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Fitting Infiltration Equations using Double Ring Infiltrometer to Design and Evaluate Irrigation Methods

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Abstract*— In the present Outcome Based Education in Engineering, higher order skills in psychomotor domain are required as per Dave's Taxonomy,Simpson's Taxonomy and Anita Harrow's Taxonomy.Not only computational skills are required but also experimental skills to develop the engineering skills life long. According to Walter J. Rawls et.al(1993), infiltration and soil water movement play a key role in surface runoff, groundwater recharge,evapotranspiration, soil erosion and transport of chemicals in surface and subsurface waters.The ASTM International Standard D 3385- 03 describes the " Standard Test Method for Infiltration Rates of Soils in field using Double Ring Infiltrometer". The present paper describes the methodology of development of Kostiakov Infiltration Equations from the field tests of Double Ring Infiltrometer,as part of various student projects of design and evaluation of irrigation methods. As properties of soil also influence the infiltration rate, soil properties are also determined.

In one test, the Kostiakov infiltration equation fitted is in the form $y=0.44t^{0.65}$***. The basic infiltration rate is 44 millimeters/hour. Other methods of infiltration equations are briefly mentioned.***

Keywords— ASTM International Standard, Irrigation Methods, Infiltration Rate, Kostiakov Infiltration Equation

I. INTRODUCTION

Fourteen infiltration models are compared for evaluation with the estimation of their parameters on various soils.The fourteen models are as follows:Philip model,Green-Ampt model, Linear Smith-Parlange model,Nonlinear Smith-Parlange model , Singh-Yu model, Mishra-Singh model , Smith model, Horton model,Holtan model , Overton model , Kostiakov model , Modified Kostiakov model ,Huggins-Monke model and Collis-George Model (Mishra S.K. et al 2003). Various infiltration models are described (Ven Te Chow-ed,1964; Ven Te Chow et.al,2010;Training Notes at Utah State University,1992;Walter.J.Rawls,1993; Sihag P et.al ,2017). Using Double Ring Infiltrometer , Kostiakov equations are fitted in student projects (Srinath B et.al,2004;Azizullah Khan.M et.al,2006;Kamla Raju Y et.al,2007;Durga Rao K et.al,2013;Kalpana G et.al,2018).

ASTM International Standard D 3385- 03 " Standard Test Method for Infiltration Rates of Soils in field using Double Ring Infiltrometer" was referred. Guidelines for field irrigation efficiencies and quality of irrigation water are explained (Bureau of Indian Standards,1991&1996).The aspects of On-farm water management are described (Ministry of Water Resources,Government of India , 1985;Singh D.P.et.al 1993; Training Notes of Dr.Hussain.M,1992) . Design and evaluation of Irrigation Methods are explained (Water and Power Consultancy Services(India), Ltd.1989).

II. MATERIALS AND METHODS

DOUBLE RING INFILTROMETER TEST

The Double Ring infiltrometer test equipment available in the laboratory of Gokaraju Rangaraju Institute of Engineering and Technology (GRIET),Hyderabad was used for all field tests.

The Double Ring infiltrometer test equipment consists of two concentric cylinders.

The cylinders are usually 25cm deep. The inner cylinder, from which the infiltration measurements are taken, is usually 30cm in diameter. The outer cylinder, which is used to form the buffer pond to minimize the lateral spreading of water, is about 60cm in diameter. The cylinders are installed about 10cm deep in the soil.

The water is added in inner and outer cylinder upto desired level, say 10cm above the ground. After initial reading, point gauge measurements are taken at frequent intervals, say 5 minutes to determine the amount of water that has infiltered during the time interval. Water is added quickly after each measurement so that a constant average infiltration head could be maintained. The average depth of water maintained in cylinder is 7 to 12cm which is approximately equal to the expected water level in the border or basin during irrigation. The buffer pond is filled with water immediately after filling inner cylinder to maintain the same depth in both the cylinder. The data are tabulated in the form as given in Table I.

Tests were conducted in the Agricultural farms in to assess the average infiltration rates of soils.

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The functional relation between Cumulative infiltration(Y) and elapsed time(t) is represented by Kostiakov equation $Y=a*t^{\alpha}$

This function plotted on ordinary graph paper gives parabolic curve. When data are plotted on log-log paper, a linear relationship is indicated as shown below $Y=a*t^{\alpha}$

Taking log on both sides

Log Y = log a + (α* log t)

This is the equation of a straight line and the values "a" and "α" can be found out by plotting the values of "Y" and "t" on log-log paper or by fitting the straight line by the method of least squares. Knowing the values of a and α, we can use the equation $Y=a*t^{\alpha}$ for finding out the cumulative infiltration or infiltration rate at any time 't

The observations and calculations based on the field data are shown in the following tables.

TABLE I. SHOWING THE RESULTS OF TESTS ON WATER

Sample	Particulars	pH	Electrical Conductivity	Sodium Absorption Ratio	Class of Water	R.S.C.	$Ca^{+}Mg$ me / L	$Na^{+}K$ me / L	Co_3 me / L	HCO_3 me / L	Cl me / L	SO_4
1	298	8.6	1.08	0.72	C S 3 1	4.64	4.96	5.84	Nil	9.6	8.0	Nil

TABLE II SHOWING RESULTS OF TESTS ON SOIL

PARAMETER	Depth Of Auger from Ground level For Soil Testing	
	15CM	30CM
1. Nature of soil	Silty clay loam	Silty clay loam
2. Organic Carbon	low	low
3. Available phosphorous in kg/Acres	16	26
4.Available Potassium in kg/Acres	182	158
5. pH	8.4	8.5
6. Electrical Conductivity	0.25	0.26

TABLE III. SHOWING THE COMPUTATION OF AVERAGE INFILTRATION RATE FROM DOUBLE RING INFILTRATION TESTS

Observed Clock Time	Time Elasped Since Last Reading in Minutes	Time Elasped Since begining of the test in Minutes	Distance of Water Surface from the Refer-ence Point (cm)	Infiltration Depth (cm)	Average infiltration Rate Cm / hr	Accumulated Infiltration cms
12.55	-	-	12	-	-	-
12.56	1	1	12.50	0.5	30	0.5
12.58	2	3	13.0	0.5	19.8	1.0
1.00	2	5	13.4	0.4	16.8	1.4
1.02	2	7	13.6	0.2	13.74	1.6
1.07	5	12	13.7	0.1	8.52	1.7
1.12	5	17	14.0	0.3	7.08	2.0
1.17	5	22	15.0	1.0	8.16	3.0
1.27	10	32	15.10	0.1	5.82	3.1
1.37	10	42	15.4	0.3	4.86	3.4
1.47	10	52	15.8	0.4	4.38	3.8
Total	52			3.8		

Average infiltration rate = (3.8 / 52) x 60 = 4.38 cm / hr Or Basic infiltration rate Approximately 4.4 cm/hr = 44 mm/hr

TABLE IV SHOWING THE VARIOUS KOSTIAKOV INFILTRATION EQUATIONS FITTED AT VARIOUS PROJECT SITES

S.No.	Student Project Site	Type of soil	Fitted Kostiakov Infiltration Equation
1.	Shameerpet Mandal,Rangareddy District (old), Telangana , India	Silty Clay Loam	$y=0.35\ t^{1.125}$
2.	Jagtial,Sriramsagar Project Area, Telangana , India	Silty Clay Loam (Test 1)	$y=0.285\ t^{0.71}$
	Jagtial, Sriramsagar Project Area,Telangana , India	Silty Clay Loam (Test 2)	$y=0.345\ t^{0.7}$
3.	Agriculture farm in Hyderabad	Silty Clay Loam	$y=0.44\ t^{0.65}$
4.	Agriculture farm in Sangareddy District (old),Telangana, India	Silty Clay Loam	$y=0.36\ t^{0.2}$
5	Waste water irrigated area in Musi river catchment near Hyderabad	Silty Clay Loam	$y=0.2\ t^{0.44}$

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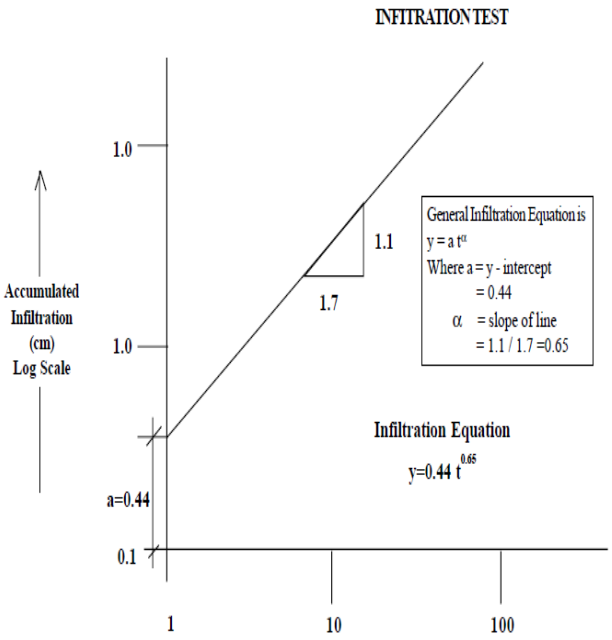
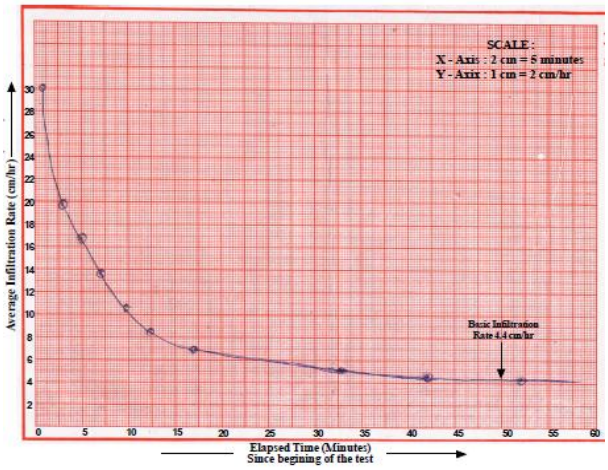
TIME IN (Minutes) ON LOGARTHEMIC SCALE



Elapsed time (minutes) Log Scale

GRAPH 1 : ACCUMULATED INFILTRATION (cm) VERSUS ELAPSED



GRAPH 2 : SHOWING THE TIME ELAPSED (Minutes) VERSUS AVERAGE INFILTRATION RATE (cm/hr)

III. RESULTS AND DISCUSSIONS

I) Table III shows the observations and calculations made under Double Ring Infiltrometer Test in an agricutural farm near Hyderabad. The basic infiltration rate obtained in the double ring infiltrometer test is 44 mm/hr (Graph 2). As per the standard of the Ministry of Water Resources, Government of India(1985), this class of soil is classified as “High with deep sand and well aggregated soil” as the basic infiltration rate is above 25mm/ hr. The infiltration equation obtained from the test is useful to find out the soil infiltration profile. This profile is useful to find out the application efficiency, water requirement efficiency, distribution uniformity and deep percolation ratio.

Thus, it is useful to understand whether it is over irrigation or underirrigation. If this awareness is created in the farmers by continuous training programmes, irrigation management will be effective. The infiltration equation is fitted in this case in the form

$Y=0.44\ t^{0.65}$ (Graph 1)

Table IV shows the various Kostiakov Infiltration Equations fitted at various project sites

II) In the absence of soil-testing by the farmers, farmers apply fertilizers in excessive dosages. These pollute the soil and the groundwater below. Farmers have to be encouraged to get their soil tested in the Soil Testing Laboratories of the State Agricultural Department and get soil health cards. Table II shows the results of soil tests by soil testing laboratory . In the study area, the soil samples are collected by Augur at depths of 15 cm and 30 cm. The nature of soil is found to be silty clay loam. The organic carbon content is found to be low. The available phosphorous in kg/acre are 16 and 26 respectively. The available potassium in kg/acre are 182 and 158 respectively. Having known the available phosphorous and potassium in the soil, the required fertilizers can be estimated.

III) Table I shows the irrigation water analysis report by the Soil Testing Laboratory . The source of Irrigation in the study area being a bore well, the water sample was collected from the bore well and was given for testing. The pH of water is 8.6 (Basic). The electrical conductivity is 1.08 milli mhos per centimeter. As this electrical conductivity falls in the range of 0.75 to 2.25, the water is highly saline. This water cannot be used on soils with poor drainage. To use this water, drainage should be improved and plants with good salt tolerance should be selected. Sodium absorption ratio of 0.72 indicates that it is low in sodium. The bi-carbonates of 9.6 milli equivalents / litre contribute to temporary hardness of water. The carbonates content is nil. This water is classified under C3 S1, indicating that it is highly saline with low sodium. This water can be used for irrigation on almost all the crops with very low accumulation of sodium at harmful level.

IV. CONCLUSION

1. Soil samples and water samples at the sites of irrigation are collected and analyzed. Kostiakov Infiltration equation of the soil is obtained by conducting a double-ring Infiltrometer test.
2. In one test, the infiltration equation fitted is in the form y=0.44t0.65.
3. The basic infiltration rate is 44 millimeters/hour.

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