International Journal of Technical Innovation in Modern Engineering & Science (IJTIMES)
Impact Factor: 5.22 (SJIF-2017), e-ISSN: 2455-2585
Volume 4, Issue 7, July-2018

Correlation between infiltration capacity and permeability of soil

[1] Aayush Mittal [2] S.K Singh

[1]*Water Resource Engineering Department, PEC, Chandigarh, mittalaayush93@gmail.com*
[2]*Professor, Department of Civil Engineering, PEC, Chandigarh, sksingh@pec.ac.in*

Abstract- Infiltration is the surface phenomenon through which water enters the ground. Infiltration capacity of an area depends on various factors, like land use, Texture, Permeability, Soil type among others. Permeability value of surface affects the infiltration largely. In this study double ring infiltrometer is used to accurately estimate the infiltration capacity of open areas in twenty four places of Chandigarh city. Constant head permeability test is used to calculate the permeability value of the soil. On the basis of collected data, a correlation is developed between infiltration and permeability of soil. The statistical significance of the correlation is checked using the regression analysis by plotting different types of trend lines and then best fit line is selected to represent the relationship using a significance value. The correlation coefficient comes out to be +0.91 that means the infiltration and permeability are positively correlated. When the value of permeability increases then the infiltration value is also found out to be increasing. Statistical significance is proved through the logarithmic trend line which has coefficient of determination R^2 value equal to 0.927 which shows it is a good fit.

Keywords-Infiltration capacity, Permeability, Correlation, Soil, Infiltration

I. INTRODUCTION

Water comes to earth in various forms of precipitation and a part of which contributes to groundwater through infiltration into the ground and rest of the part flows as runoff into the streams, rivers or drains in case of urban areas. Infiltration plays an important role in the hydrological cycle and is of prime importance as this factor decides the volume of runoff. Infiltration refers to the downward entry or movement of water into the soil surface of the earth and replenishes soil moisture, recharges aquifers and ultimately supports stream flows during dry periods. It is a surface characteristic and hence primarily influenced by the condition of the surface soil. Soil surface with vegetative cover has more infiltration rate than bare soil. Permeability indicates the relative ease of movement of water with in the soil. The characteristics that determine how fast air and water move through the soil is known as permeability. Soil infiltration is characterized by scale dependence, (Nie et al., 2017) so the accuracy and reliability of indirect methods used to estimate soil infiltration properties from available soil physical data are often below expectations. Over the years, prediction models ranging from empirical to physical bases have been developed (Kostiakov, 1932; Horton, 1941; Philip, 1957). However, not all the models are satisfactory for field application.

The infiltration rate of a soil and its permeability are two important experimentally determined parameters for any soil system. Both parameters vary with time largely infiltration being more variable than permeability. Possibly because permeability is more easily measured in the laboratory, considerable information is available concerning the variations in permeability. Much of this information would be useful in both qualitative and quantitative determinations of the infiltration rate if only a suitable analysis relating these parameters were available. Several methods have been employed to measure the rate of water intake by soils. These include (1) sprinkling infiltrometers and (2) flooding methods using cylinder infiltrometers, furrow, or basins (Al-Qinna and Abu-Awwad., 1998). Large amounts of rainfall are lost through runoff in arid and semiarid regions owing to surface sealing. Soil surface sealing is a common feature on most soils of these regions and is considered to be the major cause of low infiltration. Whilst, the final infiltration capacity and the saturated permeability can be easily obtained in the laboratory, and the rainfall intensity can be assigned based on statistical analysis of rainfall records in the area, the initial infiltration capacity depends on the in-situ conditions and will be strongly affected by antecedent rainfall conditions (Jianfeng et al., 2008).

Definition of infiltration state that it is the percolation of water through soil and it is an important parameter in the hydrological modelling of runoff, irrigation management, watershed modelling, groundwater studies etc. At catchment level, infiltration characteristic dominates the parameters in determining the flooding condition. The infiltration rate is determined by soil characteristics which include ease of entry, storage capacity, and transmission rate through the soil. The soil vegetation, soil types, its texture and structure and land cover or land use, moisture content of soil, soil temperature, and rainfall intensity all play a role in infiltration rate. In order to find out the parameters like permeability and its correlation dependence on the value of infiltration capacity of soil is of prime importance in this study.

II. METHODOLOGY

Infiltration value is found out by field investigation using Double Ring Infiltrometer or flood basin method. In this study field data is collected from different sites spread across different sectors in city of Chandigarh (U.T), India. Different sites are selected considering actual rainfall scenario and using runoff coefficient for the selected area, in order to get a rough estimate to find out infiltration from the previous rainfall and runoff data. Actual field investigation is done to verify the data with the calculated runoff and infiltration value. Permeability is measured for each location using the site sample of soil in the geotechnical laboratory using a constant head permeability test apparatus.

After the collection of data for infiltration capacity and permeability of all the selected sites in the study area, statistical tools and analysis is done to find the correlation between the two parameters using regression technique by plotting one variable on x-axis ad other on the y-axis and to evaluate the correlation coefficient of the relation between the two variables. The statistical significance is measured by using the regression analysis and verifying it with best fit trend lines which are plotted simultaneously to select the line which describes the correlation between infiltration and permeability correctly.

III. STUDY AREA

For the present study the open areas in Union Territory of Chandigarh were selected to conduct field testing of soil for the infiltration and permeability properties for finding out the correlation between the two variables. Many sites were selected from the open areas designated as institutional area according to current land use report by Department of Urban Planning Chandigarh Administration. The total number of sites for the testing and reporting the infiltration capacity is twenty four. They are selected on the basis of the green area and open land which was available in the vicinity.

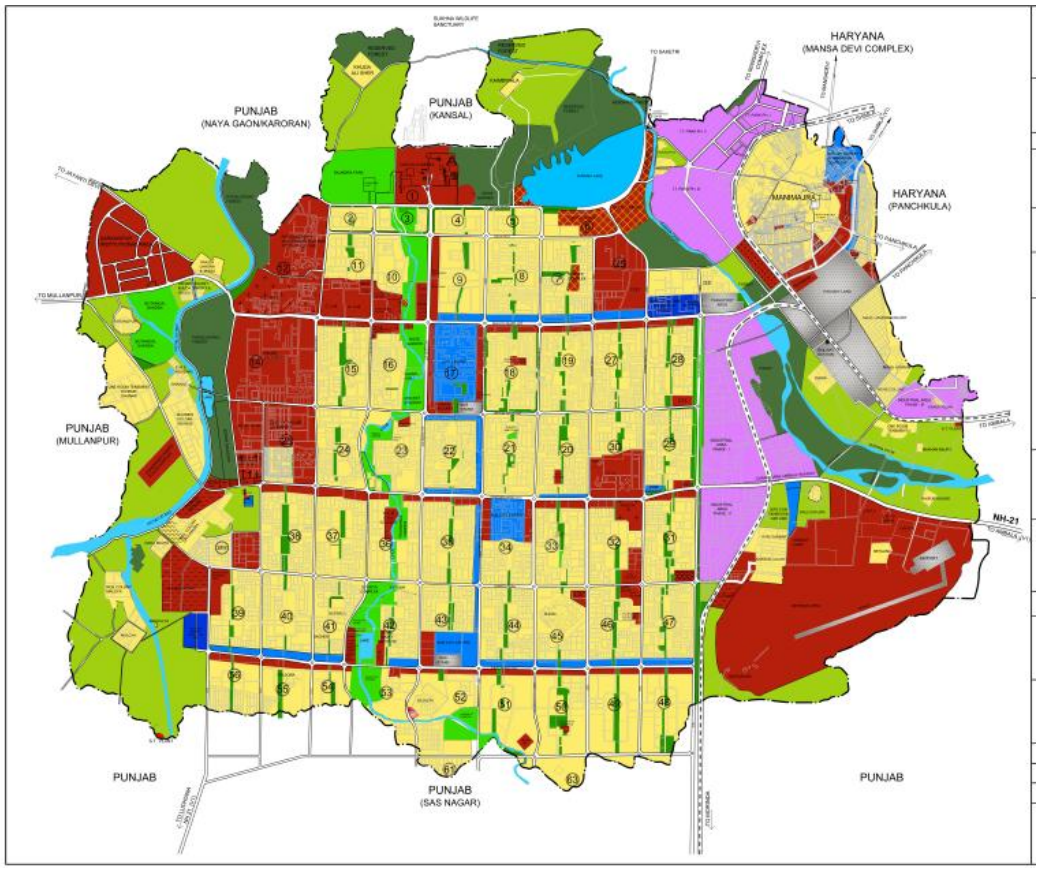

Figure 1 Study area Different sectors in City of Chandigarh (U.T)

(Source: http://download.masterplansindia.com/maps/chandigarh/existing-land-use-plan-chandigarh.jpg)

IV. EXPERIMENTAL SETUP

The double ring infiltrometer is a simple instrument used for determining water infiltration of the soil (Measurements according to ASTM D3385-03 standard test method and DIN 19682 page 7). The rings are partially inserted into the soil and filled with water, after which the speed of infiltration is measured. The double ring limits the lateral spread of water after infiltration. Dimensions of infiltrometer used –Outer Ring Diameter: 26 cm Inner Ring Diameter: 15 cm Depth of instrument: 15cm.

First of all double ring infiltrometer is setup at the desired location using a log of wood and hammer. A log of wood is kept on the instrument which is hit with help of hammer to a depth of 5 cm into the ground surface. Now water is poured up to few centimetres below the top surface and simultaneously stop watch is started. Measurement of depth of water reduction is taken at different time intervals; initially time difference is less between the readings due to high infiltration initially and decreases exponentially. From the measurement chart after few hours when infiltration value become constant is taken as infiltration capacity.

Figure 2 Measurement of depth during the field investigation using Double Ring Infiltrometer

Permeability is measured using the laboratory setup for constant head permeability test as specified according to guidelines stated in IS 2720(Part 17): 1986 Methods of test for soils, Laboratory determination of permeability. For a constant head test arrangement, the specimen shall be connected through the top inlet to the constant head water reservoir. The bottom outlet shall be opened and when the steady state of flow has been established, the quantity of flow for a convenient time interval shall be collected and weighed or measured. Alternatively, the inlet may be at the bottom and water may be collected from the outlet at the top. The collection of the quantity of flow for the same time interval shall be repeated thrice. The inside diameter and the height of the permeameter are measured and recorded as diameter D and length L of the specimen. The heights H_1 and H_2 are measured to determine the head h. The temperature of water T is also measured and recorded.

IV. RESULTS

The results from the selected twenty-four sites in the city of Chandigarh are collected for infiltration and permeability studies which are then evaluated for correlation coefficient. The coefficient of correlation which is calculated from the statistical tool in Microsoft excel and then the graph is plotted for best fit relation between the two parameters infiltration and permeability value. Different trend lines are plotted which include linear, polynomial, logarithmic and exponential, from which logarithmic trend lines follow more statistical significance. The equations for the trendlines are also found out from the plotted trend lines which are displayed on the graph. Infiltration capacity and permeability for one of the site (site number 4) is described below and the chart for the infiltration capacity is also drawn to scale with infiltration capacity on y axis and time on x axis. Infiltration capacity value: 16.02 mm/hr. Permeability value: 1.23×10^{-4} cm/s. Soil classification of site: Silty sand (Loam type of classification according to Infiltration rate).

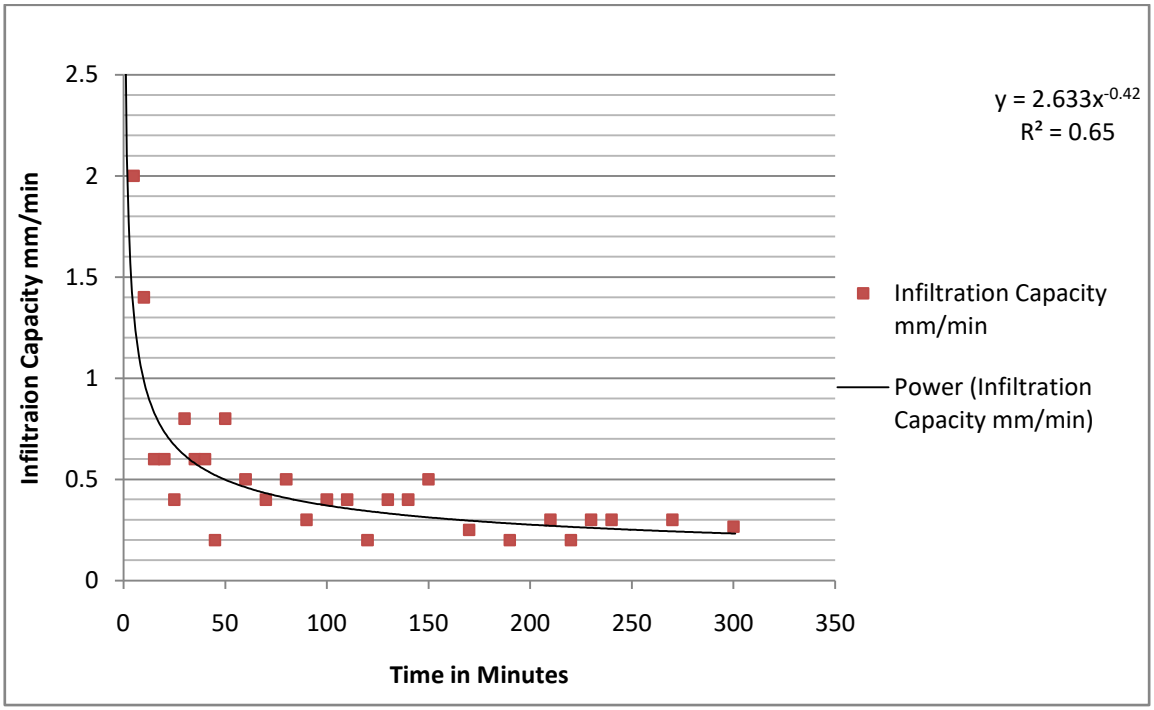

Figure 3. Infiltration Curve for the one of the selected sites in study area

Table 1 Correlation Infiltration capacity vs. Permeability

Site Number	Infiltration Capacity(mm/hr)	Permeability(cm/s)	Site Number	Infiltration Capacity(mm/hr)	Permeability(cm/s)
1	7.500	3.181E-05	13	6.820	3.050E-05
2	19.980	2.450E-04	14	7.410	3.160E-05
3	19.200	2.200E-04	15	8.800	3.210E-05
4	16.020	1.231E-04	16	9.830	3.320E-05
5	4.080	2.370E-05	17	14.500	1.050E-04
6	10.700	3.380E-05	18	15.200	1.120E-04
7	5.500	2.940E-05	19	15.500	1.140E-04
8	5.610	2.960E-05	20	10.300	3.500E-05
9	4.600	2.920E-05	21	15.800	1.180E-04
10	9.810	3.290E-05	22	16.400	1.260E-04
11	7.100	3.150E-05	23	16.000	1.210E-04
12	5.840	2.980E-05	24	13.400	1.030E-04
Correlation Coefficient between Infiltration and Permeability 0.91					

The values of twenty four sites are collected in the above table for their infiltration capacity value and their respective permeability value which represents the experimental value collected from the different sites in the city. These values of infiltration vs. permeability are plotted in on normal axis graph and plotted data is fitted with trend lines namely polynomial, logarithmic, linear, exponent series. Also the equations for these trend lines are plotted with least squares method and their equations are written in forthcoming lines.

Polynomial trend line equation

$$y = -3E + 08x^2 + 141455x + 3.256$$

R^2=0.912

Logarithmic trend line equation

$$y = 6.174 \ln(x) + 71.454$$

R^2=0.927

Linear trend line equation

$$y = 71158x + 5.679$$

R^2=0.838

Exponent trend line equation

$$y = 6.184e^{6329.5x}$$

R^2=0.692

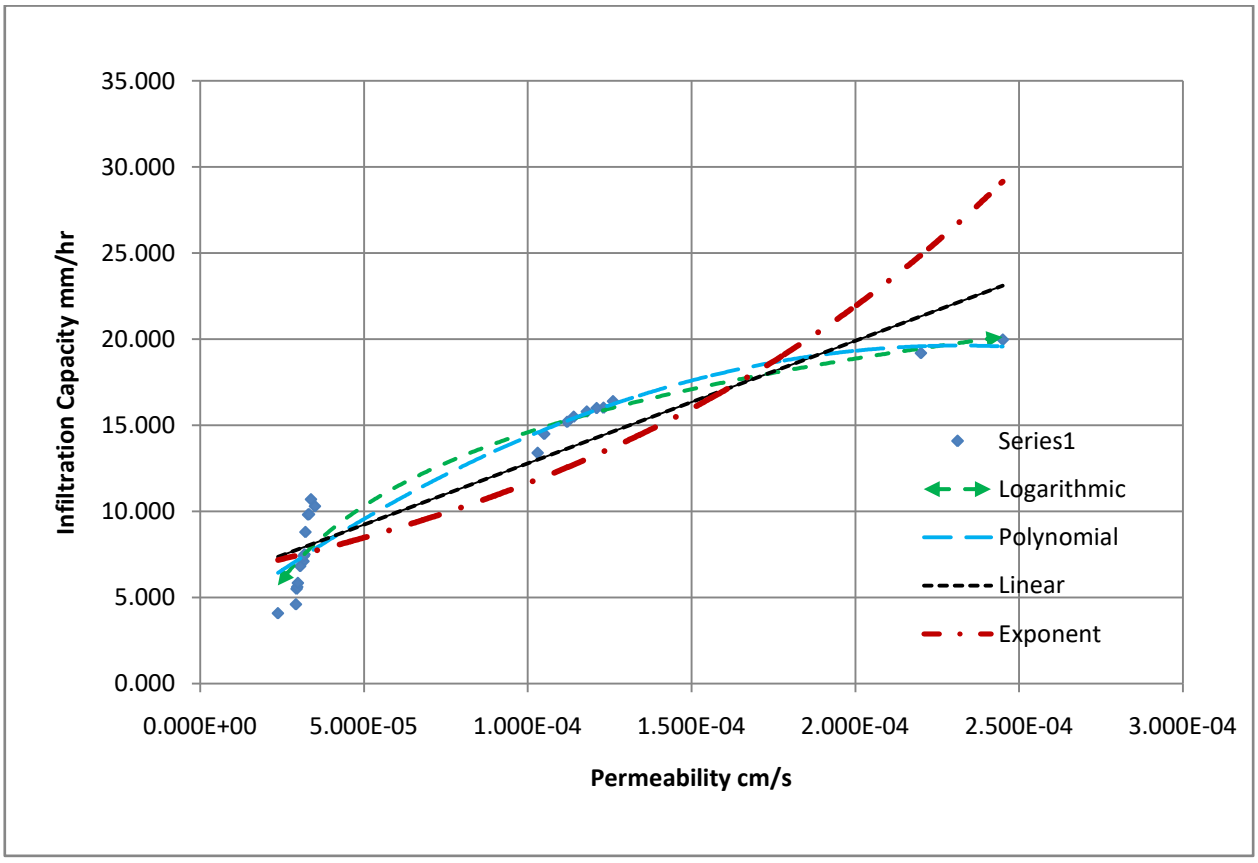

Figure 4. Graph between Permeability value (cm/sec) and Infiltration capacity of selected area (mm/hr)

V. CONCLUSION

After conducting the field experiments and finding the permeability and infiltration properties of the described twenty four sites in the city the data is analysed to find the correlation coefficient between infiltration and permeability. The infiltration curve for all the sites are plotted to get infiltration capacity at saturation and their respective properties like permeability are found out using constant head permeability test apparatus accurately. Both variables are plotted on a linear scale with permeability as x- coordinate and infiltration capacity as y-coordinate and a linear regression line is fit through the plotted points on scale. Also the Pearson correlation coefficient 'R' is find out using statistical software Microsoft excel with a positively correlated value of 0.91. This highly relatable value indicates that if one parameter (in this case permeability) increases then other variable (infiltration capacity) increases to a large extent. Among the factors affecting the infiltration capacity the permeability and soil type affect infiltration value of the location significantly. To establish the statistical significance the regression analysis results are plotted for various trend lines show logarithmic trend line the best fit among the linear, polynomial, exponential and logarithmic. Statistical significance is proved through the logarithmic trend line which has coefficient of determination R^2 value equal to 0.927 which shows it is a good fit.

REFERENCES

[1] Al-Qinna, M.I. and Abu-Awwad, A.M., 1998. Infiltration rate measurements in arid soils with surface crust. Irrigation Science, 18(2), pp.83-89.
[2] ASTM D3385-03 Standard Test Method for Infiltration Rate of Soils in Field Using Double-Ring Infiltrometer
[3] Horton RE. 1941. An approach towards a physical interpretation of infiltration capacity. Soil Science Society of America Journal 5: pp. 399–417.
[4] Indian Standard 2720(Part 17):1986 Method of Test for soils, Laboratory determination of Permeability.
[5] Jianfeng Xue, Kenneth Gavin (2008) Effect of Rainfall Intensity on Infiltration into Partly Saturated Slope Geotechnical and Geological Engineering Volume 26, Number 2, Page 199
[6] Kostiakov AN. 1932. On the dynamics of the coefficient of water percolation in soils and on the necessity of studying it from a dynamic point of view for the purposes of amelioration. In Transactions of the Sixth Congress of International Society of Soil Science. Part A: Moscow; p 15–21.
[7] Morbidelli, R., Govindaraju, R.S., Corradini, C., Saltalippi, C. and Flammini, A., 2008. A preliminary analysis of field-scale infiltration into layered soils. In World Environmental and Water Resources Congress 2008: Ahupua'A (pp. 1-8).
[8] Nie, W., Ma, X. and Fei, L., 2017. Evaluation of Infiltration Models and Variability of Soil Infiltration Properties at Multiple Scales. Irrigation and Drainage, 66(4), pp.589-599.
[9] Philip JR. 1957. The theory of infiltration: 1. The infiltration equation and its solution. Soil Science 83(5): pp. 345–357.