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RESEARCH ARTICLE - CIVIL ENGINEERING

Indirect Estimation of Swelling Pressure of Clayey Subgrade Under Pavement Structures

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Abstract Predicting the swelling pressure (Ps) in subgrades constitutes a new approach in pavement structural design. It is shown, however, that current conventional testing programs could lead to erroneous results. Several approaches to estimate Ps have so far been proposed; yet, no universally accepted method has been suggested. In this study, 40 subgrade soil samples taken from a route in Tebessa city (Algeria) were subjected to different laboratory tests. Values of free swelling pressure were measured by using an odometer. A statistical model capable of indirectly estimating Ps is provided. The model is based on a correlation of Ps with dry density (ρ_d), water content (w) and plastic limit, and has been checked by variance inflation factors method to examine multicollinearity. The proposed equation demonstrates a high correlation coefficient (R^2) of 0.887 when compared to the direct laboratory results. Excellent estimation capability was achieved using this method in comparison with previously developed models. The equation, proposed in this paper, provides another evaluation method for the design engineers to estimate swelling pressure in practice.

Keywords Clay soils · Swelling pressure · Subgrade · Pavement · Statistical model

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1 Introduction

Development of transportation infrastructures, such as roads and railways, is fundamentally related to earthworks due to their construction foundations and supportive embankments [1,2]. Several road sections constructed on expansive clayey subgrades have experienced severe pavement cracking and premature loss of serviceability. Such roads often become distressed due to volume change associated with seasonal moisture content fluctuations in the underlying soils [3]. The annual cost of damage is estimated at £150 million in the UK, $1000 million in the USA and many billions of Pounds worldwide [4]. Rational design of a pavement dictates identification and estimation of the swelling characteristics of the clayey layers under the pavement structure to avoid damage. Swelling-related parameters, particularly pressure, can be estimated during preliminary site investigation by the use of the correlations available in the literature. The empirical expressions relate the swelling parameters to other geotechnical characteristics determined by relevant tests [5]. Generally, direct estimation of swelling parameters is difficult to measure, but sometimes it is desirable in order to ascertain the predicted results. The available correlations are either mechanistic-empirical or empirically based on statistical analysis.

The earlier prediction equations have logarithmically related the swelling pressure to liquid limit and dry unit weight [6,7]. These two parameters are important in describing soil behavior and to develop prediction expressions based on soil index properties and physical state of the clayey soils [8]. Several regression equations have correlated between swell percentage and pressure of Madinah clay and initial dry unit weight, initial water content, clay content, and liquidity index at the start of test. Liquid limit and plasticity index have also been introduced [9]. However, it was claimed that for pavement design process using the new model developed within this research project.

6 Conclusions

The main conclusions through this study can be summarized as follows:

XRD analysis revealed that soils were clayey marls with 64% calcite and 35% aluminosilicate. Montmorillonite has been observed to be abundant with smaller percentage of illite and kaolinite. The mineralogical composition of clay affects the swelling pressure, where the percentage of calcite controls the dry density of the soil and increase in the amount of aluminosilicate influences soil behavior considerably. A new equation to estimate the swelling pressure in subgrade soils to be used in pavement structural design and avoid future damages due to excessive heave was developed. The proposed expression was obtained by multiple regression between the swell test results, measured by a free swelling odometer, and the soil dry density, ρ_d, water content, w, and plastic limit, PL, of 40 samples collected along the sections of national roads of Tebessa city, Algeria. The strength of modeling was checked by VIF method to examine multicollinearity. The proposed equation presented a high correlation coefficient, R^2, of 0.887 when compared to the direct laboratory results. The model proved its excellent estimation ability when compared with the previous models cited in the literature.

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