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An Experimental Investigation to Develop Horton's Infiltration Capacity Curve for Gadigi's Empire Layout, Ballari

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Abstract: *Infiltration occurs when water enters the ground strata. Infiltrated water further moves in lateral direction to reach nearby streams or in vertical directions to reach groundwater. The rate of infiltration depends on the depth of surface detention and thickness of the saturated layer of ground surface soil. As soil on the ground surface gets saturated, the rate of infiltration slows down. In this study, the rate of infiltration is determined at five locations in Gadigi's Empire Layout, near Satyam International school and P.U college, Ballari, using double ring infiltrometer method. Red soil and black cotton soil is identified in the study area. The surface of the soil is loose, uncompacted, dry and free from the growth of weeds. By using two concentric cylindrical rings, with the inner ring 30cm and outer ring 50 cm being made of mild steel. During the experiment, it is observed that initial infiltration rate is high in location - 1 (40.6621 cm/hr.) and location - 2 (36.7312 cm/hr.) compared to location - 3 (10.2461 cm/hr.), location - 4 (8.755 cm/hr.) and location - 5 (8.983 cm/hr.). Horton's Infiltration Capacity Curve parameters are determined to develop a relationship between rate of infiltration and time at five locations in the considered study area, location – 1:* $f_t = 19.23+(27.54)\ e^{-1.50451t}$, *location – 2:* $f_t = 14.423+(26.151)\ e^{-0.9336t}$, *location – 3:* $f_t = 3.790+(6.72)\ e^{-0.2404t}$, *location – 4:* $f_t = 1.690+(7.276)\ e^{-0.176t}$ *and location - 5:* $f_t = 1.566+(7.65)\ e^{-0.1852t}$, *where* f_t *is rate of infiltration in cm / hr for t hour duration*

Keywords: Infiltration

I. INTRODUCTION

Infiltration is the process in which water enters into the ground strata. Once infiltrated, the water can be present in soil as soil moisture or move in lateral direction or further moves in vertical downward direction and reach groundwater. Rate of infiltration or infiltration rate is the speed at which water enters into the ground, usually it is measured in terms of depth of infiltration per unit time and expressed as centimeter per hour or millimeter per hour. Infiltration capacity is the maximum rate at which soil is capable of absorbing water and it varies with soil type, soil structure, and moisture content. Infiltration capacity is denoted by 'f'. If actual infiltration capacity for a given soil be 'fa' and 'i' be the intensity of rainfall.

Infiltration is measured in terms of the depth of water entering the ground strata, usually expressed in cm or mm. The rate of infiltration is measured in terms of the depth of water entering the ground strata per unit time, usually expressed in cm per hr or) mm per hr. Common methods to determine the depth of infiltration and rate of infiltration include single ring infiltrometers, double ring infiltrometers, Phillip-Dunne Permeameters, Guelph Permeameters, and Tension infiltrometers.

II. PRESENT STUDY

The study investigates the rate of infiltration at five locations in Gadigi's Empire Layout, near Satyam International School and P.U college, Ballari. The double ring infiltrometer experiment uses two concentric cylindrical rings, with an inner ring and outer ring, to measure the water level in the soil. The ASTM standard method is used, with the inner ring placed on the ground and the outer ring over the inner cylinder. The study focuses on red and black cotton soil, with the soil being loose, uncompacted, dry, and free from weed growth. The results are used to develop a relationship between infiltration rate and time. Using the readings were observed at the time of experiment, parameters involved in the Horton's Infiltration Capacity Curve are determined to develop a relationship between rate of infiltration and time for the present study area.

Horton's equation

$$f_t = f_c + (f_0 - f_c)\, e^{-kt} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

where,

f_t = Infiltration capacity at any time t from the start of the rainfall
f_0 = Initial infiltration capacity at t=0
f_c = Final rate of infiltration
$f_0 - f_c$ = Final steady state infiltration capacity
k = (Horton's decay coefficient which depends upon soil characteristics and vegetation)
t = Time

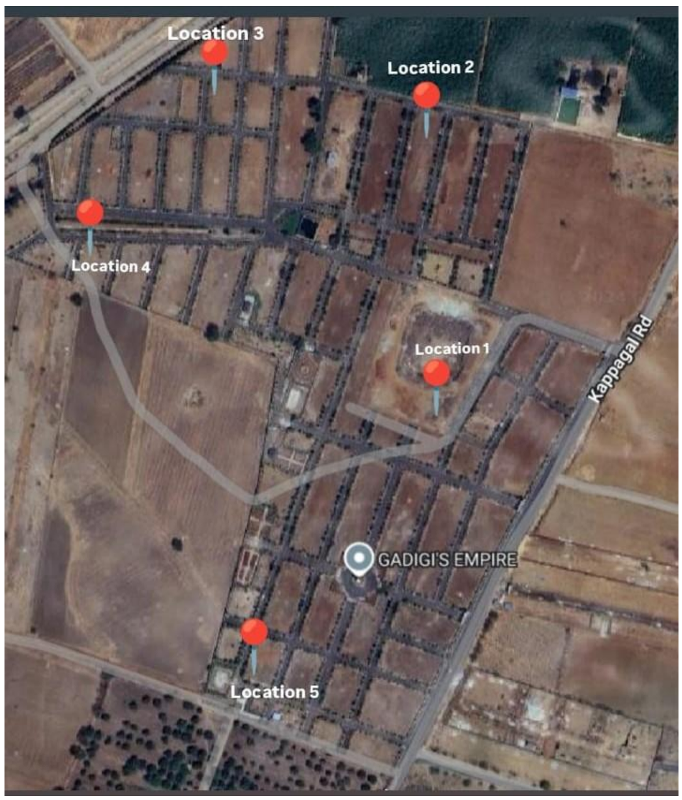

Fig no 1: Location of the study area for conduction of double ring infiltrometer test.

III. METHODOLOGY

A study was conducted in a location with level surfaces and free from weed growth. Two-cylinder rings were placed on the ground, with sharp surfaces facing the ground. Piece of timber is place on the top of rings during hammering to protect the ring from damage. Hammering was done till the rings penetrate for a depth of 10cms.Water was filled in both rings, maintaining the same level. The outer cylinder saturates the soil, creating a buffer zone. The inner cylinder contained water, preventing lateral seepage. A transparent 30cm scale was placed in the inner cylinder ring, and water levels were observed. The time required for water level to fall was recorded for random values, likely 5 cm, 3 cm, 2 cm,

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and 1 cm. The cylinders were refilled, and observations were recorded until the time required for water level to fall was the same for two successive readings.

Preparation of ground surface Installation of rings into the ground

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Adding water to both inner and outer rings Measuring the depth of water

Fig no 2: Process of conducting double ring infiltrometer experiment.

IV. RESULT AND DISCUSSION

Using the readings observed at the time of experiment (as tabulated in Table no – 1), the calculation is made to calculate Infiltration rate (f) for each observed reading till ultimate or steady state of infiltration (f_c) is reached. ($f - f_c$) is calculated, then log is applied to draw scatter plot of rate of infiltration against time, and trend line is drawn considering all the scattered points as shown in from the fig no 3 to 7. r^2 value of the trend line is observed to analyse the best fit of the line drawn for the points under consideration. From the graph, the parameter values of Horton's infiltration equation (C and k) are determined. The calculated values of f_o and k are substituted in equation 1 to obtain the relationship between the rate of infiltration and time for the considered location.

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Table no - 1: Observation made during the Experiment at all five locations

Location - 1		Location - 2		Location - 3		Location - 4		Location - 5	
Time (hr)	Depth of infiltration (cm)	Time (hr)	Depth of infiltration (cm)	Time (hr)	Depth of infiltration (cm)	Time (hr)	Depth of infiltration (cm)	Time (hr)	Depth of infiltration (cm)
0.1442	5	0.141	5	0.504	5	0.602	5	0.635	5
0.1822	5	0.207	5	0.729	5	0.980	5	0.972	5
0.1062	3	0.220	5	0.468	3	0.682	3	0.708	3
0.1347	3	0.159	3	0.551	3	0.833	3	0.859	3
0.0908	2	0.159	3	0.388	2	0.589	2	0.636	2
0.0933	2	0.109	2	0.400	2	0.671	2	0.685	2
0.0458	1	0.118	2	0.201	1	0.356	1	0.420	1
0.0475	1	0.063	1	0.206	1	0.592	1	0.639	1
0.0500	1	0.069	1	0.208	1	0.592	1	0.639	1
0.0520	1	0.069	1	0.264	1	-	-	-	-
0.0520	1	-	-	0.264	1	-	-	-	-

Table no - 2: Initial Rate of Infiltration (f_o) and Final Rate of Infiltration (f_c) for all five locations.

Locations	f_o	f_c
Location -1	40.66	19.297
Location -2	36.731	14.999
Location -3	10.246	6.358
Location -4	8.755	5.288
Location -5	8.983	5.213

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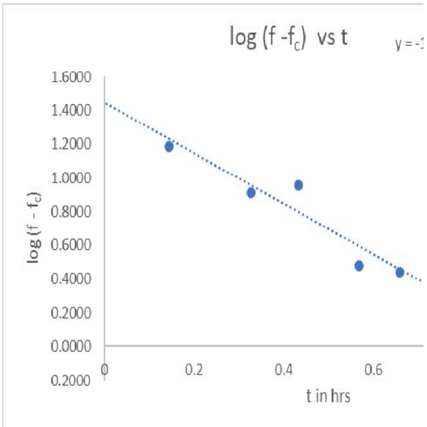

Fig no 3: Scatter plot for location – 1

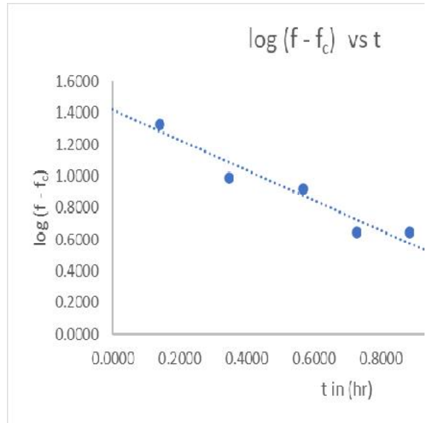

Fig no 4: Scatter plot for location – 2

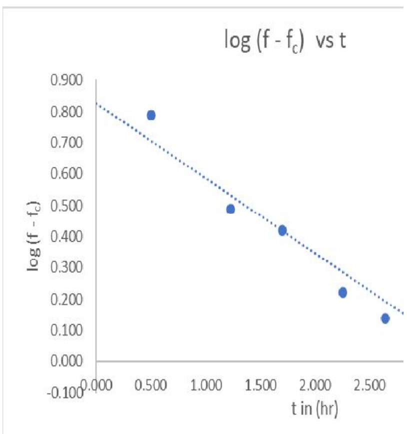

Fig no 5: Scatter plot for location – 3

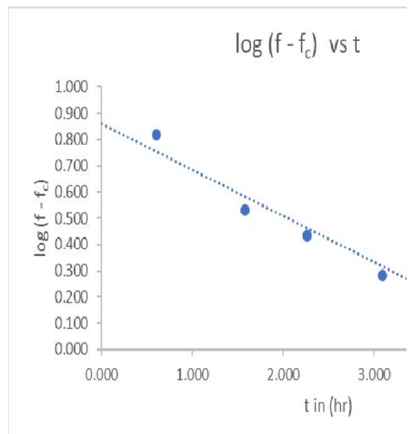

Fig no 6: Scatter plot for location – 4

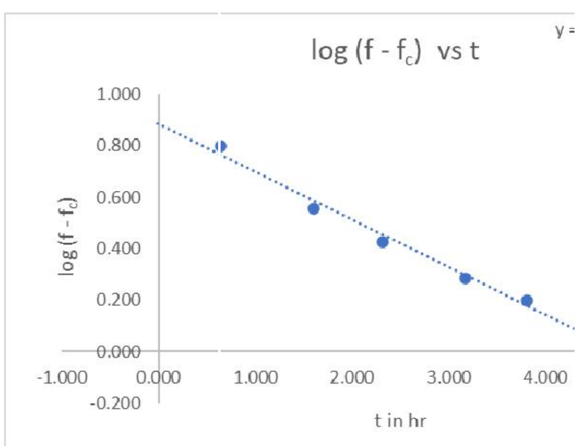

Fig no 7: Scatter plot for location – 5

The values of f_o and k are substituted in eq (1) to obtain the relationship between the rate of infiltration and time. Relationship between infiltration rate and time for all five locations are developed using scatter plots which are drawn based on the observations made while conducting the experiment are as mentioned below:

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- Location – 1: $f_t = 19.230 + (27.540)\ e^{-1.5045\ t}$
- Location – 2: $f_t = 14.423 + (26.151)\ e^{-0.9536\ t}$
- Location – 3: $f_t = 3.790 + (6.720)\ e^{-0.2404\ t}$
- Location – 4: $f_t = 1.690 + (7.276)\ e^{-0.176\ t}$
- Location – 5 $f_t = 1.566 + (7.65)\ e^{-0.1852\ t}$

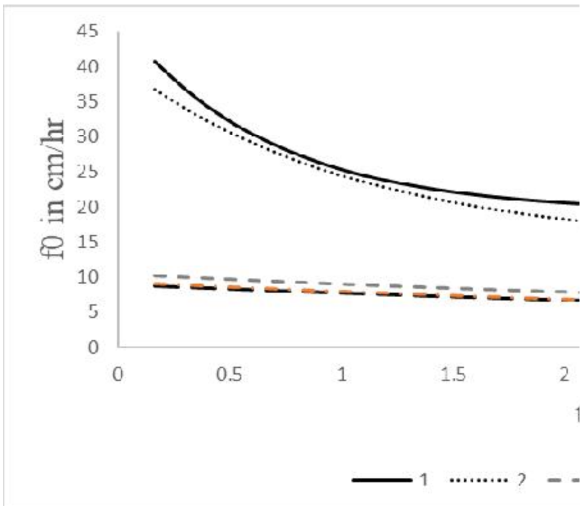

Fig no 8: Relationship between infiltration rate and time for all five locations

V. CONCLUSION

The present study is concluded with the following points

- Location 1 has higher initial rate of infiltration, 40.6621 cm / hr.
- Location 5 has slower rate of infiltration, 8.983 cm / hr.
- Rate of infiltration observed at location 1, location 2 and location 3 is more, so infiltration pits can be provided at these locations to recharge ground water.

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