Available online www.jsaer.com

Journal of Scientific and Engineering Research, 2017, 4(11):46-51

Research Article

ISSN: 2394-2630
CODEN(USA): JSERBR

Effect of Position of Least Permeable Layer on the Equivalent Permeability in a Stratified Soil System

Priyank Gupta[1]*, Javed Alam[2], Mohd. Muzzammil[2]

[1]*Research Scholar, Department of Civil Engineering, Aligarh Muslim University, Aligarh, India
[2]Professor, Department of Civil Engineering, Aligarh Muslim University, Aligarh, India

Abstract Permeability is a measure of indicating the capacity of soil to allow fluids to pass through it. It plays a vital role in various Civil Engineering problems such as seepage through the body of earthen dams, slope stability problems, ground water flow, drainage problems etc. The soil present in the natural strata of earth or in artificial made embankments is not of single type and is present in the form of layers representing a stratified soil. The flow through stratified soil may be inclined, parallel or perpendicular to the bedding plane. The materials used in this study were sand, fly ash and silt. The observed values of permeability under several arrangements of layers were determined. A comparison was also made between the results obtained in the present study and that available in literature. Present study reveals that the equivalent permeability of soil sample is dependent on the permeability of least permeable layer in the stratified sample. Moreover the change in its position within the soil samples also has a significant effect on the equivalent permeability of stratified sample. In this paper an attempt has been made to study the effect of change in position of least permeable soil in a three layer stratified soil system. The results obtained under various combinations of position of soil samples were also discussed.

Keywords Permeability; Stratified Soils; Compaction; Porosity

1. Introduction

Permeability is the measure of the soil's ability to permit water to flow through its interconnecting pores or voids. Soil permeability is a characteristic property of soil, and studying it helps to erect better structures, construct stable foundations. The knowledge of soil mechanics is important in various disciplines such as engineering geology, geotechnical engineering, agricultural engineering, hydrology and soil physics etc. In the field of geotechnical engineering, permeability has a significant influence on the consolidation characteristics of soil and as a consequence of drainage, on the mobilization of shear strength of soils. Permeability depends upon various properties of soil mass such as porosity, size and shape of soil particles, initial moisture content and compaction etc. Generally the passage of flow may be parallel, inclined and vertical to the bedding plane. Each layer will have its own value of permeability (k) depending upon the direction of flow. The direction of flow with respect to the orientation of bedding plane governs the observed value of coefficient of permeability of the stratified soil. The most simple and generally observed phenomenon is when flow is perpendicular to the stratified deposit.

Darcy's law states that the equivalent coefficient of permeability for stratified soil when the flow is taking place perpendicular to the bedding plane is-

$$k_{calc}=\sum_1^n Z_i \,/\, \sum_1^n \frac{Z_i}{k_i} \quad (1)$$

Where,

k_{calc}= calculated permeability of stratified soil based Darcy's law; Z_i= thickness of i^{th} layer; k_i= permeability of i^{th} layer; n= number of layers.

A study was carried out on three layers of different soils of equal thickness subjected to a flow perpendicular to the bedding plane [1]. The soils used were sand flour, coarse kaolinite and black cotton soil. With these three soils, six three layer systems were formed and subjected to flow perpendicular to bedding plane. Sridharan concluded that the mutual interaction among different layers of various soil types forming a stratified deposit affects the equivalent permeability of stratified deposit, which cannot be simply calculated by the use of the equation available in literature for the equivalent coefficient of permeability of a stratified deposit. Though it is known that the Darcy's law is valid for the flow through the component layers forming the stratified deposit.

In the present study the behaviour of triple layered stratified soil composed from different non cohesive and cohesive materials namely fly ash, sand and silt subjected to flow normal to the orientation of bedding planes has been presented.

2. Experimental Procedure

In the experimental work the required sediment samples i.e. sand, fly ash and silt in appropriate amount were collected. Sand was collected from Ganga river, whereas silt was taken from the nearby field in the university campus and fly ash brought from NTPC Power plant, Dadri. After proper sieving of sediments to remove unnecessary large sediments or rubbish, considerable amount of sample were taken for each type. All the sediment samples were kept in oven to dry for about 24 hours at 105^0C temperature [2]. All samples were subjected to particle size distribution analysis [3].

Specific gravity of sediments was determined by using the density bottle for silt and fly ash and pycnometer for sand [4]. Specific gravity for sand, silt and fly ash were found to be 2.60, 2.57, 2.16 respectively. The specific gravity of fly ash was observed to be less than that of silt and sand. The low specific gravity of fly ash may be due to high proportion of cenospheres or hollow particles [5].

In order to achieve the aim of the present study, a Falling head permeameter was used to determine the value of permeability of silt and fly-ash and constant head permeameter was used for sand [6] at a known porosity of 40%, which is generally achievable in most of the granular materials. In order to get a porosity of 40%, the specific gravity of silt, fly-ash and sand as well as the volume of the mould in which the material is to be compacted, was determined [7]. By knowing the volume of mould and specific gravity of the material, the mass required at 40% porosity to fill the mould was determined. Known mass of each material was filled in the mould in three equal layers with required compaction effort and thus giving a test-bed having 40% porosity. The test bed so prepared was completely saturated by passing water through it, and observations of permeability were taken by noting the time of known fall in water surface in the permeameter standpipe using a stopwatch having a least count of 0.2 seconds. The temperature was also recorded during the experimental work. In this way the permeability of sand, silt and fly-ash, were determined. The placement of individual soil samples is shown in figure 1.The six combinations of equal thickness were made by using the above mentioned selected materials as shown in figure 2. The mass required for each combination at 40% porosity was determined and filled in the mould in the same manner as mentioned earlier. All samples were tested under falling head permeameter test and coefficient of permeability was determined by using equation 2. Coefficient of permeability (k) so determined at recorded temperatures was used to compute the value of k at 27°C by using equation 3.

$$k = 2.3\frac{aL}{At}\mathrm{Log}_{10}\frac{h_1}{h_2} \tag{2}$$

$$\frac{k_{27}}{k_T} = \frac{\mu_T}{\mu_{27}} \tag{3}$$

Where,

a= area of stand pipe (cm^2); L= length of sample (cm); A= cross-sectional area of sample (cm^2); t= time (sec); h_1= initial head (cm); h_2= final head (cm); k_{27}= permeability at 27^oC (cm/s) ;k_T= permeability at test temperature (cm/s); μ_T= dynamic viscosity of water at test temperature; μ_{27}= dynamic viscosity of water at 27^oC temperature.

3. Result and Discussions

Table 1 shows the observed values permeability of each single soil sample. Table 2 and table 3 shows the observed and predicted values of permeability of triple layered soil samples in different arrangements. The predicted values of permeability were computed based on the darcy's eq. (1). The main reason behind the deviation between observed and predicted values is the effect of suction and head. Head is created when a more permeable soil lies above a less permeable soil due to which the water passing through the stand pipe of falling head permeameter flows through the above permeable layer without much restraint. On the other hand suction is effective when a more permeable soil lies below a less permeable soil due to which more permeable soil tries to suck water from the less permeable soil which results in the phenomenon of suction.

In Table 2, the first reading corresponds to a system in which silt is at top, sand is in middle and fly ash is at bottom, in second and third readings, the position of least permeable soil layer i.e. silt changes. In all the three cases the observed values are more than the predicted values because of the effect of head or suction. When least permeable layer is at top ,the bottom layers having more permeability causes suction resulting in increase in the value of permeabilty of stratified sample, and the percentage increase was found to be 35.79%. In the second case when silt is in between sand and flyash, the effect of head and suction both are there and the observed value of permeability increases by 63.60%. In the third case when silt is at bottom, the observed permeability of the stratified soil gets increased by 39.46% because of the suction effect.

In Table 3, the first reading corresponds to a system in which silt is at top, flyash is in middle layer and sand acts as a bottom layer, similarly in second and third reading the position of silt i.e. least permeable layer changes. As it is clearly shown in table 3 that due to change in position of soil, value of observed permeability also changes, which in turn again signifies that position of soil layer also plays an important role.

Fig. 3 and 4 shows a bar graph which shows the permeability of individual soil layers along with their position in the sample and the observed permeability of the stratified sample, which was obtained by experimental studies. A perusal of Fig. 3 and 4 reveals that the observed permeability is more than the permeability of least permeable soil in each case. The trend signifies that the observed permeability is mainly dependent on the least permeable soil because in every case it is more than the individual permeability of silt and less than individual permeability of sand and fly ash.

Figure 5 and 6 shows a bar graph which is obtained by the findings of Sridharan [8]. Almost a same trend is visible in his study that the observed permeability is more than the permeability of least permeable layer i.e. black cotton soil and is less than the individual permeability of the other two layers, but in some cases the observed permeability is more than the individual permeability of Kaolinite which is having permeability more than Black cotton soil. The reason behind this increase is that the individual permeability of soil samples used in their study is very close to each other.

Figure 7 shows a graph which consist of a wide variation of permeability values ranging from double layered samples to triple layered soil samples. This graph contains results from different studies carried out by Sridharan et al. [8], Sridharan et al. [1] and Javed et al. [9] as well as the results from the present study.

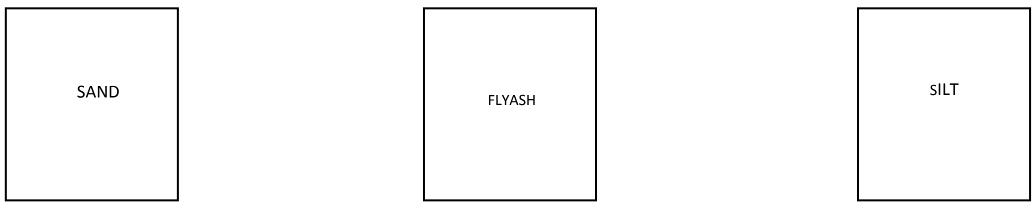

Figure 1: Single layer soil samples.

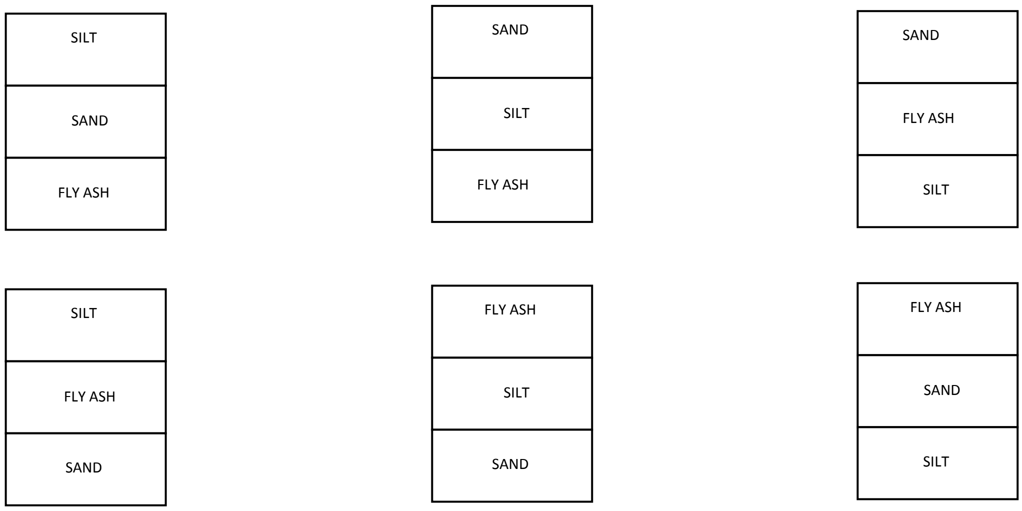

Figure 2: Triple layer soil samples.

Table 1: Permeability of individual soil samples

S. No.	Sample	Observed Permeability
1.	Sand	7.236×10^{-3}
2.	Fly Ash	5.7696×10^{-4}
3.	Silt	3.9898×10^{-5}

Table 2: Permeability of triple layered soil samples

S. No.	Sample	Observed Permeability	Predicted Permeability	Percentage increase
1.	Silt, Sand, Fly Ash	3.063×10^{-4}	1.113×10^{-4}	35.79
2.	Sand, Silt, Fly Ash	2.155×10^{-4}	1.113×10^{-4}	63.60
3.	Sand, Fly Ash, Silt	1.838×10^{-4}	1.113×10^{-4}	39.46

Table 3: Permeability of triple layered soil samples with some different arrangement of layers

S. No.	Sample	Observed Permeability	Predicted Permeability	Percentage increase
1.	Silt, Fly Ash, Sand	2.168×10^{-4}	1.113×10^{-4}	48.60
2.	Fly Ash, Silt, Sand	3.083×10^{-4}	1.113×10^{-4}	63.40
3.	Fly Ash, Sand, Silt	1.809×10^{-4}	1.113×10^{-4}	38.49

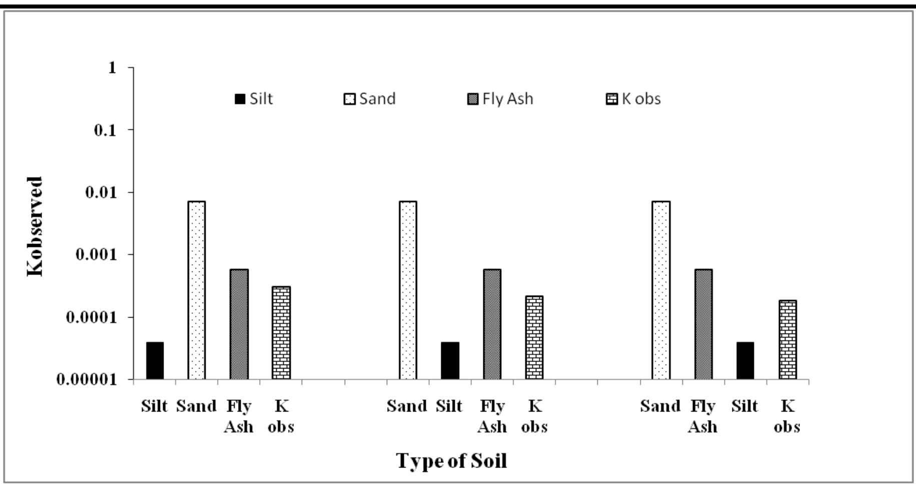

Figure 3: Bar graph showing the change in position of soil samples in triple layered stratified soil sample v/s observed permeability as per table 2

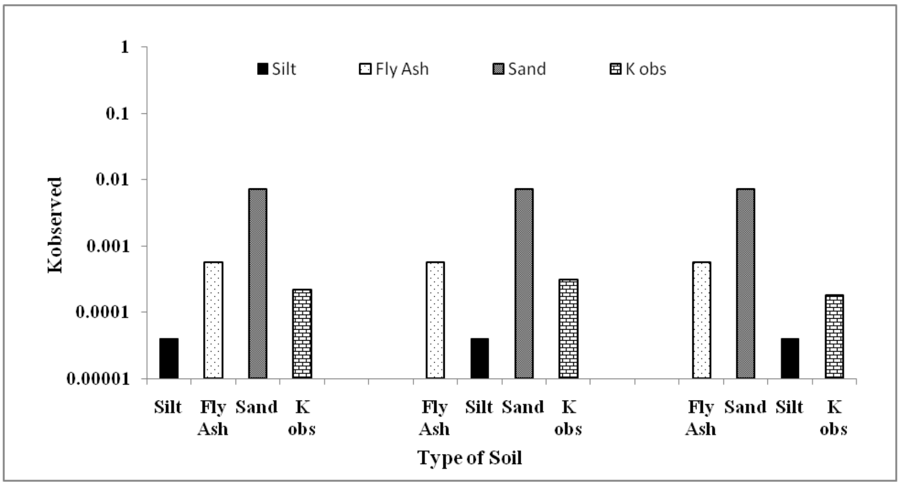

Figure 4: Bar graph showing the change in position of soil samples in triple layered stratified soil sample v/s observed permeability as per table 3

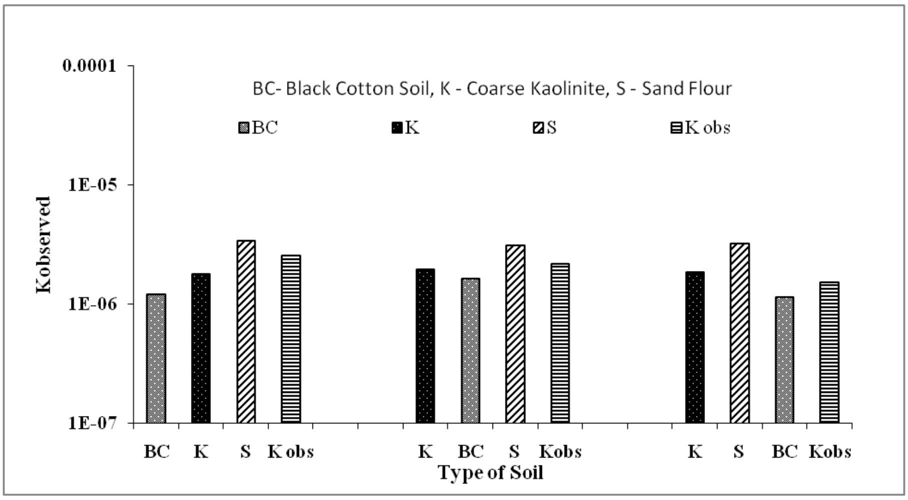

Figure 5: Bar graph showing the change in position of soil samples in triple layered stratified soil sample v/s observed permeability (Sridharan's Study)

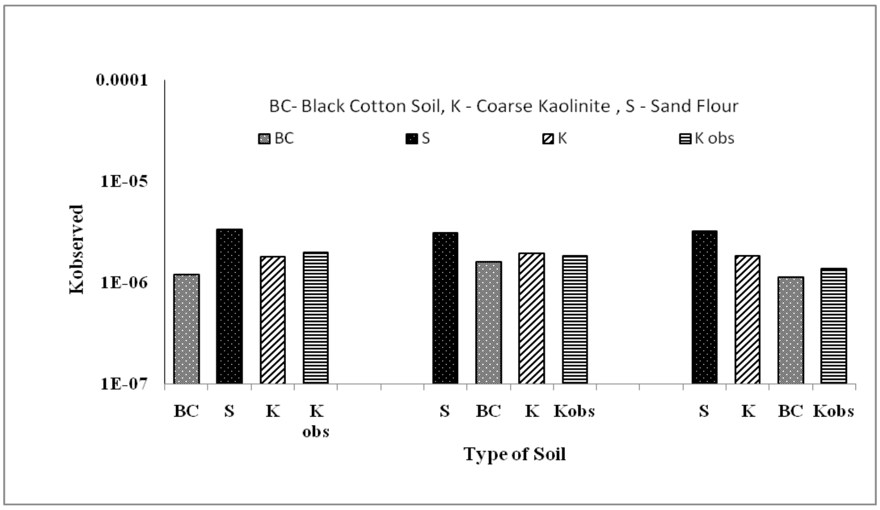

Figure 6: Bar graph showing the change in position of soil samples in triple layered stratified soil sample v/s observed permeability (Sridharan's Study)

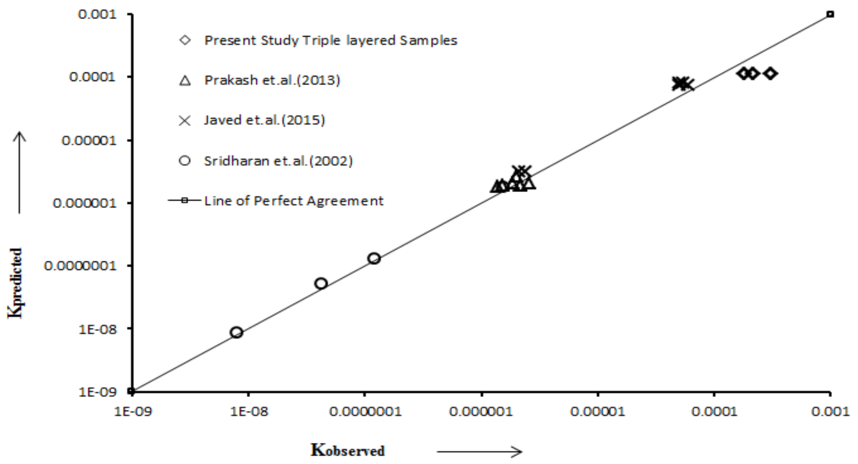

Figure 7: Variation of predicted and observed values of permeability for different combinations of soil layers

4. Conclusion

A comparative study of the observed coefficient of permeability of 3-layer soil sediments with the theoretically calculated values has been made. The results demonstrate that, by and large, the coefficient of permeability of the least permeable layer controls the observed permeability of stratified soil. The consequence of this observation is the realization that the observed permeability of any layered soil deposit is not just dependent upon the values of k of the individual layers constituting the deposit, but it also depends upon the relative positioning of the layers in the system as well as the permeability of least permeable layer.

5. Acknowledgment

My research is funded by Council of Scientific & Industrial Research (CSIR), Human Resource Development Group (HRDG), New Delhi. CSIR Sanction letter/file number- 09/112(0550)2K17. I PRIYANK GUPTA would like to give special thanks to Council of Scientific &Industrial Research (CSIR), HRDG for funding my research work.

References

[1]. Prakash, K., Sridharan, A.(2013). Permeability of layered soil: An extended study, GeotechGeolEng, 31:1639–1644, doi 10.1007/s10706-013-9684-9.

[2]. IS 2720-Part-I, (1983). Methods of test for soils, Second revision, Reaffirmed 1995, Indian Standards Institution, New Delhi.

[3]. IS 2720-Part-IV, (1985). Methods of test for soils, Second revision, Reaffirmed 1995, Bureau of Indian Standards, New Delhi.

[4]. IS 2720-Part-III, (1980). Methods of test for soils, Second revision, Reaffirmed 1997, Bureau of Indian Standards, New Delhi.

[5]. Kaushik, S.K., Kumar, A. (1998). Fly ash–silica fume high performance concrete–a state of the art. Proceeding of Workshop on Utilization of Fly ash; ICI, Roorkee: 15–47.

[6]. Ranjan, G., Rao, A.S.R. (2011). Basic and Applied Soil Mechanics, New Age International Publishers, New Delhi-110002.

[7]. IS 1498, (1970). Classification and Identification of soils for general engineering purposes, First revision, Reaffirmed 2007, Bureau of Indian Standards, New Delhi.

[8]. Sridharan, A., Prakash, K. (2002). Permeability of Two-Layer soils, Journal of Geotechnical testing, ASTM International, 25(4):447-448.

[9]. Alam, J., Muzzammil, M., Singh, H.P., Gupta, P. (2015). Permeability of stratified soils for flow normal to bedding plane; Aquatic Procedia 4: 660 – 667.