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Constant Head Determination of the K-Value of Umudike Aquifer Medium Granular Soil

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ABSTRACT

The permeability coefficient or the hydraulic conductivity K-value of Umudike granular soil of an aquifer medium was determined using the constant head permeameter to ascertain the ease with which ground water seeps through the soil. The sample was collected at a bore-hole site of 54m deep, the depth of the dynamic ground water level DGWL. The site is located at latitude 5.477012 (05°28'36.900''North) and longitude 7.539770 (07°32'23.170''East) at Umudike within the university surrounding. The test conducted includes sieve analysis and permeability test (constant head). The sieve analysis test enabled us classify the soil as recommended by the Unified Soil Classification System (USCS) as a sandy soil (medium sand soil). The constant head experiment was conducted to enable us determine the coefficient of permeability as it is the recommended test for granular soil. From the results of the experiments, the coefficient of permeability K of the soil sample ***K =1.794 X 10^{-3}cm/s*** *is in the range of 1.0 – 10^{-3}cm/s which means that the coefficient of permeability is medium. Based on this result, if the soil was taken at a deeper level, the coefficient of permeability K will be higher, showing that water can subsequently flow with ease from the water level to the suction pipe of the bore-hole system.*

Keywords- *constant head, permeability, Umudike soil, granular soil, determination.*

I. INTRODUCTION

With wide applications in agricultural, geotechnical, mechanical and civil engineering, granular materials simulation has attracted a significant attention in scientific and technical fields. An increase of the number of the projects has been launched to investigate its internal mechanism and comprehensive properties. According to the definition, granular materials is a compound of matter of a large number of discrete solid particles with the intestinal void filled with liquid or gases [1]. Some representative samples are soil, gravels, coals, and wheat flour. Granular materials have many distinct features such as Mohr-column failure, fluidization and liquefaction behaviours [2]. The study of such medium normally involves inter-discipline concepts like fluid dynamics, elasticity and plasticity theories continuum and structure mechanics and rheology (study of the flow of matter primarily in the liquid state but also as soft solid or solid under conditions in which they respond with plastic flow rather than reforming elastically in response to applied force). Granular materials can be classified by the size and shape of particles, the influence of stuffing fluid, the speed of motion, the compactness of structures and some other factors. Permeability is considered one of the most important parameters in soil mechanics. In common practise, the permeability coefficient is usually obtained by constant head permeability test and is utilized in filtration-drainage, settlement and stability and catenations. These problems are extremely important for environmental aspects such as waste water management, slope stability control, erosion, and structural failure related with the ground settlements issues. In this aspect, empirical equations are utilized to predict these parameters. The term granular material covers a variety of natural occurring and artificial graded aggregates. The materials used include sand, gravel and crushed rocks with the maximum particle size often being as large as 38mm. All of these materials exhibit some similarities in their mechanical behaviour, because their strength is derived from interlock between the aggregate particles [3]. Permeability in fluid mechanics and earth science commonly symbolized as K is a measure of the ability of a porous material to allow fluid to pass through it. The S.I unit of permeability is m/s [1]. Permeability is primarily an indication of the ability of the soil to store water. The more permeable the soil is, the greater the seepage. Pore soil structure can lead to excessive water loss from the soil surface, due to reduce water entering (infiltration) into the profile. Various physical properties of the granular materials enhance its permeability properties such as soil texture, pore size present in the soil. Water moves faster through large pores than small pores. The bigger the pore, the more material it will move. Other biological factors enhancing permeability are roots and worm channel, organic matters which increases permeability by increasing the stability of soil aggregates. In road pavements, permeability influences the performance of super pavements. Percolation of water through interconnected voids of an asphalt pavement causes stripping of the asphalt- bound layers as well as the deterioration of the foundation layers. This is why it is very important to construct with adequate fluid density and they should be relatively impermeable to moisture. Consequently, on a structural ground, high permeability causes differential settlement. Therefore, soil permeability study becomes very important during preconstruction planning and also in maintenance too. The present research work is aimed at determining the ease at which Umudike aquifer soil medium of granular texture transmits ground water.

II. THEORY

Water moves through the soil due to the force of gravity, potential head, velocity head, pressure head and capillarity. At from zero to one-third situation, water moves through soil due to gravity. This is called saturated flow. At higher suction, water movement is called unsaturated flow. Water infiltration into the granular soil is controlled by the following factors:

- Soil texture
- Soil structure. The fine texture soils with granular structure are most favourable to infiltrate water
- The amount of organic matter. Coarse matter is best and if on the surface helps prevents the destruction of soil structure and the creation of crusts.

- Depth of soil to impervious layer such as hard pans or bed rock.
- The amount of water already in the soil.
- Soil temperature. Warm soil take in water faster while frozen soils may not be able to absorb depending on the type of freezing.

Water infiltration rates ranges from 0.25(0.098m) per hour for clay particles to 2.5 (0.98) per hour for sand and well stabilized and aggregated soil structures. Water flows through the ground unevenly called "gravity fingers", because of the surface tension between the water particles [4]. Permeability is the property of a porous material to permit passage or seepage of fluids such as water through the interconnecting voids. The nature of ground flow through soil can be laminar or turbulent. In laminar flow, adjacent flows are parallel. The resistance to flow depends upon the type of soil, size and shape of the soil particles (rounded, angular, or flaky), and the degree of packing (density of soil and thus upon the size and geometry). Turbulent flow is prevented by soils finer than gravel and hence for the most practical purposes in studying ground water flow, It is sufficient to consider laminar flow [5]. The ground water flow can be under pressure or under no pressure. Example of pressure flow is the artesian water flowing under pressure head between two confining impermeable layers of soil or rock. For speeds of flow of water through fine sands and soils of smaller particle sizes that are likely to occur in nature, Darcy's empirical law may be valid thus:

$$\frac{Q}{At} = V = \frac{Kh}{L} = Ki \qquad (1)$$

Q = total volume of water flowing through a porous medium of total cross-section A. Under a hydraulic gradient **(i =h/L),** in time **(t), K** is called coefficient of permeability, its dimension is **(L/T)**.

V is the velocity of discharge over the whole area. The mean seepage velocity through the voids is

$$\mathbf{Vs} = \frac{\mathbf{V}}{\mathbf{n}} \qquad (2)$$

K is the engineer's concept of permeability. The physicist defines permeability of a media K in such a way that it is independent of the fluid. Therefore, K depends on temperature. In solids the fluid is invariable water and K = K/ɲ when ɲ =kinematic viscosity of the fluid [6].

Flow of the water in soils occurs in response to a difference in total head between two points (or more precisely), it occurs in response to a gradient in total head, with flow being down gradient- in the direction of reducing total head. Two important issues are related to the permeability; the first is anisotropy. A soil is called anisotropic when the permeability is not the same in different directions. The second is that of homogeneity or heterogeneity. A soil is called heterogeneous when the permeability differs from place to place. A homogenous soil can either be isotropic or anisotropic, the same holds for heterogeneous soils. Darcy's law is a simple mathematical statement which neatly summarizes several familiar properties that groundwater flowing in aquifers exhibit. If there is no pressure gradient over a distance, no flow occurs (these are hydrostatic conditions). If there is a pressure gradient, flow will occur from high pressure towards low pressure (opposite the direction of increasing gradient- hence the negative sign in Darcy's law) the greater the pressure gradient, (through the same formation material), the greater the discharge rate.

III. MAT-METHODS

The sample for the experiments was collected at a borehole site at a solid-liquid medium just at the point of the dynamic ground water level DGWL at that area. The location is at Umudike just within the university surrounding at a latitude of 5.477012 **(05°28'36.900''North)** and longitude of 7.539770 **(07°32'23.170'' East)** as shown in Fig 1 below**.** The particle size distribution method was used in the classification. Table 1 shows the available sieve sizes in the laboratory and the result of the sieve analysis is as shown below in Tab.2. The constant head permeameter was used to determine the permeability (hydraulic Conductivity) of the sandy soil by the constant head test method. The constant head test method is used for permeable soils with k>10-4 cm/s.

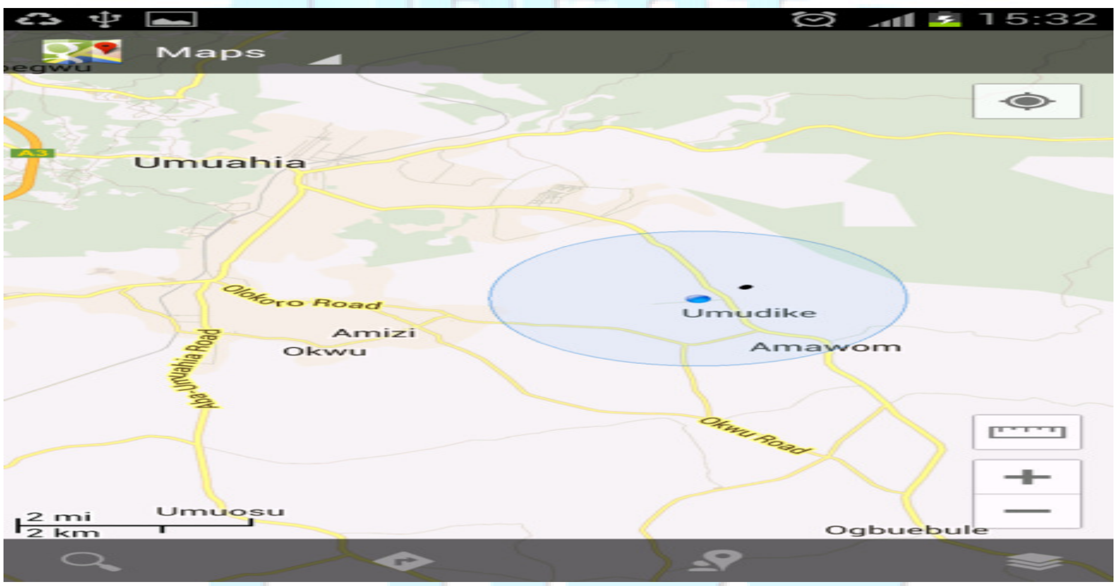

Figure 1: Map Location of sample Site

Table 1: Sieve sizes available in the laboratory

Sieve size	Number
2.00mm	10
1.18mm	16
1.00mm	18
0.6mm	30
0.5mm	35
0.425mm	40
0.25mm	60

IV. RESULTS AND DISCUSSION

The sieve analysis was done properly and the result gotten is as shown in Table 2 below

Table 2: Sieve analysis result

Sieve size	Initial weight of sieve	Mass of soil retained on each sieve	Percentage of mass retained on each sieve	Cumulative percentage retained	Percentage finer
2.00mm	0.335kg	0.16kg	9.91	9.91	90.09
1.18mm	0.355kg	0.54kg	33.44	43.35	56.65
1.00mm	0.365kg	0.135kg	8.36	51.71	48.29
0.60mm	0.375kg	0.35kg	21.67	73.38	26.62
0.50mm	0.315kg	0.155kg	9.60	82.98	17.02
0.425mm	0.325kg	0.06kg	3.72	86.70	13.30
0.25mm	0.285kg	0.185kg	11.46	98.16	1.84

From the constant experiment, the quantity of water discharged will be taken against the time with the help of the stop watch. Thus after that the graph of the Q (volume of water discharged) against time (T), the slope of the graph gives the effective value of discharge (q) of flow. The graph is as follows:

From the above graph, the slope of the graph which is q =18.96cm^3/s.

Table 3: Showing the discharge rate.

Volume of water discharge, (Q) cm^3	Time (t) sec
450	32.56
460	33.00
470	33.90
480	34.05
490	34.30
500	35.11

Thus Coefficient of permeability for a constant head test is given by

$$k = \frac{Q}{iAt} \qquad (3)$$

Where Q = volume of water discharged (cm^3)

i = hydraulic gradient = h/L

h = effective head (cm)

L= length of the soil sample (cm)

A = total cross-sectional area (cm^2)

t = time (sec)

Thus the equation will be

$$k = \frac{qL}{hA} \qquad (4)$$

The reading from the laboratory experiments is as follows.

L = 11.2cm
h = 235.5cm
A = area of a cylinder = $2\pi r^2 + 2\pi rh$. Where r =4.95 then A = 502.359cm^2
q = 18.96cm^3/s
i = h/L =235.5/11.2 = 21.027
Therefore, K = 18.96/(21.027 X 502.359) = **0.001794cm/s**

K =1.794 X 10^{-3}cm/s

V. CONCLUSION

From the results of the laboratory examination, it is concluded that,

1. **The soil was classified as sandy soil according to universal classification system,**
2. **The soil being a granular soil has a medium hydraulic conductivity,**
3. **A higher value of permeability could be achieved by boring deeper than 53meters in Umudike, Nigeria.**

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