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Experimental Determination of Infiltration Rates For Some Selected Soils In Ado Ekiti

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ABSTRACT : *Thisstudy used experimental method to examine the infiltration rates for three major types of soils (sandy, loamy and clayey) in Ado Ekiti Metropolitan area of Nigeria. The experimental method include laboratory and field tests. The laboratory tests done for the classification of the samples consist of moisture content, specific gravity, sieve and hydrometer analysis as well as atterberg test to British Standard (BS) 1377 (1975). The samples were later classified using Unified Soil Classification System (USC) and textural triangle method. The Field Tests include use of fabricated double-ring infiltrometer (ASTM, 1994) for the determination of infiltration and estimation of water in the soil two days after the infiltration test was carried out. The classification revealed the samples as coarse sand, sandy clay loam and clayey soils with infiltration rate of 71mm/hr, 24.7mm/hr and 2.3mm/hr respectively. The water retained in the samples for the first 100mm depth decreases by half of the initial water content that is from 5.84 % to 2.90% for sandy, 7.89% to 4.05% for loamy and 28.05% to 14.50% for clayey. The moisture content further decrease to almost one-third of the initial values for the next 100mm depth. The soil thereafter maintained a steady increase in the water content with 3% for sandy, 12% for loamy and 16% for clayey for every additional 100mm depth. The water retention in clayey soil is thereby higher than other samples.*

KEYWORDS; *Experimental method, infiltration rate, sandy, loamy, clayey, Ado Ekiti.*

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I. INTRODUCTION

Infiltration is the process by which water on the soil surface penetrates the soil [1] [2]. According to Diamond, (2004), it also refers to the vertical movement of water down wards from the soil surface to replenish the soil water/moisture deficiency, with excess percolating down to build up the water table by gravitational flow.Water applied to the soil surface through rainfall and irrigation events subsequently enters the soil through the process of infiltration. It replenishes the soil moisture deficiency which is of paramount importance for the plants' growth. Infiltration rate in soil science is a measure of the rate at which a particular soil is able to absorb rainfall or irrigation water. [3] describes infiltration as the process by which water enters soil and thus the vadose zone through the soil-air interface. Infiltrability or infiltration capacity is a term generally used to define the maximum rate at which rain or irrigation water can be absorbed by a soil under a given condition. [4] [5] [6] stress that the infiltrability of a soil depends on the initial moisture content (initial wetness), condition of the soil surface, hydraulic conductivity of the soil profile, texture, porosity, degree of swelling of soil, colloids, and organic matter, weather (temperature), land use, entrapped air, depth of the ground water table, vegetal cover, intensity and duration of rainfall or irrigation and viscosity of water.

The soil structure has a pronounced effect on such properties as erodibility, porosity, hydraulic conductivity, infiltration and water holding capacity. The size limits of the soil-particle fractions have been established by various national and international organizations. The most commonly used classifications are those proposed by United States Department of Agriculture (USDA), International Soil Science Society (ISSS), American Society for Testing Materials (ASTM), Massachusetts Institute of Technology (MIT), British Standards Institution (BSI), American Association of States Highways Highway transportation Officials (AASHTO), United States Public Roads Administration (USPRA), German Standard (DIN) as well as Unified Soil Classification System (USC). The intricate nature of the space between soil particles which are normally referred to as soil pores is of more importance in flow in soils. The sizes of soil pores can vary from more than 1cm in diameter to less than 0.001mm in diameter. Pore larger than about 0.1mm are often referred to as macrospores, those in the 0.1 to 0.01mm size range as mesopores and those less than 0.01mm in size as micropores [7] [8].

[9] postulates that the process of water infiltrating through a surface soil is a complex interaction between rainfall intensity, soil type and surface cover, and condition. Soil surface conditions govern the ability or rate at which water passes through the soil. [10] conclude that the infiltration capacity of soil is a major factor that influences the occurrence of overland flow. Indirectly, Infiltrability determines how much of the water will

flow over the ground surface into streams, or river, and how much will enter the soil, and thus assists in providing an estimate of water available for downward percolation through drainage or return to the atmosphere by the process of evapotranspiration. Knowledge of the infiltration process as it is affected by the soil's properties and transient conditions by the mode of water supply is therefore a prerequisite for the efficient water management [11]. The process of water movement is very dynamic, changing dramatically over time and space. A thorough understanding of infiltration process, therefore, would require an in-depth knowledge in the conceptualization of the movement of water in the soil and the soil itself which serves as the medium for the passage of water. Therefore, this study which is set to determine the infiltration rate of water in some selected soils by experimental method with the view to investigate water movement and retention capacity of the soil for plant growth is a right step in a right direction.

II. MATERIAL AND METHODS

A Location of Ado Ekiti

The study took place in Ado Ekiti, the capital city of Ekiti State in Nigeria. The city is located within the North-Western part of the Benin-Owena River Development Area. The city lies between Latitude 7^o 34' and 7^o 44' North of the Equator and Longitude 5^o 11' and 5^o 18' East of the Greenwich Meridian and occupies a central position in Ekiti State geographically. The topography of the area is rugged due to the presence of crystalline basement rocks like charnokite and quartzite ridges which rise abruptly above the surrounding country rocks. The area is underlain by the Precambrian basement complex rocks of South-western Nigeria and drained by River Ireje, Elemi,Omisanjana and Awedele Stream.

B Experimental procedure

The soil samples of about 3kg each were collected with the aid of an Auger at a depth of not more than 0.5 meters from the surface. Immediately the samples were collected, about 50g of each sample was put inside labeled moisture content polythene nylon and the mouth sealed so as to prevent loss of moisture before reaching the laboratory for the moisture content test. The remaining samples from these sources were shielded from direct rainfall (kept under a roof) and allowed to dry naturally on being exposed to air for about two weeks. This was to control the water content for other tests. The tests carried out could be grouped into three categories:

i. Pre-infiltration Test (Test carried out for classification of samples)
ii. Infiltration Test (Determination of the rate of flow of water into the soil)
iii. Post-infiltration Test (Test carried out for determination of water retention capacity of the samples)

C Pre-infiltration Test:

The following tests were carried out under the Pre-infiltration tests

i. Soil Wetness/Moisture Content Test

Three aluminum moisture content cans with their lids were labeled, cleaned, dried and weighed on an electronic balance. A representative sample of the wet soil of the sample was put inside each can and weighed. The cans were opened with their lids placed underneath and the cans with wet soils were put inside an oven to dry to a temperature of 105. The dried soils were placed inside desiccator to cool so as to avoid the soil samples from absorbing moisture from the atmosphere. The cans with the dried soils were re-weighed and the moisture content of the soil as a percentage of its dried mass was determined for each sample.

ii. Specific Gravity

The second test carried out to accurately classify the soil samples was the specific gravity test, although it was of limited value in the identification and classification because the specific gravity of most soils classification falls within a narrow range. The method used to determine the specific gravity of each samples is as follows:

A gas jar and ground glass plate were dried and weighed (m_1). A representative soil sample was put inside the gas jar with the ground glass plate and was re-weighed (m_2). A certain amount of volume of tap water was added to the soil sample inside the gas jar and the content was shaken / agitated for some minutes. The new weight of the gas jar was determined (m_3). The content of the gas jar was emptied washed out thoroughly, and now filled completely to the brim with water. The gas jar and plate together with the water were now weighed as (m_1). The experiment was repeated twice on each sample of the soils. The specific gravity is taken as the ratio of the mass of a given volume of soil sample to the mass of an equal volume of water.

iii. Sieve Analysis

A dried representative sample soil of unknown mass was passed through a series of standard sieve of known aperture (BS sieves) having successively finer aperture size and the mass of soil retained on each sieve was measured. This enables the cumulative percentage by mass of the soil to be plotted against the relative aperture sizes. Sieves of appropriate sizes for the materials being tested were selected from the range of test sieves commonly used for the particles size analysis\

iv. Sedimentation Analysis

A sample of known mass (50 – 200g) of loamy and clayed samples was mixed with distilled water to form a smooth thin paste. A deflocculating agent was added to the paste and the mixture washed into a graduated jar which is ultimately filled with distilled water to bring the level to the 1000cc mark. This suspension is agitated for about 30 seconds after which hydrometer is inserted and the timer started. The hydrometer readings were taken at different times and recorded.

v. Atterberg Limits Tests

An already air dried representative of each of the sampled soil of known mass was sieved through 425mm in micro mesh. The sample was mixed with distilled water and allowed to soak overnight, so that the water can equilibrate. The soaked sample was brought out and smoothened on a small curved dish. A grooving tool was applied in the middle of the sample to divide it into equal halves. The samples was disturbed by tapping it up and down, and counting the number of blows until two halves come together. A sample of about 2 grams from dish was taken out and weighted for moisture content determination. More water was added repeatedly and the process was started all over again, counting and recording the number of blows, as well as determining the water content for each process. Four processes were done. A plot of water content against log of blows was drawn to give the "flow curve". The water content at twenty-five blows from the curve is the "liquid limit". Thereafter, moist sample of each of the soil samples was mixed thoroughly and rolled on a glass plate with hand until a 3mm diameter tread which shows sign of a crumbling on a further rolling was formed. A sample of the crumbling materials was taken for the water content determination. This water content is the "plastic limit". The numerical difference between the liquid limits gives the plasticity index. This is recorded to the nearest whole number.

In order to determine the linear shrinkage, a representative damp sample was mixed with water to get close to its liquid limit. A rectangular box mould (40mm x 40mm x 600mm internal dimension) was then filled with this mixture in three roughly equal layers and tapped after every layer to remove entrapped air in the soil. The mould counting the soil was placed in a shedder area and allowed to dry. It was observed after some days that the soil was shrinking away from the sides of the mould. When the drying was completed, the length of the dried soil ws measured accurately and recorded. The difference between the internal length of the mould box and dried soil length is the linear shrinkage.

vi. Permeability or Hydraulic Conductivity

Permeability or vertical hydraulic conductivity test was also carried out on the soil samples not only to access the suitability of the soil samples for engineering purpose, but to determine the case with which water passes through a porous medium of the sample. The falling heads permeability device was used for the experiment. The weight, height and diameter of the mould were determined and recorded. The samples was carefully placed inside the mould and the rim of the mould was clean. A rubber gasket was placed on the rim and the cover firmly sealed and tightened. The new weight of the mould and the soil sample was determined and recorded. The permeameter was then put inside a container of water overnight for the sample to reach full saturation. The permeameter was removed from the container and the inlet tube of the permeameter was attached to the hose from the falling head standpipe. The standpipe was filled with water to a convenient height and the hydraulic head h_1 across the sample was recorded. The water inside the standpipe was allowed to flow through the sample and simultaneously the stop watch were stopped when the standpipe was almost emptied or reached a convenient mark to obtain the final head h_2. The standpipe was refilled to the same mark so as to make h_1 to be the constant and the test was repeated four times on the samples of the soil

D Infiltration Test

Infiltration rate was measured with the use of fabricated double-ring infiltrometer , consisting of two concentric rings. The diameter of the inner ring is 300mm and the diameter of the outer ring is 600mm. Rings were 300mm deep and were made from 12mm-guage steel with sharpened bottom edges; they were driven to the ground to 150mm depth. Grass was cut to the near soil level and a pad was placed inside the inner ring to prevent pudding. The inner and outer edges were tamped to seal possible cracking.

The rate of fall of water was measured in the inner ring while a pool of water was maintained at approximately the same level in the outer ring to reduce the amount of lateral flow from the inner ring. Generally, the water level was kept at or above 50mm depth; the difference in height between the inner outer rings was kept to a minimum. The amount of water required per site varied from $0.3m^3$ to $3.5m^3$. The rate of fall of the water level of the cylinder was measured at 2, 5, 10, 20, 30, 40 and 60 minutes and at 20-minutes interval thereafter. The process was stopped once a steady infiltration rate had been found. The duration of each test was from 1.2 to 3.5 hours and the experiment was repeated three times at each site.

E Post-infiltration Test

The last aspect of the field work is the estimation of the moisture contents of the partially saturated soils at different depth at different time interval. The experiments were carried out two days for sandy and loamy samples and three days for clayey sample after the infiltration test had been done so that the soils were nearly at the field capacity. Moisture content of the partially saturated soils were determined immediately the infiltration test was completed

III. RESULTS AND DISCUSSION

The moisture content tests (Table 1) shows that 6.44%, 8.99%, 32.45% is the amount of water present in the sandy, loamy and clayey samples respectively. The water retained in the clayey soil is higher than others due to the nature of the soil particles and its tenacity in water. The specific gravity of sand (Table 2) is 2.665, for loamy soil is 1.625 and 2.795 for clayey soil. This is in agreement with values specified in the work of [9]. Table 3 shows that 1.3% of the particles of the sandy soil passed through No. 200 sieve while 69.3% and 81.92% passed through the same sieve for loamy and clayey samples thereby necessitating hydrometer analyses (Table 4 and 5). The result clearly indicates that grains of the sandy sample are mostly well-graded coarse materials.

Table 1: Moisture content determination results

Sample No/Name	Sandy soil	Loamy soil	Clayey soil
Container No	A	B	C
Mass of wet soil + can (m_2)	1027	1180.8	1060.5
Mass dry soil + can (m_3) g	1000	1132	943
Mas of can (m_1) g	581	589	580.9
Mass of moisture ($m_2 - m_3$) g	27	48.8	117.5
Mass of dry soil ($m_3 - m_1$) g	419	543	362.1
$W = \frac{M_V}{M_S} = \frac{m_2 - m_3}{m_3 - m_1} \times 100$	6.44%	8.99%	32.45%

Table 2: Results of specific gravity test on samples

Soil samples	Sandy soil		Loamy soil		Clayey soil	
Gas Jar Number	A	B	C	D	E	F
Mass of jar full of water (m_4) g	111.4	114.5	135.3	154.0	91.9	93.7
Mass of gas jar + soil + water (m_3) g	139.2	142.9	154.6	175.97	105.1	104.8
Mass of gas jar + soil (m_2) g	77.4	81.6	83.9	95.5	57.9	46.8
Mass of gas jar (m_1) g	32.9	36.0	34.0	38.1	37.0	29.8
Mass of soil used ($m_2 - m_1$) g	44.5	45.8	49.9	57.4	20.9	17.0
Mass of added water ($m_4 - m_1$) g	78.5	78.5	101.3	115.9	54.9	63.4
Mass of water used ($m_3 - m_2$) g	61.8	61.3	70.7	80.47	47.2	58.0
Volume of soil ($m_4 - m_1$) - ($m_3 - m_2$) g	16.7	17.2	30.6	35.43	7.7	5.9
Specific gravity of soil samples $G_S = \frac{(m_2 - m_1)}{(m_4 - m_1)(m_3 - m_2)}$	2.66	2.66	1.62	1.62	2.71	2.88
	2.665		1.625		2.795	

Table 3: Results for Sieve Analysis for Sandy Soil

Sieve No.	Diameter (mm)	Mass retained (g)	% Retained	% Passing
4	9.50	0.00	0.00	0.00
8	4.75	1.30	0.4	99.6
16	2.36	13.00	4.3	95.3
30	1.18	38.00	12.7	82.6
40	0.60	99.70	33.2	49.4
50	0.425	58.80	19.6	29.8

200	0.300	41.70	13.9	15.9
Pan	0.075	16.90	5.6	1.3

Table 4: Results for Sieve Analysis and Hydrometer Test for Loamy Soil

Sieve No	**Diameter (mm)**	**Mass Retained (g)**	**% Retained**	**% Passing**
	9.50	0.00	0.00	0.00
4	4.75	0.00	0.00	0.00
8	2.36	0.00	0.00	0.00
16	1.18	1.43	0.30	99.70
30	0.60	8.61	1.70	98.0
40	0.425	54.50	10.90	87.10
50	0.300	27.00	5.40	81.70
100	0.212	39.09	7.80	73.90
200	0.075	23.00	4.60	69.30
Particle size from Hydrometer	0.063			68.70
	0.020			68.00
	0.010			63.00
	0.008			45.00
	0.0065			39.85
	0.005			34.00
	0.002			27.50
	0.001			25.00
	0.0005			17.500
	0.0003			10.000
	0.0002			4.950

Table 5: Results for Sieve Analysis and Hydrometer Test for Clayey Soil

Sieve No	**Diameter (mm)**	**Mass Retained (g)**	**% Retained**	**% Passing**
	9.50	0.00	0.00	0.00
4	4.75	0.00	0.00	0.00
8	2.36	0.00	0.00	0.00
16	1.18	0.00	0.00	0.00
30	0.60	0.00	0.00	0.00
40	0.425	1.30	0.26	99.74
50	0.300	7.58	1.52	98.22
100	0.150	54.5	10.90	87.32
200	0.075	27.0	5.40	81.92
Particle size from Hydrometer	0.063			77.50
	0.050			75.00
	0.030			73.50
	0.010			61.60
	0.065			59.50
	0.045			58.45
	0.0020			56.00
	0.001			50.00
	0.0007			41.00
	0.00055			27.40
	0.0004			16.00
	0.002			7.00

The loamy sample has liquid limit of 40.67 and plastic limit of 17.53 while clayey sample has liquid limit of 63.41 and plastic limit of 24.70. The result of classification reveals that the sandy sample is brown, coarse and well-graded sand and this represents one extreme soil condition for agricultural purposes. The loamy soil is classified as sand clay loam while the clayey sample is also described as light gray, fine fat clay

Soil texture of sandy soil will allow water to flow easily while the texture of the clayey soil will not allow easy flow of water. The texture of loamy soil that has 32.7% of sand content , 41.00% of silt content and

27.00%of clay content will hold enough water, better aerated for plant growth and easier to work on. This is justified also, with the results of the permeability

Results of the moisture content taken immediately after the infiltration test at the three sites and taken at different depths two-three days after the infiltration test are presented on Table 6. It can be seen that the water retained in the clayey soil at the respective depth is higher than that of loamy and sandy soils due to the fine nature of the soil particles.

Table 6: Results of moisture contents at varying depth

Depth (mm)	**Sandy soil (%)**	**Loamy soil (%)**	**Clayey soil (%)**
Ground level	5.84	7.89	28.05
100	2.90	4.05	14.05
200	1.89	2.83	9.86
300	4.89	14.83	25.86
400	7.89	26.83	41.86
500	10.89	38.85	57.86

The results fall within the range specified in literatures especially [11] [5] [12]. However, it can be established that the sandy soil has good internal drainage since most of the soil pores are macrospores leading to high infiltration rate. The clayey soil has low infiltration rate since the pores are mostly microspore and therefore has the high capacity of holding and storing water.

The relative amount of water present in the soils at the three sites determine two-three days after the infiltration test is shown on the Table 6 The results show that after the application of infiltration water, there is a sudden dropped in the water retained in the soil from 5.84% to 2.90% for sandy soil and from 7.89% to 4.05% for loamy soil as well as from 28.05% to 14.50% for clayey soil for the first 100mm depth of the soil. This represents almost half of the initial water content of the soils after infiltration test. The water content of the soil reduced further for the next 100mm depth (i.e. 200mm) to nearly one third of the initial water content with sandy soil having 1.89%, loamy with 2.83% and clayey soil with 9.86%. the water taken subsequently at 100mm depth interval thereafter increase by 3% for sandy, 12% for loamy and 16% for clayey soil.

Water in the soil was drained or pulled out under the force of gravity until it reached the field capacity. This is the gravitational water from the macropores in the soil. The water has moved out of the macropores but the micropores and capillary pores are still filled with water and will supply plants with the needed moistures. The result shows that clayey soil has more water retained in it but the ability of the plant to absorb the water depends on the depth of the root, density of the root as well as the water potential gradient between the roots and the soil where the water is being extracted. [12] claims that plants will require 0.3 bars retention from field capacity to -15 bars tension at permanent wilting point for it to draw the water in the soil depending on the type of plant and soil

IV. CONCLUSION

The texture of the sandy soil allows easy flow of water with infiltration rate of 71.7mm/hr. whereas the clayey sample would not allow free flow of water with infiltration rate of 2.3mm/hr. this implies that grains of sandy soil consist of mostly macropores compare to that of clayey which are mostly micropores. The texture of the loamy sample with infiltration rate of 24.7mm/hr. on the other hand would hold enough water, better aerated for plant growth and easier to work on. The water retention capability of the samples is very moderate as the moisture content of the soil increase by 3% for sandy soil, 12% for loamy and 16% for clayey soil for every 100mm depth. This is good for plant growth even when all gravitational water has drained out of the macrospores, there would still be moisture in the micropores and capillarity pores for the root, density of the root and water potential gradient between the roots and the soil where the water is been extracted.

It is therefore recommended that the clayey material that has been found to have high water retention capability can be used in earth dam construction to prevent seepage with caution for other properties. The sandy material that consists mostly of coarse grained particles can be used as sharp sand for construction purpose. The soil-water relationship established in the research work can be used for soil management for planting of crop species.

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