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Study of Infiltration Capacity of Different Soils

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Abstract: Infiltration is a process that continuously affects the magnitude and distribution of surface runoff. Field measurement of infiltration is often a tedious task and the infiltration rates can be estimated from the proposed models. Single-ring and Double-rings are used to estimate the infiltration rate of different soils. The main aim of the study is to analyse the importance of infiltration.

Keywords: *Infiltration, Factors affecting infiltration, Types of Soil, Textural Classification, Single Infiltrometer, Double Infiltrometer, Physical Based Model*

I. INTRODUCTION

Infiltration is the process by which water on the ground surface enters the soil. Infiltration is the downward entry of water into the soil. The velocity at which water enters the soil is infiltration rate. Infiltration rate in soil science is a measure of the rate at which soil is able to absorb rainfall or irrigation. It is measured in inches per hour or millimeters per hour. The rate decreases as the soil becomes saturated. If the precipitation rate exceeds the infiltration rate, runoff will usually occur unless there is some physical barrier. It is related to the saturated hydraulic conductivity of the near-surface soil. The rate of infiltration can be measured using an infiltrometer. It is different from the term percolation because percolation means movement of water in the soil mass. From the definition it follows that the process of infiltration will stop unless percolation removes infiltrated water. Thus although the two phenomenon viz. infiltration and percolation are different they are closely related.

Infiltration is caused by two forces: gravity and capillary action. During the rain, infiltration loss occurs quickly almost exclusively from the water that has reached the ground surface. The water infiltrating into the soil moves downward through larger soil pores under the force of gravity. The smaller surface pores take in water by capillarity. The downward moving water is also sucked in by capillary pores.

The gravitational water moves towards the ground water following the path of least resistance. When the capillary pores at the surface are filled and intake capacity reduced infiltration rate decreases. As a trend the rate of infiltration is high in the beginning. It decreases rapidly in the initial stages and then slowly till it approaches a nearly constant rate in about 30 to 90 minutes depending upon the type of soil.

A. Factors Affecting Infiltration

- Soil Texture and Structure
- Conditions at Soil Surface
- Soil-Moisture Content
- Type of Vegetative Cover
- Soil Temperature
- Human Activities on Soil Surface
- Soil Density
- Biological crusts

II. STUDY OF DIFFERENT SOILS

A. Alluvial Soils

- Mostly available soil in India (about 43%) which covers an area of 143 sq.km.
- Widespread in northern plains and river valleys.
- In peninsular-India, they are mostly found in deltas and estuaries.
- Humus, lime and organic matters are present.
- The porosity and texture provide good drainage and other conditions favourable for bumper crops.
- The chemical composition of the alluvial soils makes this group of soils as one of the most fertile in the world. The proportion of nitrogen is generally low, but potash, phosphoric acid and alkalies are adequate, while iron oxide and lime vary within a wide range.
- Highly fertile.
- Indus-Ganga-Brahmaputhra plain, Narmada-Tapi plain etc are examples.
- They are depositional soil – transported and deposited by rivers, streams etc.
- Sand content decreases from west to east of the country.
- New alluvium is termed as Khadar and old alluvium is termed as Bhangar.
- Colour: Light Grey to Ash Grey.
- Texture: Sandy to silty loam or clay.
- Rich in: potash
- Poor in: phosphorous.
- Wheat, rice, maize, sugarcane, pulses, oilseed etc are cultivated mainly.

B. Black Soils

- Regur means **cotton –** best soil for cotton cultivation.
- Most of the Deccan is occupied by Black soil.
- Mature soil.
- High water retaining capacity.
- Swells and will become sticky when wet and shrink when dried.
- in the hot dry season, the moisture evaporates, the soil shrinks and is seamed with broad and deep cracks, often 10 to 15 cm wide and upto a metre deep. This permits oxygenation of the soil to sufficient depths and the soil has extraordinary fertility.
- Some of the major crops grown on the black soils are cotton, wheat, jowar, linseed, Virginia tobacco, castor, sunflower and millets. Rice and sugarcane are equally important where irrigation facilities are available. Large varieties of vegetables and fruits are also successfully grown on the black soils.
- **Self-ploughing** is a characteristic of the black soil as it develops wide cracks when dried.
- **Rich in:** Iron, lime, calcium, potassium, aluminum and magnesium.
- **Deficient in:** Nitrogen, Phosphorous and organic matter.
- **Colour:** Deep black to light black.
- **Texture:** Clayey.

C. Red Soils

- Seen mainly in low rainfall area.
- Also known as **Omnibus group.**

- Porous, friable structure.
- Absence of lime, kankar (impure calcium carbonate).
- In their chemical composition they are mainly siliceous and aluminous; with free quartz as sand the alkali content is fair, some parts being quite rich in potassium.
- The main parent rocks are acid granites and gneisses, quartzitic and felspathic
- **Deficient in**: lime, phosphate, manganese, nitrogen, humus and potash.
- **Colour:** Red because of Ferric oxide. The lower layer is reddish yellow or yellow.
- **Texture:** Sandy to clay and loamy.
- Wheat, cotton, pulses, tobacco, oilseeds, potato etc are cultivated

D. Laterite and Lateritic Soils

- Name from Latin word 'Later' which means Brick.
- Become so soft when wet and so hard when dried.
- In the areas of high temperature and high rainfall.
- Formed as a result of high leaching.
- Lime and silica will be leached away from the soil.
- Laterite and lateritic soils have a unique distinction of providing valuable building material
- Organic matters of the soil will be removed fast by the bacteria as it is high temperature and humus will be taken quickly by the trees and other plants. Thus, humus content is low.
- **Rich in**: Iron and Aluminum
- **Deficient in**: Nitrogen, Potash, Potassium, Lime, Humus
- **Colour**: Red colour due to iron oxide.
- Rice, Ragi, Sugarcane and Cashew nuts are cultivated mainly.

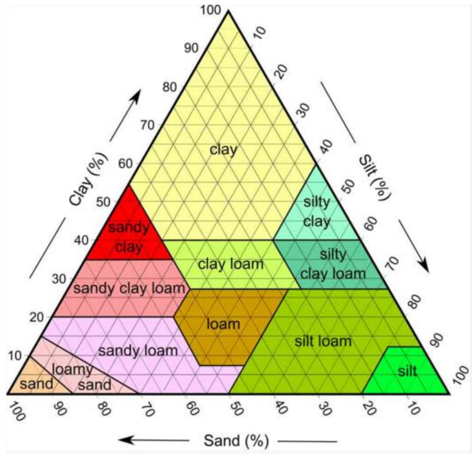
E. Arid and Desert Soils:

- Seen under Arid and Semi-Arid conditions.
- Deposited mainly by wind activities.
- High salt content.
- Lack of moisture and Humus.
- Kankar or Impure Calcium carbonate content is high which restricts the infiltration of water.
- Nitrogen is insufficient and Phosphate is normal.
- In large areas of desert soils, only the drought resistant and salt tolerant crops such as barley, rape, cotton, wheat, millets, maize and pulses are grown
- **Texture:** Sandy
- **Colour:** Red to Brown.

III. SOIL TEXTURAL CLASSIFICATION

Soil textural classification is being made because as the **texture** of a soil determines **soil** water-holding capacity, permeability, and soil workability. Sand, silt, clay, and organic matter particles in a soil combine with one another to form larger particles.

Soil textures are classified by the fractions of each soil separate (sand, silt, and clay) present in a soil. Classifications are typically named for the primary constituent particle size or a combination of the most abundant particles sizes, e.g. "sandy clay" or "silty clay". A fourth term, loam, is used to describe a roughly equal concentration of sand, silt, and clay, and lends to the naming of even more classifications, e.g. "clay loam" or "silt loam".



A. Importance of Soil Texture

- Soil texture is one of the most important properties of a soil, and it greatly affects land use and management.
- It affects the amount of water and nutrients that a soil can hold and supply to plants.
- Soil physical properties such as structure and movement of air and water through the soil are affected by texture.

Maximum Application Rates for Various Soil Types				
	Grass/Sod		Cultivated	
Soil Type	[in/hr]	[mm/hr]	[in/hr]	[mm/hr]
Clay	0.25	6.5	0.1	2.5
Silt Loam	0.35	9	0.15	4
Clay Loam	0.3	7.5	0.2	5
Loam	0.35	9	0.2	5
Fine Sandy Loam	0.4	10	0.25	6.5
Sandy Loam	0.45	11.5	0.25	6.5
Loamy Sand	0.65	16.5	0.35	9
Sand	0.75	19	0.4	10

IV. STUDY OF METHODS FOR MEASUREMENT OF INFILTRATION CAPACITY

A. Field Method

Single-Ring Infiltrometer:

Single-ring Infiltrometer test was conducted using 15cm and 30 rings as shown in the figure. The ring is driven into the soil approximately 12-14 inches into the soil. Then water is poured into the ring that above the soil surface. In some cases the above surface of the ring is covered to avoid evaporation. For measuring the depth of water in ring we need hook gage, steel tape or scale. We should take care of a ring while it is driving into the ground there may be chance of having hapless connections between the thin wall of a ring and soil. That hapless connection may cause leak of water and that leads to over estimation of a Infiltration rate.

Double-Ring Infiltrometer:

Double-ring infiltrometer was well known technique for measuring or estimating the infiltration rate of soils. Double ring infiltrometer are developed in reaction to fact that single-ring infiltrometer tends to estimate the over infiltration rates. This has been ascribed the fact that liquid in the cylinder is not purely vertical but it also diverges laterally. Double ring infiltrometer understate the standard errors affiliated with the single-ring infiltrometer because the water in the outer ring forces vertical infiltration of water inside the inner ring. We should take care of a ring while it is driving into the ground there may be chance of having hapless connections between the thin wall of a ring and soil. A typical Double-ring infiltrometer consists of 45cm diameter inner ring and 60cm diameter outer ring. Whereas there are two techniques used in double-ring one is constant head method and the other is falling head method. In constant head method water is systematically added to both the inner and outer rings. The volume of water wanted to maintain the constant level of inner-ring is measured. For measuring the depth of water in ring we need hook gage, steel tape or scale.

Physically based model

These models describe in a simplified manner the water movement in soils, especially at the humidity front level, depending on certain physical parameters.

Author	Function	Legend
Horton	$i(t)=i_f+(i_0-i_f)e^{-\gamma}$	$i(t)$ - infiltration capacity during time [cm/s] i_0 - initial infiltration capacity [cm/s] i_f - final infiltration capacity [cm/s] γ - constant depending on the soil type
Kostiakov	$i(t)=i_0t^{-\alpha}$	α - parameter depending on soil conditions
Dvorak-Mezencev	$i(t)=i_0+(i_1-i_f)t^{-b}$	i_1 - infiltration capacity at time t=1min [cm/s] t - time [s] b - constant
Holtan	$i(t)=i_f+cw\left[(IMD)-F\right]^n$	c - factor variable from 0.25 to 0.8 w - Holtan equation flow factor n - experimental constant approximately = 1.4
Philip	$i(t)=\frac{1}{2}st^{-0.5}+A$	s - sorptivity [$cms^{-0.5}$] A - gravity component depending on hydraulic conductivity at saturation [cm/s]
Dooge	$i(t)=a(F_{max}-F_t)$	a - constant F_{max} - maximal retention capacity F_t - water quantity retained on soil at time t
Green&Ampt	$i(t)=k_s\left(1+\frac{h_0-h_f}{z_f(t)}\right)$	k_s - hydraulic conductivity at saturation [mm/h] h_0 - surface pressure load [mm] h_f - pressure load at the humidity front [mm] z_f - humidity front depths [mm]

CONCLUSION

- Soil testing enables a successful and effective storm water management design that incorporates a suitable infiltration rate for design calculations.
- Soil Testing also helps investigate the subsurface conditions below existing surfaces/pavement, and identifies existing soil horizons (layers),as well as any limiting features, historic conditions, etc.

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