of the compaction test parameters.

2. Vehicle-terrain interaction and modeling of pavement compaction

Road construction and maintaining of the road is very important subjects for economical, commercial, social, political, etc. reasons. Construction of the best road is a main purpose of the local and national authority. The road can be constructed for different aims. The road can be grouped different category accordance to their function. A road, has been constructed different layer which have different thickness and different material properties. In generally a road is built as three layers. These layers named beginning from the bottom layer as sub base, base and cover layers. The properties of materials used in the building process of road are different in the each layer. In generally, while stone and coarse gravel are using in the sub base, thinner aggregates are using in the base and cover layers. The roads have to be built to resistance the vehicle loads, environmental conditions, freezing–thawing effects, etc. and the other negative conditions. To achieve these aims as a firstly the road layers have to be compacted while the road construction. Without compaction of these layers it is not possible to construction a durable road. Compaction of the layers increases the friction angle between particles, decrease the porosity and water absorbs of layers and as a result increase the load capacity of road through the service life. Load capacity of road is very important for vehicle-terrain interaction especially for the suburban roads. The vehicle–terrain interaction cannot be achieved without compaction of the road layers. Compaction is dependent on the compaction energy, water content of materials, physical and chemical properties of materials, and thickness of the layers. To achieve the best compaction of road layer, maximum dry unit weight and optimum water content has to be determined. Max dry unit weight and optimum water content can be determined with