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Impact of Compaction State and Initial Moisture on Infiltration Characteristic of Soil

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Abstract: Infiltration is the flow of water through the soil surface into a porous medium under gravity action and pressure effects. First the water moist soil grains and subsequently the surplus water moves down due to resulting gravitational force. The present study deals with the effect of compaction state and water content on infiltration property, in particular the saturated hydraulic conductivity. Two soil types have been selected and results have been determined. It is concluded that there is marginal reduction of infiltration rate with increasing the dry density in case of sandy soil and successively reduction of infiltration for Red (Loam) soil. It is found that infiltration rate variation is approximately constant with water content for higher dry density state.

Keywords: Compaction, Infiltration Parameters, Disc Infiltrometer

1. Introduction

Infiltration process is necessary for inhibiting the runoff in various watershed regions. The knowledge of infiltration characteristics is important in flood modeling, artificial recharge of aquifer, mass transport through subsurface, performance evaluation of landfill covers etc (Chow, 1988). Infiltration rate is strongly related to hydraulic properties, such as the saturated hydraulic conductivity. Prasad et al. (2010) estimated unsaturated hydraulic parameters from infiltration and internal drainage experiments. Kinner and Moody (2010) estimated spatial variability of steady-state infiltration into a two-layer soil system on burned hillslopes. Amer (2011) found out effects of infiltration and retention during surface irrigation. Dagadu and Nimbalkar (2012) carried out infiltration studies on different type of soils under different soil conditions. They also fitted the field data to various infiltration models. Other factors such as compaction in practice, hydraulic conductivity is known to be highly heterogeneous in space and large number of dense points could be required for proper and complete study related to variation of infiltration properties. A disk infiltrometer has become a handy instrument for determining infiltration characteristics and permeability of soil. There are several numerical studies simulating cumulative infiltration versus time response from a disc infiltrometer, where in, the initial condition of soil is important. Jaramillo et al. (2000) measured soil surface hydraulic properties using disc and ring infiltrometers. Pitt et al. (2008) have found that the infiltration rates are mainly depending on soil type, soil compaction, initial saturation, and ponded water depth. Fernandez and Cebollada (2009) developed a new method for monitoring soil water infiltration rates in a disc infiltrometer. In the present paper, degree of compaction and initial moisture contents have been related with the infiltration rates for two specific soil types.

2. Locations of the Study Area

The experiments of this study were performed in the Laboratory of Water Resource Engineering of the Department of Civil Engineering of IIT Guwahati. Experiments were repeated many times and best results have been enclosed here.

3. Material and Method

The mini disk infiltrometer is manufactured by Decagon devices (USA) have been used for performing the infiltration test. The mini disc infiltrometer is ideal for field measurement as well as for laboratory and classroom; due to its compact size, the water needed to operate it can easily be carried in a personal water bottle. For class room it is easy to demonstrate basic concept of soil hydraulic conductivity.

This infiltrometer enable us to measure the hydraulic conductivity of any soil accurately and affordably. Disc infiltrometer commonly use low-capacity water-supply reservoirs made of small diameter tubes. The infiltration tests have been conducted in the field and a sequence of minidisk infiltrometer measurements was obtained for tension 0-6 cm, on all the locations. The water content of the soil samples was measured. In each case, the desired tension head is set in the Marriot bubbler and the water from the reservoir assembly is allowed to infiltrate the soil through the foot assembly. The rate of water level drop against time is then recorded till it attains a constant rate, which is called steady state infiltration.

A PVC cylindrical mold as depicted in Fig. 1 with diameter of 20 cm and height equal to 20 cm were used. A rammer as shown in Fig. 2 is used to impart necessary compaction to the soil sample.The weight of the rammer and mold is 3.350 and 1.703 kg respectively.

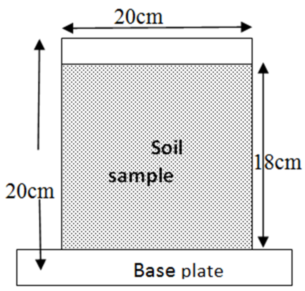


Fig. 1. *PVC Mold.*

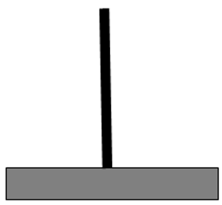


Fig. 2. *Rammer (15cm dia.).*

The required mass of air dried soil sample was mixed with appropriate amount of tap water to obtain desired water content. The bulk quantity of sand to was packed in PVC cylinder in three layers by giving equal number of blows with the rammer on each layer. The weight of the sand filled in the cylinder is noted and the bulk density is determined. Similarly, three soil samples have been taken during compaction to determine the water content. Similar experiments have been performed on red soil and different results have been perceived and by Knowing water content and bulk density, the dry density of compacted samples has been computed. The method requires determining cumulative infiltration vs. time and fittingthe results with the function

$$I_1 = C_1 t + C_2 \sqrt{t_2}$$

Where C_1(m s^{-1}) and C_2 (m $s^{-1/2}$) are parameters. $C_1$is related to hydraulic conductivity, and $C_2$is the soil sorptivity. The hydraulic conductivity of the soil (k) is then computed from

$$k = \frac{C_1}{A}$$

Where $C_1$is the slope of the curve of the cumulative infiltration vs. the square root of time, and A is a value relating the van Genuchten parameters for a given soil type to the suction rate and radius of the infiltrometer disk.

4. Results and Discussion

4.1. Infiltration Test Performed on Sandy Soil

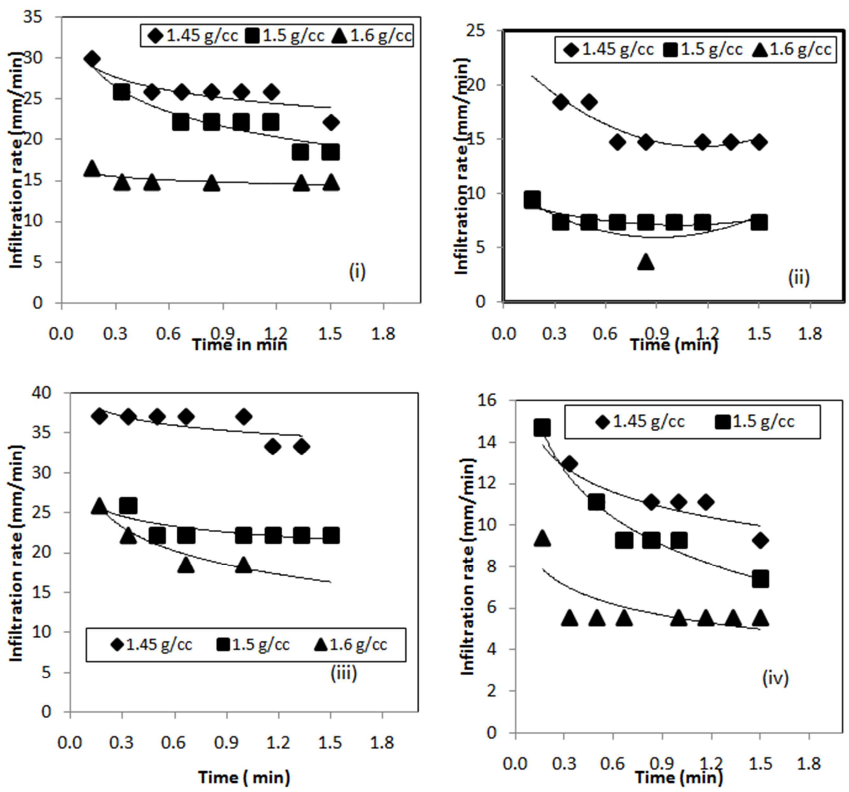


Fig. 3. *Variation of infiltration rate with time at suction 2cm for different water contents (i) w= 1.3% (ii) w=5.2 % (iii) w= 8.2 % and (iv) w= 12.4 %.*

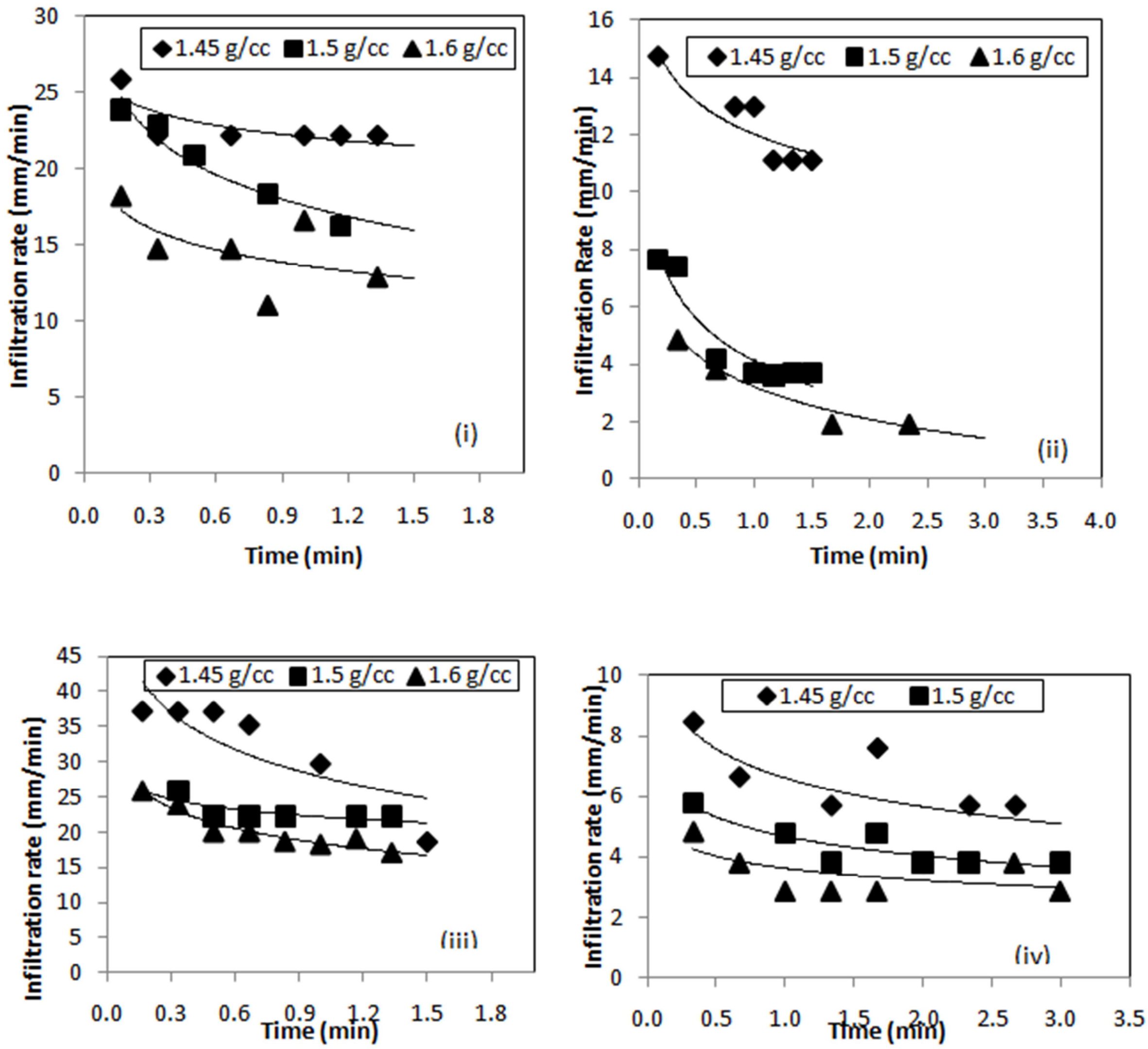


Fig. 4. *Variation of infiltration rate with time at suction 6cm for different water contents (i) w= 1.3% (ii) w=5.2 % (iii) w= 8.2 % and (iv) w= 12.4 %.*

Sand has been selected for conducting experiments, because it is more or less inert soil and hence water retention will not play much role. The infiltration corresponding to two suctions 2cm and 6cm has been performed on all compacted (sand) soil samples.

Fig. 3 and 4 exhibits the variation of infiltration rate versus time. However some compacted states, infiltration rate versus time does not exhibit a well-defined trend. This may be mostly attributed to the high infiltration in sands due to which some of the measurements were quite irregular. As a result, it is difficult to obtain well defined steady infiltration rate for some of these measurements. For these cases, final reading is considered as the infiltration rate. These results were repeated three times, and most accurate result has been chosen.

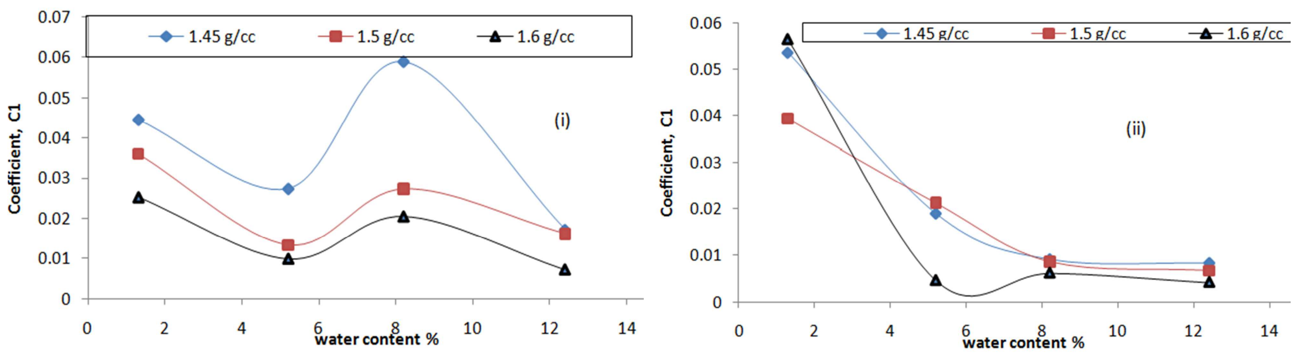


Fig. 5. *Variation of coefficient C_1 with water contents for different suctions (i) 2 cm and (ii) 6 cm.*

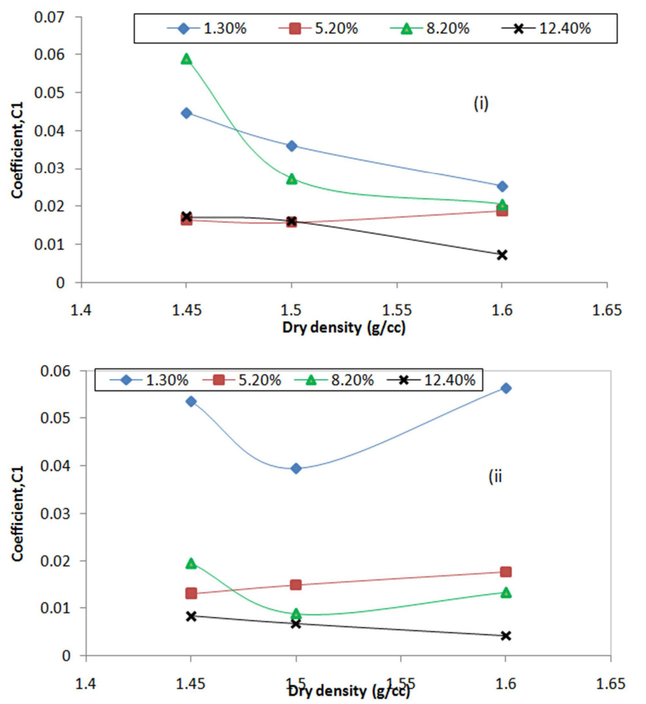
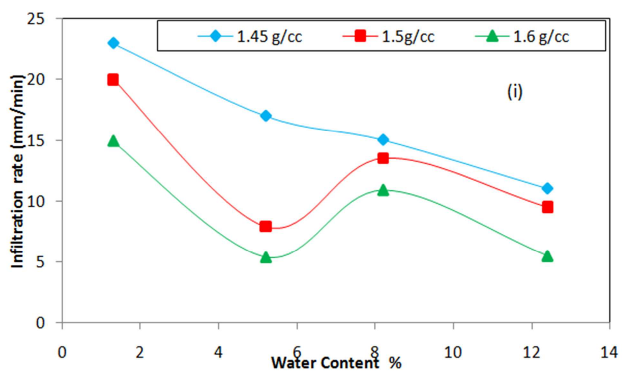


Fig. 6. Variation of Infiltration rate with dry density for different suctions (i) 2 cm and (ii) 6 cm.

Fig. 5 depicts the variation of C_1 with water content for a given dry density. For infiltration study conducted at suction equal to 2 cm, it can be noted that C_1 variation up to 8% water content it may be increase or decreases, but after 12% water content onward the variation of C_1 value is only decrease continuously. It is expected that as water content increases, infiltration decreases and hence C_1 also decreases. And study conducted for 6cm suction as it is clearly visible by trend and expected that as water content increase the value of C_1 should decrease. It is also noted that for study of sands suction 6cm shows the more accurate result as compare to 2cm suction head.

Fig. 6 depicts the variation of C1 with dry density for given water content. There is a decrease in C1 with an increase in dry density for all the water contents. Such a trend is true for both suctions 2cm and 6cm. As dry density increases, there is a decrease in pores and hence infiltration reduces. Such a decrease in infiltration results in reduction of C1.



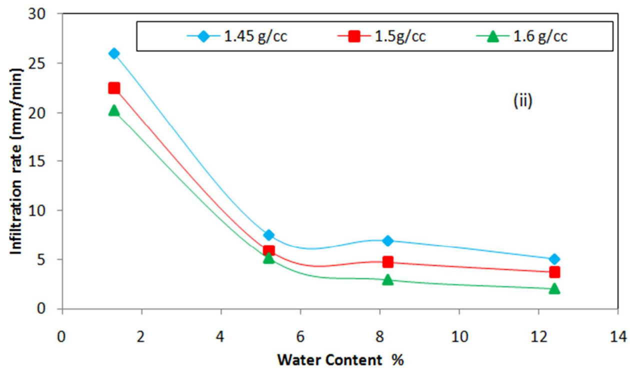


Fig. 7. Variation of Infiltration rate with water content for different suctions (i) 2 cm and (ii) 6cm.

In Fig.7 for suction equal to 2cm, with dry density 1.45g/cc the trend clearly shows that infiltration rate decreases with increase of water content. And other such as 1.5 g/cc and 1.6 g/cc density shown that infiltration rate decrease close to 6% of water content and then increase up to 8% of water content, and further decrease of infiltration rate up to 12% of water content, and it is expected that infiltration rate should decrease continuously with increasing of water.

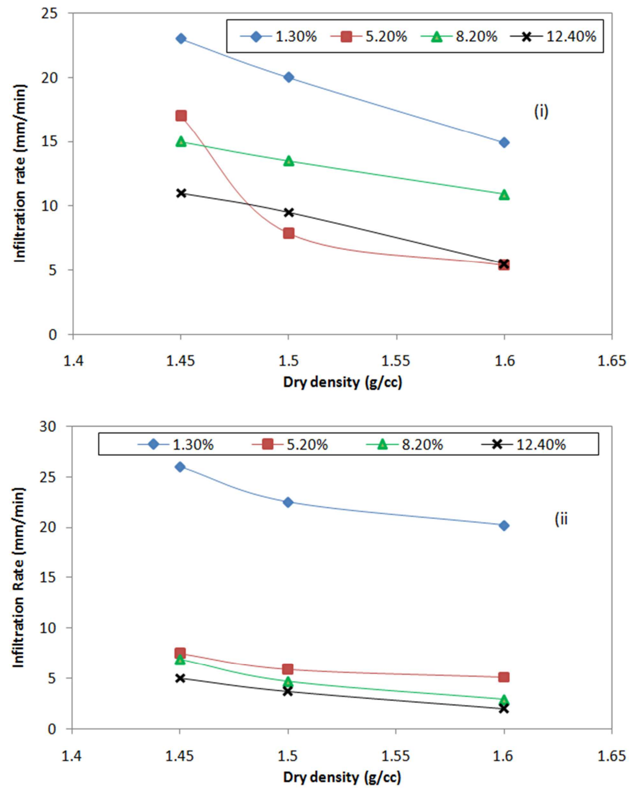
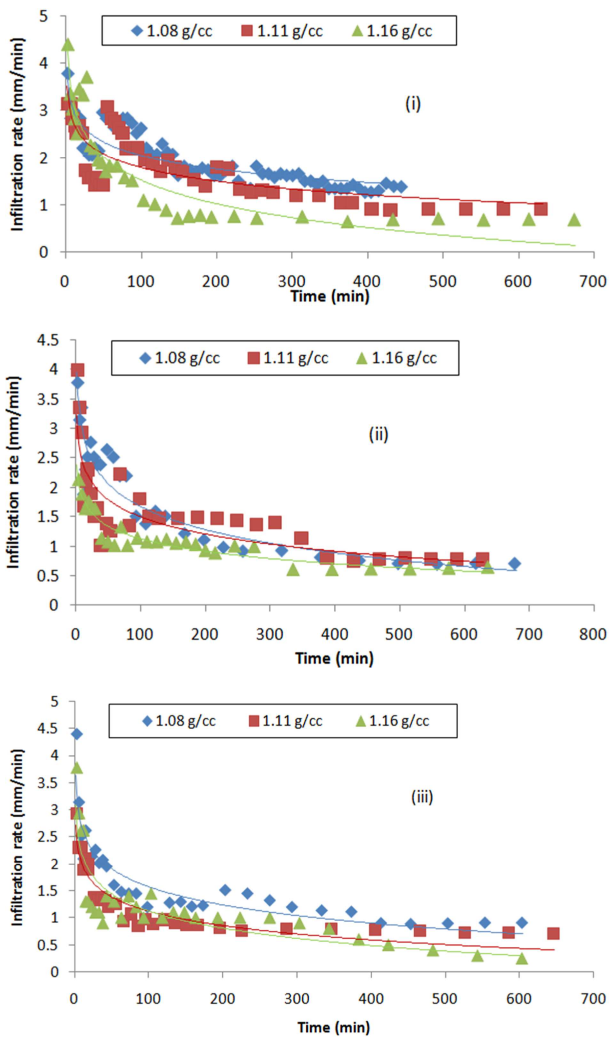


Fig. 8. Variation of Infiltration rate with dry density for different suctions (i) 2 cm and (ii) 6cm.

Fig. 8 exhibits the variation of infiltration rate with dry density for particular water content. It can be noted that infiltration rate decreases with an increase in dry density due to decrease in pore space. For infiltration studies conducted at suction equal to 2 cm, all the trend of all water content presents that infiltration rate decreases with the increase of dry density, except at 5.2% of water content, it may decrease of infiltration rate with dry density, but trend indicate the lower value of infiltration rate and it should be between 1.3% and 8.2% of water content. For infiltration studies conducted at suction equal to 6 cm, it is noted that all cases infiltration rate has marginal decrease with increase of dry density. For air dried water is more infiltrate and decrease with increasing the dry density.

4.2. Infiltration Test Performed on Red (Loam) Soil

The infiltration on suctions equal 2cm has been performed on all compacted soil samples. Fig. 9 shows variation of infiltration rate for selected dry densities under different water contents. The infiltration rate versus time exhibits a well-defined trend for all the cases. So the results indicate that the trend show the constant infiltration in majority cases. These experiments carried out for a long duration unlike a sand experiment, and the best results have been obtained. Based on these results, the infiltration parameters such C1 and infiltration rate are correlated with water content and dry density, to study the influence of initial compaction parameters on infiltration. These are shown in Fig. 10 to 13.



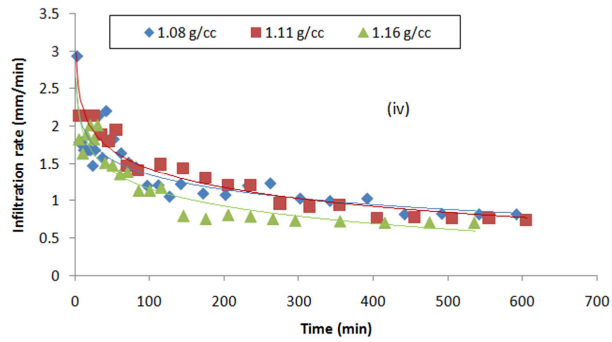


Fig. 9. *Variation of infiltration rate with time at suctionequal to 2cm for different water contents (i) w= 3.3% (ii) w=7.3 % (iii) w= 11.02 % and (iv) w= 15.01 %.*

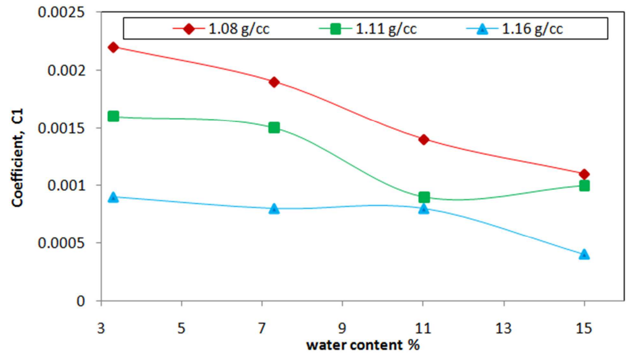


Fig. 10. *Variation of coefficient C1 with water contents for suctions equal to 2 cm.*

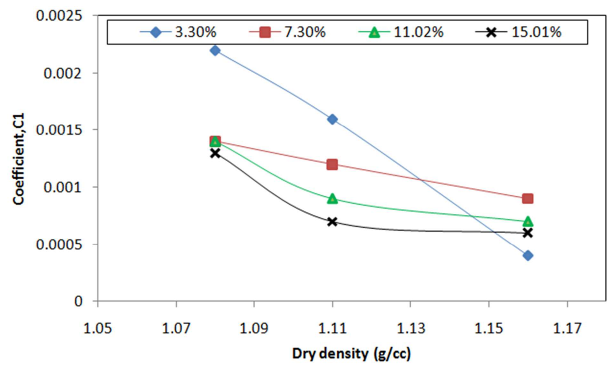


Fig. 11. *Variation of coefficient C1 with dry density for suctions equal to 2 cm.*

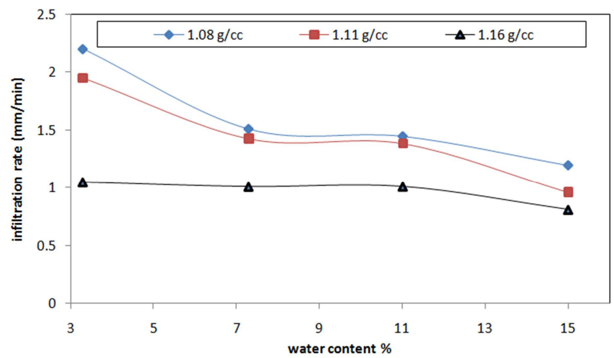


Fig. 12. *Variation of Infiltration rate with water content for suction equal to 2 cm.*

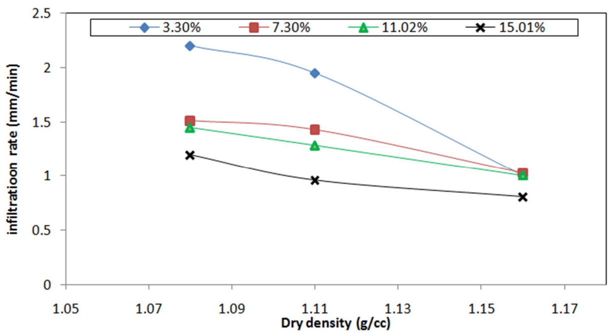


Fig. 13. *Variation of Infiltration rate with dry density for suction equal to 2 cm.*

5. Conclusion

Based on the present infiltration experimental studies various conclusions were drawn. Infiltration studies conducted for sand indicate that C_1 decreases with water content. Decrease in C_1 variation is quite drastic for water content up to 8%. Further, decrease in C_1 is marginal with increasing water content.The reduction of infiltration rate is drastic up to 5% water contents, for higher water content there is marginal change in infiltration rate. And it is also noted that there is marginal reduction of infiltration rate with increasing the dry density.It is also noted that for lower dry density infiltration rate is drastically decreasing with water content for suction equal to 2cm.

Infiltration studies performed on Red (Loam) soil indicated the various results.For red soil it was indicated that C_1 is successively decreased with water content.It is noted that there is a decrease in $C_1$with an increase in dry density for all the water contents, While there is a rapidly change in variation of C_1 with dry density for air dry red soil condition.It is also observed in the case of red soil experiments infiltration rate decreases with water content, because soil becomes saturated.It is also noted that infiltration rate variation is approximately constant with water content for higher dry density state. It can be noted that infiltration rate decreases with an increase in dry density due to the decrease in pore space. Infiltration rate variation with dry density gives the best results unlike sand experiment.

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