Alexandria Engineering Journal (2016) **xxx**, xxx–xxx

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Alexandria University

Alexandria Engineering Journal

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ORIGINAL ARTICLE

Estimation of soil permeability

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Received 3 November 2015; revised 3 July 2016; accepted 11 July 2016

KEYWORDS

Hydraulic conductivity;
CPT;
Pumping;
Falling head

Abstract Soils are permeable materials because of the existence of interconnected voids that allow the flow of fluids when a difference in energy head exists. A good knowledge of soil permeability is needed for estimating the quantity of seepage under dams and dewatering to facilitate underground construction. Soil permeability, also termed hydraulic conductivity, is measured using several methods that include constant and falling head laboratory tests on intact or reconstituted specimens. Alternatively, permeability may be measured in the field using insitu borehole permeability testing (e.g. [2]), and field pumping tests. A less attractive method is to empirically deduce the coefficient of permeability from the results of simple laboratory tests such as the grain size distribution. Otherwise, soil permeability has been assessed from the cone/piezocone penetration tests (e.g. [13,14]). In this paper, the coefficient of permeability was measured using field falling head at different depths. Furthermore, the field coefficient of permeability was measured using pumping tests at the same site. The measured permeability values are compared to the values empirically deduced from the cone penetration test for the same location. Likewise, the coefficients of permeability are empirically obtained using correlations based on the index soil properties of the tested sand for comparison with the measured values.

1. Introduction

Soils are permeable materials because of the presence of interconnected voids that permit the flow of fluids from locations of high energy to locations of low energy. Proper measurement/evaluation of soil permeability is required for calculating the seepage under hydraulic structures and water quantities during dewatering activities. Soil permeability is affected by several factors including voids ratio, distribution of inter-granular pores, and degree of saturation. The discussion presented herein is limited to evaluating the coefficient of permeability of saturated soils. The coefficient of permeability exhibits a wide range of values up to 10 orders of magnitude from coarse to very fine grained soils [16]. Furthermore, previous studies on the coefficient of permeability show that the coefficient of permeability is highly variable within the same deposit with a coefficient of variation as high as 240% [17]. Laboratory constant and falling head permeability tests (e.g. [1]) are easy to perform. However, it is very difficult and expensive to obtain undisturbed samples from granular soil deposits. Accordingly, these tests are typically performed on specimens reconstituted to relative densities “close” to those from the field. Thus, the measured permeability may not be representative of the field permeability because the soil fabric is destroyed due to sampling techniques. Field permeability tests offer another technique for measuring permeability without sample disturbance

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Peer review under responsibility of Faculty of Engineering, Alexandria University.

http://dx.doi.org/10.1016/j.aej.2016.07.034

making it more suitable for granular soils. However, it is difficult to evaluate the hydraulic gradient acting on the soil during field permeability tests. Furthermore, most methods of permeability calculation from field tests are theoretically based on several assumptions regarding the test including the water head, flow path. The reliability of the measured values of permeability using field testing depends to what degree the assumptions represent the actual site conditions.

Field permeability may be measured using pumping tests which provide a good measurement of the permeability of an aquifer (e.g. [3,6]). Pumping tests provide an average value of the coefficient of permeability at the test site. Alternatively, permeability could be measured using either falling or constant head tests performed in boreholes (e.g. [2–5]). Tests performed in boreholes provide a detailed permeability profile of the measured permeability values versus depth compared to the average permeability from pumping tests. The test equipment and procedures used meet the guidelines and conditions of BS 5930 [3] and BS 6316 [7]. The measured permeabilities are compared to the values obtained from the results of the Cone Penetration Test (CPT) which was performed in the top soil layer. Moreover, the measured values are matched to permeability estimates obtained from grain size distribution tests as outlined below.

2. Subsurface ground conditions

Rotary drilling and coring were used to execute the boreholes. Water was used as a drilling fluid to eliminate the influence of other drilling fluids (e.g. bentonite) on the soil permeability. Disturbed soil specimens were obtained using split spoon samplers in cohesionless soil layers. Undisturbed samples were extracted using a double tube core barrel with a 76 mm internal diameter in rock formations. The extracted soil specimens were examined, visually classified and then sent to the laboratory for testing.

The subsurface ground consists of a top silty sand layer which extends from the natural ground surface to a maximum depth of 5-m. This layer is underlain by weak sandstone and very dense sand with cemented bands and lumps which extend to the end of drilling, located 40 m below the natural ground surface. The Standard Penetration Test (SPT) was performed in the sand layers at 1-m intervals. Cores were extracted from the rock layers and Rock Quality Designation (RQD) values were calculated at different depths. Fig. 1a and b shows the variation of the SPT-N and RQD with depth, respectively. The recorded SPT-N values of the top silty sand layer exhibit large variability ranging between 2 and 44 indicative of very loose to dense sand. The measured RQD values vary between 10% and 78% with an average value of approximately 30%. Thus the rock quality is described as very poor (RQD less than 25%) and good (RQD between 75% and 90%). The groundwater table at the site is located approximately 1-m below the natural ground level. Representative soil specimens were extracted from the various layers for laboratory testing which included natural moisture content, gradation, Atterberg limits on fines, specific gravity, and natural unit weight for core samples. Grain size distribution curves of representative soil specimens at different depths from a number of boreholes are shown in Fig. 2. According to the Unified Soil Classification System, the tested soil specimens are mainly composed of sand which constitutes 51.4–73.5% of the samples. The percentage

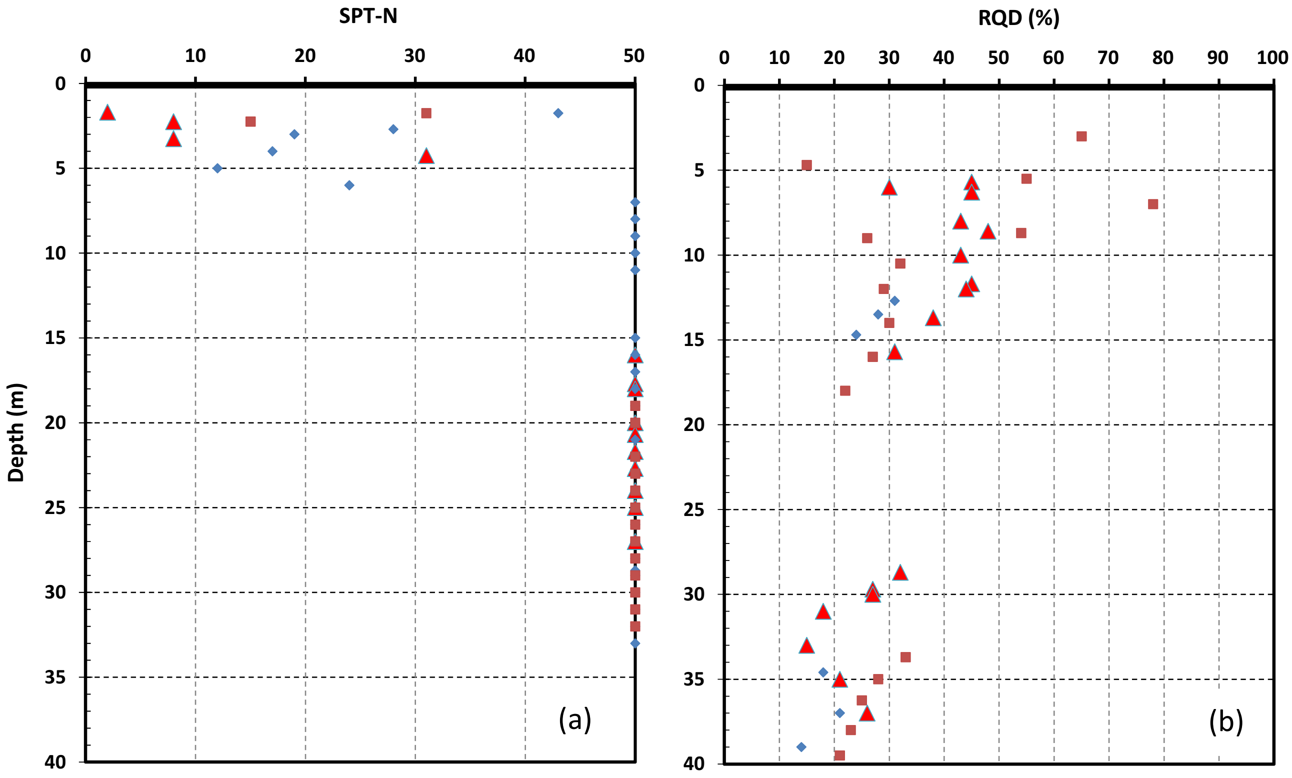

Figure 1 (a) Variation of SPT-N with depth and (b) variation of RQD with depth.

Please cite this article in press as: A.F. Elhakim, Estimation of soil permeability, Alexandria Eng. J. (2016), http://dx.doi.org/10.1016/j.aej.2016.07.034