Anisotropy Analysis Of Hydraulic Conductivity In Artesin Well

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Abstract— *The use of numerical models to investigate the flow in groundwater porous media has grown significantly in the world with the purpose of analyzing the planet water resource. There is a need of understanding the underground water storage to create an objectives of how to explore it. Groundwater has great potential for exploitation, with the privilege of normally containing good quality for human consumption. The hydraulic conductivity of the soil can be measured through different empirical models that correlate the permeability and properties of the grains. This work develops a microscopic analysis of the grains and through a numerical simulation of the flow in porous media evaluates the hydraulic conductivity of the soil. The numerical model was developed in the Computational Fluid Dynamics software, OpenFoam and allows to investigate the anisotropy of hydraulic conductivity.*

Keywords— Groundwater; Porous Media; Computational Fluid; Dynamics, Hydraulic; Conductivity; Soil Anisotropy.

I. Introduction

This work develops a soil characterization through the test of real grain density, soil grain size and analysis of the geometric shape of the grain. The experimental results were used to create a numerical Computational Fluid Dynamics model at OpenFoam. This work was analyzed only in nature, then the study consists of analyzing the soil without deflocculates. For the mesh construction, it was necessary to calculate the mean quantity of grains retained in each sieve, by the granulometry test and to use the measurement of the soil grains volume, to represent the value of each void dimension. The computational domain was built in proportionality to the quantity of grains and the volume of fraction for each dimension of grain analyzed. Considering that the soil sample used for the experiment contained grains without deflocculates, it was possible to observe the difference between the existing empty spaces in the longitudinal and transverse directions of the well. The hydraulic conductivity anisotropy of the soil was identified and investigated for two different directions of the flow. The results suggest a model of a bi-dimensional hydraulic conductivity for the studied soil sample from the Brazilian crystalline aquifer.

II. TEST AREA

A. Water distribution

Water is a fundamentally resource for maintenance of life planet. However, around 2% this water is fresh water and about 12% these waters are groundwater found in aquifers (MACHADO, 1999).

In Brazil around 55% of the cities use groundwater as their main resource.

B. Crystalline aquifer

The analyzed area is the crystalline aquifer located in São Paulo state at Nazararé Paulista region. Fractured rocks form the area where water is stored, but above the fractured rock, there is a region with granular porosity, enabling the use of wells (AMBIENTE, 2007)

III. Metodology

The samples were collected in the Nazaré Paulista region and analyzed at the civil engineering and mechanical engineering laboratory at Rio de Janeiro federal university, on the campus of Macaé.

The analysis ware made according five steps for soil characterization and each step is critical for later mesh construction.

A. Real Grain Density

For this test about 500 grams of soil sample were used. The first distilled water was used for humidify different soil samples. After the samples ware placed in three different temperature, twenty one Celsius degrees as room temperature, one hundred five Celsius degrees for drying in green houses

ISSN 2447-8326. V.1

and one hundred fifty Celsius degree for air removal between soil particles.

With the following procedures completed, the samples were weighed together with perforated cords and after the collection of experimental data; it was possible to obtain the real grain density of soil sample.

The Fig.1 show the methodology described above. This figure is by the authors of this paper.

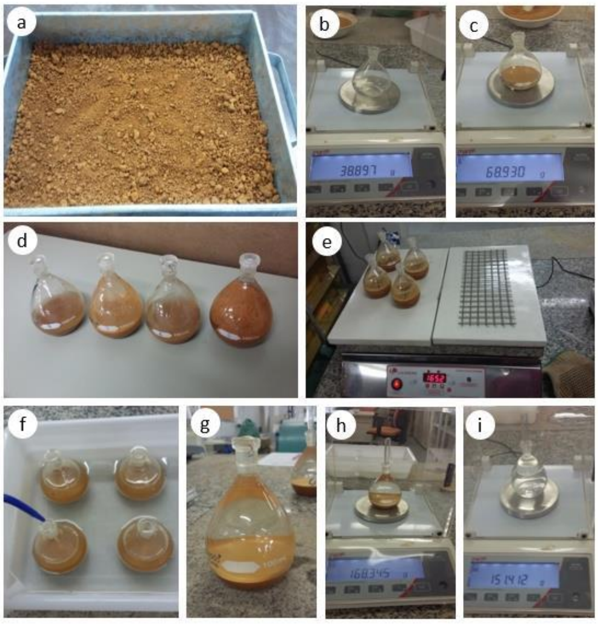

Fig.1: Methodology for to analyze the Real Grain density of the sample.

In the above figure, the letters represent the following steps to determine the actual grain density:

a) soil in greenhouse form;

b) Weight of empty pycnometer;

c) Weight of the pycnometer with soil;

d) Pycnometers with water to cover the ground;

e) Being heated;

f) In a water bath;

g) Pycnometer with water to the meniscus;

h) Weight of the system with the cork stopper;

i) Weight of the pycnometer with water and the cork stopper.

Thus, the measured density is 2.624g/cm^3.

B. Grain Size Test

About sixty grams of the soils sample were placed in greenhouse with temperature from one hundred five to one hundred ten Celsius degrees, about twenty for hours.

After this process, the samples were placed in a mechanical stirrer with seven sieves sequentially. Each sieves has 1.18; 0.6; 0.425; 0.212; 0.150 and 0.075 millimeters in diameters respectively.

Finally, after the whole screening process the mass in each sieves were weighed and an estimate was made of the proportion of grain sizes in the sample. The Fig.2 show the process of sample in the mechanical stirrer and the sample being placed in sieves.

Fig.2: Sieving the soil on the mechanical stirrer.

C. Soil Microscopy

After of to analyze the mass in each sieves, a analyze microscopy of the soil sample were made whit a professional USB Zoom 1000x digital microscope and a scanning electron microscope.

With the digital microscope, it was possible to analyze the shape of the grains retained in larger sieves, already the smallest sieves had the retained grains analyzed by electron microscope.

The Fig. 3 show the shape of the grain retained by sieves from 1.18 mm to 0.075 mm.

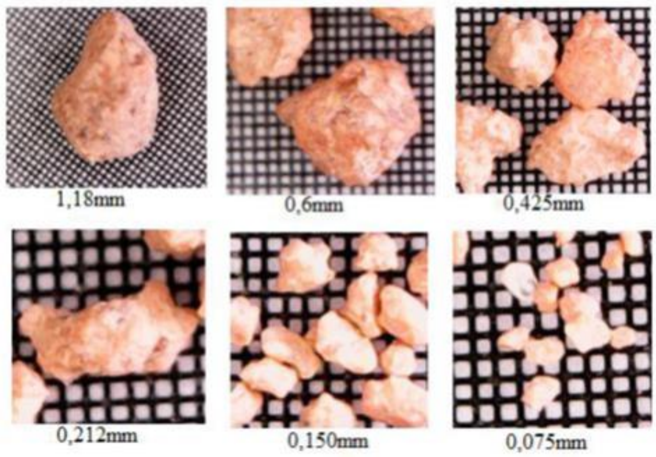

Fig.3: Shape of the grains by digital microscope

The Fig.4 show the shape of the grains found below 0.075 mm diemeter sieve. Thus, it was possible to estimate a size of aroud 0.030 millimeters diameter for sample whitout deflocculants.

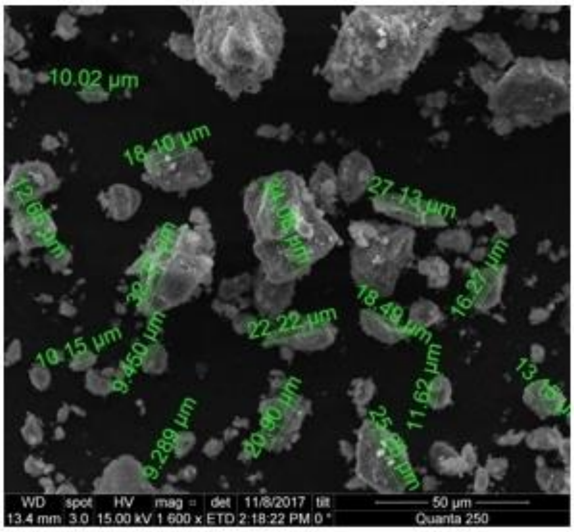

Fig.4: Shape of the grains by eletron microscope

Following the figures and analyzing them it is correct to state that the soil sample is composed of grains with characteristics of sub-angle for larger grains and sub-rounded for smallest grains.

Also, it is necessary to observe that the types of geometry cause higher voids indices, because the interaction of the grain is smaller.

D. Liquidity limit

For to determine the liquidity limit of the soil sample, 100.1 grams of sample were used and water was added until a homogeneous mass was reached.

Part of the mass was transferred to the Casagrande meter and distributed so that the center reached ten millimeters diameter.

For small portions of the dough are taken from the edges and placed in different containers to determine the moisture.

This process was redone five more times and it was possible to find a curve that show liquidity limit 46% for this soil.

E. Plasticity Limit

The test of plasticity limit used ten grams of sample and water for a homogeneous mixture. The dough was then shaped into ellipsoidal shape to a diameter of three millimeter and one hundred millimeters in length.

Fragments this mass were removed and weighed before and after drying to determine the moisture contend. Through the data it was possible to estimate a plastic limit 35% in sample.

IV. Mesh Result

For mesh building it was necessary to estimate by calculations the amount of the grain retained in each sieves in the grain size test and the void volume for an area 2576 cubic millimeters, according to a study by Stanford University on media flow porous.

For a porosity of 6.76% obtained through of previous data, the grains were draw in software Solid Works and attached in OpenFoam.

This second software is used to represent porous media flows, also is the open source software used in engineering and science to solve complex problems (ARAÚJO, 2016).

The Fig.5 show the flow in OpenFoam with two-dimensional flow and the solver used is the SimpleFoam.

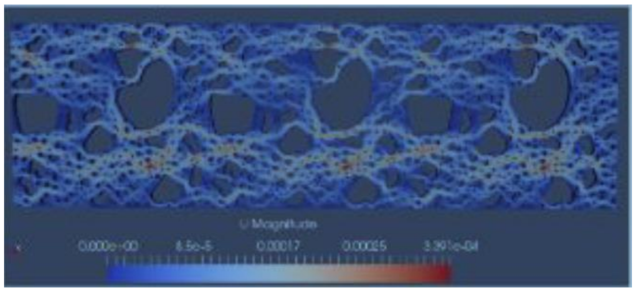

Fig.5: Water flow velocity profile

V. Anysotropy

Through of the mesh, it is possible to analyze and to observe that the number and the shape of the grains is different in vertical and horizontal directions and this entail in different flow.

Through the simulation analisys it is possible to predict the hydraulic conductivity anisotropy in of this soil. Each sample has a degree of anisotropy and the objective of this work is to have a computational support this soil parameter. With the methodologies proposed in the literature by Hazen, Gustafson, Nishida e Nakagawa and Kozeny-Carman the two-dimensional conductive of this soil has been investigated (SVENSSON, 2014)

Acknowledgment *(Heading 5)*

This work benefited from the support of Rio de Janeiro Federal University Laboratories. The research was part of the Advanced Computational Fluid Dynamics project approved by Foundation for Research Support of Rio de Janeiro State - FAPERJ.

VI. References

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