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Design, Fabrication and Testing of Falling Head Permeability Test Apparatus

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Abstract: The project is a fabrication of head permeability equipment using locally sourced material. The aim is to provide a local way to determine the hydraulic conductivity of soil for engineering design and construction of projects such as dam, irrigation Schemes, Dykes, and Drainages etc. The permeability test in this regard was based on falling head approach and is the hydraulic property of the porous material which is the measure of the ease with which fluid is allowed to pass through the void spaces of a soil mass. The equipment was used in testing of soil samples for coefficient of permeability of soil for practical and construction purposes. The fabrication apparatus is low cost and easy to operate and portable equipment hence can easily be procured by construction companies and schools.

Keywords: Permeability, hydraulic conductivity, dykes, falling head, coefficient of permeability

1. Introduction

Permeability is a measure of the ease in which water can flow through a soil volume. It is one of the most important geotechnical parameters. However, it is probably the most difficult parameter to determine. It is the measure of the ability of a material to support the formation of a magnetic field within itself, otherwise known as distributed inductance in transmission line theory. Hence, it is the degree of magnetization that a material obtains in response to an applied magnetic field (Brown et al; 2004).

A certain number of problems relating to the interacting factor of soils had been the major concern of geotechnical engineers over the years. This is because the engineering properties of soils exhibits varying and uncertain behaviors, due to the complex and imprecise physical process associated with the formation of these materials which is a matter of concern for geotechnical engineers. Amongst the many interacting factors of the soil that the engineer has to deal with, permeability is one of its very important engineering properties (Whiteman, 1969).

This reason is attributed to the fact that it plays a predominant role in solving a good number of engineering problems such as settlement of buildings, yield of aquifer, seepage through and below the earth structures; it also controls the hydraulic stability of soil masses. It is important to note that the permeability of soils is influenced by various factors such as particle size, structure of soils, shape of particles, void ratio, properties of water and degree of saturation (Handsbo, 1994). Furthermore, it is needful to mention that several methods can be adopted in the determination of the coefficient of permeability in the field and laboratory generally depending on the site conditions and type of soil. Other research works have been carried out to relate permeability and compaction characteristics of soils to their physical properties: Rowan and Graham (1948) used gradation, specific gravity, and shrinkage limit in their correlation equations, Davidson and Gardiner (1949) eliminated the specific gravity from the equations of Rowan and Graham (1948but included a plasticity index. Taylor (1948) formulated a theoretical equation, based on the capillary tube model, for flow through porous media, relating the permeability with a representative grain size etc. The physical properties used generally include plasticity characteristics (liquid limit, plastic limit, shrinkage limit, and plasticity index), specific gravity, and grain size distribution that are attainable from relatively straightforward laboratory tests. However, specific index properties used in various correlation equations differ considerably. To ascertain the permeability coefficient of the soil, soil samples are to be collected and taken to the laboratory to carry out the above mention practical.

1.1. Statement of the Problem

Soil permeability is a key test for the determination of infiltration capacity of any soil for civil engineering construction of most water related facilities in the laboratory. The major equipment used in determining the coefficient of permeability in the laboratory is the falling head permeability apparatus which is rare to come by and it is very expensive. The department of civil Abdu Gusau Polytechnic has only one and many students deserve to have good knowledge of the permeability theory and practical.

1.2. Aim of the Project

The aim of the study is to fabricate falling head permeability apparatus, using local source material.

1.3. Objectives of the Research

1. To fabricate the falling head permeability equipment and make this apparatus readily available with local materials and efforts.
2. To provide more avenues to avail students the use of the apparatus by adding more quantity to the civil engineering profession.

2. Literature Review

Soil can be divided into three major categories which are organic soil, cohesive and cohesion less. Cohesion less soils which the soil particle does not stick together. Cohesion means the act or state of cohering, uniting, or sticking together. While the cohesive soil contains clay minerals and possess plasticity and the particles of soil stick to each other cause by water- particle interaction and attractive force between particles. Organic soils are typically spongy, crumbly and compressible. The most important property of soil related to rainfall induced slope failure is permeability (Cheng and Jack, 2005).

Soil permeability is the property of the soil pore system that allows fluid to flow. It is generally the pore sizes and their connectivity that determine whether a soil has high or low permeability. Water will flow easily through soil with large pores with good connectivity between them. Small pores with the same degree of connectivity would have lower permeability because water would flow through the soil more slowly. It is possible to have zero permeability (no flow) in a high porosity soil if the pores are isolated (not connected). It is also to have zero permeability if the pores are very small, such as in clay (Cheng and Jack, 2005).

Actual water movement is thought of as small, interconnected, irregular conduits. Because the water moves through the voids, it follows that the soils with large voids such as sands are generally more permeable than those with smaller voids such as clays. Additionally, because soils with large voids generally have large void ratios, it may be generalized that permeability tends to increase as the void ratio increase. Because water movement can have profound effects on soil properties and characteristics, it is an important consideration in certain engineering application. Cheng and Jack, 2005).

There are several factors which influence the permeability of soil such as soil texture, organic content in soil, the density of soil and vegetation. Soil texture refers to the proportions of the sand, silt, clay in soil. Course textured sandy and gravelly have the largest pores and the most rapid permeability. Fine textured clayey soils have tiny pores and very slow permeability rates. Medium textured barns, silt barns and clay barns have intermediate rate of permeability (Cheng and Jack, 2005).

3. Materials and Methodology

Figure 1: the falling head permeability Apparatus

3.1. Meterials:
Are as follows:

3.1.1. Stand Pipe: - the stand pipe is made of transparent cylindrical acrylic tube designed to indicate the difference in head, it also consist of a funnel to receive water at the top and clips at top and bottom firmly tight to prevent leakage as shown in fig. 2.

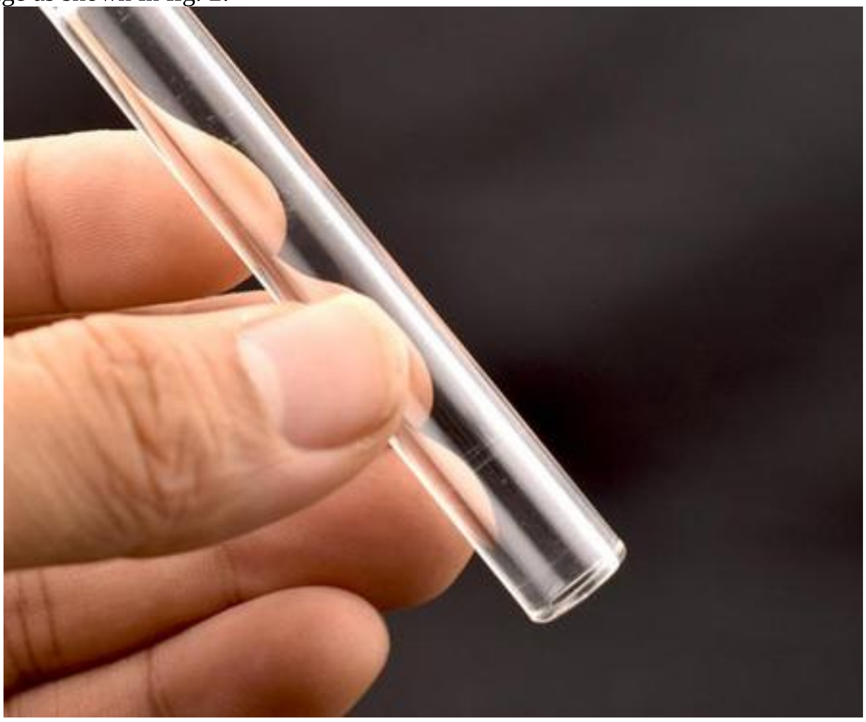

Figure 2: the stand pipe

3.1.2. Wooden/Steel Rule: - This is a wooden/steel meter rule graduated clearly to indicate the difference in head, see fig. 3 below.

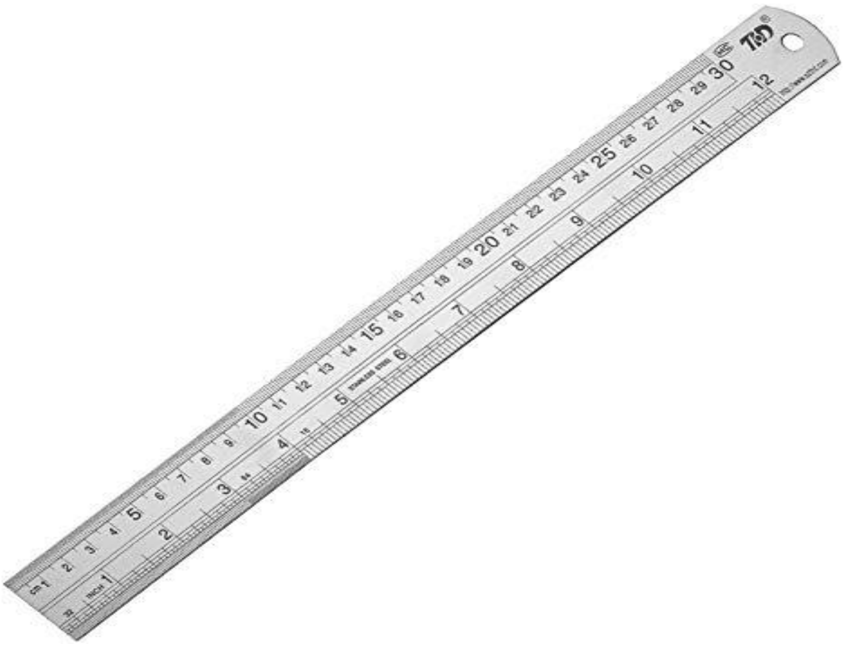

Figure 3: the wooden/steel rule

3.1.3. Frame and Board:- The frame was constructed using mild steel angle iron to serve as a stand upon which the stand pipe assembly was mounted while the board is a flat metal sheet (6.3mm thick) used as a platform for mounting the stand pipe as shown in fig. 4.

Figure 4: constructed frame with the board

3.1.4. Permeameter:- The permeameter was made of non-corrodible material with a capacity of 1000ml, with an internal diameter of 100mm, and effective height of 127.3mm, the mould has a detachable base plate fig. 5.

Figure 5: the permeameter

3.1.5. Cylinder:-This was made of non-corrodible material to keep the water and specimen in their original conditions. No matter how long the test last see figure 6 below.

Figure 6: the cylinder

3.1.6. Drainage Base:- A detachable non-corrodible material constructed with drainage pattern at the base of the cylinder having an outlet with a release valve (fig. 7).

Figure 7: the drainage base

3.1.7. Drainage Cap:- A detachable non-corrodible material constructed with inlet/outlet to serve as cap for the cylinder (fig. 8).

Figure 8: the drainage cap

3.1.8. Porous Disc:- This is a non-corrodible material porous in nature to allow free flow of water, it was provided both at the top and bottom of the soil specimen in the cylinder (fig. 9).

Figure 9: the porous disc

3.1.9. Control Valve:- This is a readymade valve ¾ in size attached at the top of the drainage cap to control the flow of water.
3.1.10. Water Sealant:- This is a rubber seal circular in nature produced from a water resistant material.

3.2. Design, Fabrication and Methodology
3.2.1. Design and Fabrication

In this project, the falling head permeability was chosen. However, the main design and fabrication approach of this type was based on the design and fabrication of falling head permeability.

The design of the falling head permeability is based on the performance test in any laboratory and upon the information extracted from various books and individuals. Permeameter was fabricated using
(i) Cylinder – A cylinder made of noncorrosive material having internal diameter 100mm, external diameter 115mm, height 127mm and volume capacity 0.997Lt.
(ii) Stand and base – A cylindrical iron stand along with a circular iron base is used to support the permeameter,
(iii) Steel rim and plate–The arrangement of plate and steel rim holds the sample in position and allows the cylinder to be filled with water to stand over it,
(iv) rubber seals – It is not a structural component of the permeameter but it is used to seal the lateral sides of the sample when the vertical permeability is being determined and vice- versa. Sometimes silicon sealant gel is used to seal any leakage of water between the steel rim and the cylinder,
(v) stand pipe – graduated transparent pipe of internal diameter 12mm used to measure the head difference.

3.2.2. Laboratory Permeability Test Methodology (Falling Head Approach).
3.2.1. Aim: To determine the Coefficient of permeability (k) for a given soil sample;
3.2.2. Apparatus:
1) Permeability apparatus. 2). Extruder 3). Spatula 4). Time 5). Permeameter
6). Distilled water 7). Wash bottle 8).Wire brush

3.2.3. Procedure:

Preparation of the sample
1. 2500g of the representative soil was taken and mixed with water to obtain O.M.C.
2. The permeameter was assembled for dynamic compaction. The inside of the mould was greased and it was placed upside down on the dynamic compaction base. The assembly was weighted correct to a gm (w). The collar was put to the other end.
3. Now, the wet soil was compacted in 3 layers with 25 blows to each layer with a 2.6 kg dynamic tool. The collar was removed and then the excess was trimmed off. The mould assembly with the soil was weighted.

4. The filter paper was placed on the top of the soil specimen and the perforated base plate was fixed on it.
5. The assembly was then turned upside down and the compaction plate was removed. The sealing gasket was inserted and the top perforated plate was placed on the top of soil specimen. And the top cap was fixed.
6. Now, the specimen was ready for test.

Test procedure

1. The soil specimen was fully prepared as specified above.
2. The specimen was then saturated using desired water.
3. The Permeameter was assembled (which was made of non-corrodible material with a capacity of 1000 ml, with an internal diameter of 100±0.1 mm and effective height of 127.3±0.1 mm) in the bottom tank and the tank was filled with water.
4. Inlet nozzle of the mould was connected to the stand pipe. The water was allowed to flow until steady flow was obtained.
5. The time interval ‘t’ was noted down for a fall of head in the stand pipe ‘h’.
6. Step 5 was repeated three times and ‘t’ for the same head was determined.

4. Conclusion and Recommendation

4.1. Conclusion.

The coefficient of permeability testing apparatus was fabricated based on Darcy’s law for falling head permeability. The results of falling head permeability (K) test conducted with the fabricated apparatus on a sandy silt material gave Coefficient of permeability of 3.068 x 10^{-4}mm/sec while a confirmatory test on the laboratory equipment on the same test conditions for same sample gave very similar results of 2.856 x 10^{-4}mm/sec. The two sets of tests produced similar results and thus validated the efficiency and effectiveness of the fabricated equipment. The fabricated apparatus can be used to test the coefficient of permeability of soils for construction purposes and hence engineers can use it for their practical.

4.2 Recommendation.

1. Sequel to the validation of the fabricated apparatus, it is recommended that the equipment be used in testing of soil samples for coefficient of permeability of soils for practical and construction purposes.
2. It is low cost and easy to operate and portable equipment, hence, can easily be procured by construction companies and schools.
3. Quality control of water related construction of facilities like Dams must be enforced for safety since such tests can be conducted with much ease now that the apparatus can be locally sourced.

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