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Modeling Drainage Ability in Synthetic Filter Materials

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ABSTRACT: This research was carried out to verify the relationship in filtering abilities of three synthetic filters (fibre, paper and sawchips) moulded on a mole drains. Fibre drain was found to give highest drainage ability followed by saw-chips moulded drain and lastly, paper moulded drain. Discharge (cl)-time (day) relation models were determined for fibre, saw-chips and paper drain respectively. Catchment radar discharge for the various filters were simulated while the correlation between the filter yields were modeled in relation to filter discharge correlation factor, k. Correlation models for individual filter under investigation were determined for a condition of k ranges between 0 to 1. The catchment radar affirmed that drainage ability of synthetic filters are relatively proportional to a specific area of the catchment. The research showed that fibre filter was capable of draining most area in the catchment, followed by sawchips and lastly paper filter; provided that drainage is adequately required.

(Keywords: synthetic filters, drainage, discharge)

I. INTRODUCTION

Drainage is a major concern in building and road construction; and agriculture. A soil can only be stabled if it is well drained. (Ritzema, 2014) [8]. Hydraulic properties of soil such as porosity, permeability play major role in soil drainage (Govindarajan& Kumar, 2020; Sterpejkowicz-Wersocki, 2014) [3][9]. In agriculture, undrained soil leads to poor aeration of the soil and subsequently distort the soil texture and structure. Soil salinity normally resulted if any soil is allowed to stay a much in a waterlogged condition (Adeniran &Awoniyi, 2017) [1]. Ability of any soil to drain to certain extent depends much on its intrinsic properties but these properties could be distorted if adequate drainage is not provided (Kanda, Senzanje &Mabhandi, 2020) [4]. An undrained soil in building construction can give rise to moisture movement at the foot of the building foundation and these can subsequently weaken and devalue the material properties of such structure.

Methods of draining soil varies in structures which ranges from open drainage to underground drainage. The use of open channels is most suitable to control external water sources of a catchment area which are most times in the form of runoff from a possible erosion (Kapoor, Ghare, Vasudeo & Bada; 2020) [5]. Underground drainage systems are majorly concerned with waters being transmitted from subsoil or waters that are been absorbed into a catchment from surrounding environment such as seepage water. The movement of this kind of waters cannot be stopped from areas with high water table hence, necessitates underground method of drainage such as filter drains which could in turn prevent pollution of the land under investigation (Newman, Nnadi&Mbanaso, 2015) [7]. Long, Taib and Salaman (2017) [6] adopted some critical parameters for pipe configuration and arrangement, soil type and filter design.

This research work focused on addressing the best practice and methodology for synthetic-moulded underground pipe drains by selecting three synthetic filter materials (fibre, sawchips and paper) and hence determines which would give the best drainage ability.

II. METHODOLOGY AND ANALYSIS FOR DESIGNS

This research was carried out in a waterlogged area at Temidire Area, Egbejila, Ilorin Kwara State, North-Centre Nigeria between September and October, 2017; in order to determine the drainage abilities of three selected artificial filters, mainly fibre, saw-chips and paper. Waters from the drain sprout were collected, measured and recorded twice a day for 23 days.

A. EXPERIMENTAL DESIGN AND LAYOUT

The experiment was conducted using twelve mole drains made of 50 mm perforated pipes wrap-moulded with three different filter materials (fibre, paper and sawdust). Each filter materials had equal numbers of drains with four each. The filter-moulded mole drains were laid horizontally to cover the catchment area. The catchment layout was spaced at 1 m interval and divided into four blocks taking in mind the land gradient uniformity. Four replication was adopted with each replicate carefully allotted in each block. This was done to have uniformity of trial in the conduct of the experiment. See Fig. 1.

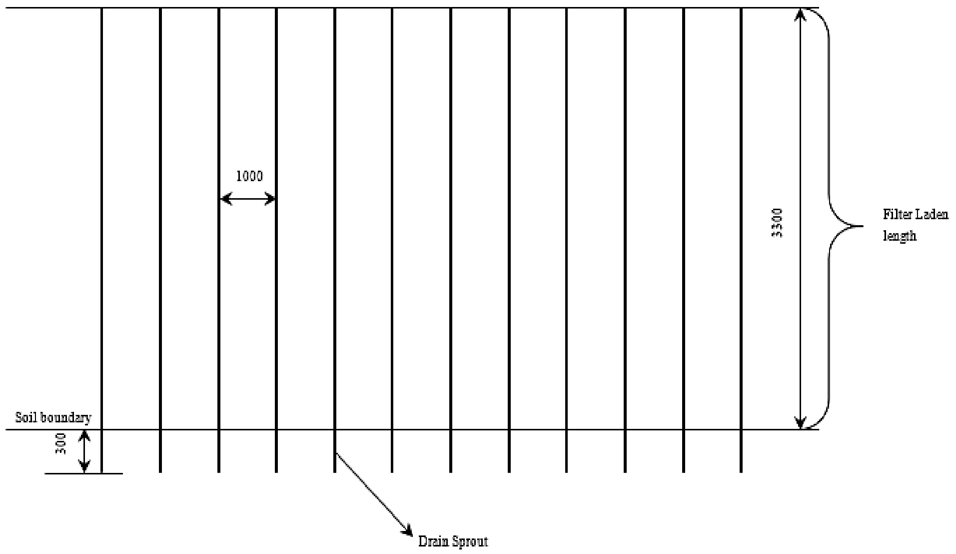


Fig.1: Drainage Layout (all dimension in "mm")

B. MODEL DEVELOPMENT

Drainage ability of a filter, neglecting the surrounding medium, is largely dependent of its interstitial spaces within the filter internal structure. The interstitial spaces define how packed the filter, the degree of perviousness and to a large extent, the degree of fluid passage through it (see Fig. 2).

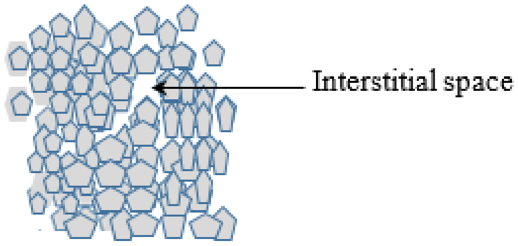


Fig.2: Filter Packing.

Fig.2 represents a typical filter structure packing. If Q is the discharge from the filter, it can be deduced that:

$Q = av$ (1)

$a = A - A_f$ (2)

$\gg Q = (A - A_f)v$ (3)

but volume of a filter, V is given by:

$$V = \frac{m}{\rho_f} = A_f h \qquad (4)$$

Therefore,

$$A_f = \frac{m}{\rho_f h} \qquad (5)$$

by substituting equation 6 in 3

$$\gg \mathbf{Q} = \left(\mathbf{A} - \frac{\mathbf{m}}{\boldsymbol{\rho_f h}}\right)\mathbf{v} \qquad \mathbf{(6)}$$

For multiple filter packing,

$$\rho_f = \frac{\rho_{f1}+\rho_{f2}+\rho_{f3}+\cdots+\rho_{fn}}{n}, for\ f = 1\ to\ n \qquad (7)$$

Notations:

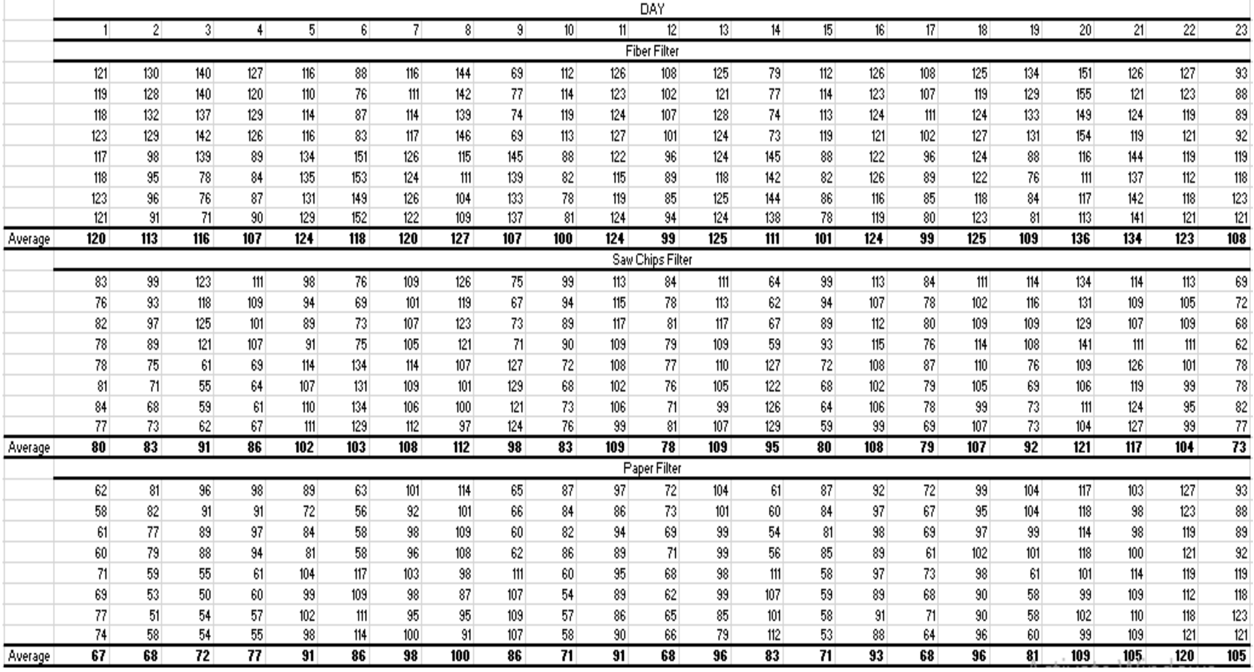
A_f = actual area of filter material
m = mass of filter
ρ_f = density of filter
h = thickness of filter
v = velocity of flow
a = interstitial area of filter
A = total area of packing

Equation (6) was adopted for quantities of filter materials to be moulded on pipe drain.

III. RESULTS AND DISCUSION

The results obtained from the conduct of the experiment are shown in Table 1. Table 2. Table 1 presents the discharges in the field considering all the experimental replicates while Table 2 gives the average discharges from the drains of each replicate. Average daily discharge (cl)-time (day) graph is shown in Fig. 3.

Table 1: Discharge (cl) from the field



	DAY																						
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
Fiber Filter																							
	121	130	140	127	116	88	116	144	69	112	126	108	125	79	112	126	108	125	134	151	126	127	93
	119	128	140	120	110	76	111	142	77	114	123	102	121	77	114	123	107	119	129	155	121	123	88
	118	132	137	129	114	87	114	139	74	119	124	107	128	74	113	124	111	124	133	149	124	119	89
	123	129	142	126	116	83	117	146	69	113	127	101	124	73	119	121	102	127	131	154	119	121	92
	117	98	139	89	134	151	126	115	145	88	122	96	124	145	88	122	96	124	88	116	144	119	119
	118	95	78	84	135	153	124	111	139	82	115	89	118	142	82	126	89	122	76	111	137	112	118
	123	96	76	87	131	149	126	104	133	78	119	85	125	144	86	116	85	118	84	117	142	118	123
	121	91	71	90	129	152	122	109	137	81	124	94	124	138	78	119	80	123	81	113	141	121	121
Average	**120**	**113**	**116**	**107**	**124**	**118**	**120**	**127**	**107**	**100**	**124**	**99**	**125**	**111**	**101**	**124**	**99**	**125**	**109**	**136**	**134**	**123**	**108**
Saw Chips Filter																							
	83	99	123	111	98	76	109	126	75	99	113	84	111	64	99	113	84	111	114	134	114	113	69
	76	93	118	109	94	69	101	119	67	94	115	78	113	62	94	107	78	102	116	131	109	105	72
	82	97	125	101	89	73	107	123	73	89	117	81	117	67	89	112	80	109	109	129	107	109	68
	78	89	121	107	91	75	105	121	71	90	109	79	109	59	93	115	76	114	108	141	111	111	62
	78	75	61	69	114	134	114	107	127	72	108	77	110	127	72	108	87	110	76	109	126	101	78
	81	71	55	64	107	131	109	101	129	68	102	76	105	122	68	102	79	105	69	106	119	99	78
	84	68	59	61	110	134	106	100	121	73	106	71	99	126	64	106	78	99	73	111	124	95	82
	77	73	62	67	111	129	112	97	124	76	99	81	107	129	59	99	69	107	73	104	127	99	77
Average	**80**	**83**	**91**	**86**	**102**	**103**	**108**	**112**	**98**	**83**	**109**	**78**	**109**	**95**	**80**	**108**	**79**	**107**	**92**	**121**	**117**	**104**	**73**
Paper Filter																							
	62	81	96	98	89	63	101	114	65	87	97	72	104	61	87	92	72	99	104	117	103	127	93
	58	82	91	91	72	56	92	101	66	84	86	73	101	60	84	97	67	95	104	118	98	123	88
	61	77	89	97	84	58	98	109	60	82	94	69	99	54	81	98	69	97	99	114	98	119	89
	60	79	88	94	81	58	96	108	62	86	89	71	99	56	85	89	61	102	101	118	100	121	92
	71	59	55	61	104	117	103	98	111	60	95	68	98	111	58	97	73	98	61	101	114	119	119
	69	53	50	60	99	109	98	87	107	54	89	62	99	107	59	89	68	90	58	99	109	112	118
	77	51	54	57	102	111	95	95	109	57	86	65	85	101	58	91	71	90	58	102	110	118	123
	74	58	54	55	98	114	100	91	107	58	90	66	79	112	53	88	64	96	60	99	109	121	121
Average	**67**	**68**	**72**	**77**	**91**	**86**	**98**	**100**	**86**	**71**	**91**	**68**	**96**	**83**	**71**	**93**	**68**	**96**	**81**	**109**	**105**	**120**	**105**

Table 2: Average Daily Discharges from Drains

	Average Discharges (Q)		
Day	Fibre (Q_f)	Saw Chips (Q_s)	Paper (Q_p)
1	120	80	67
2	113	83	68
3	116	91	72
4	107	86	77
5	124	102	91
6	118	103	86
7	120	108	98
8	127	112	100
9	107	98	86
10	100	83	71
11	124	109	91
12	99	78	68
13	125	109	96
14	111	95	83
15	101	80	71
16	124	108	93
17	99	79	68
18	125	107	96
19	109	92	81
20	136	121	109
21	134	117	105
22	123	104	120
23	108	73	105

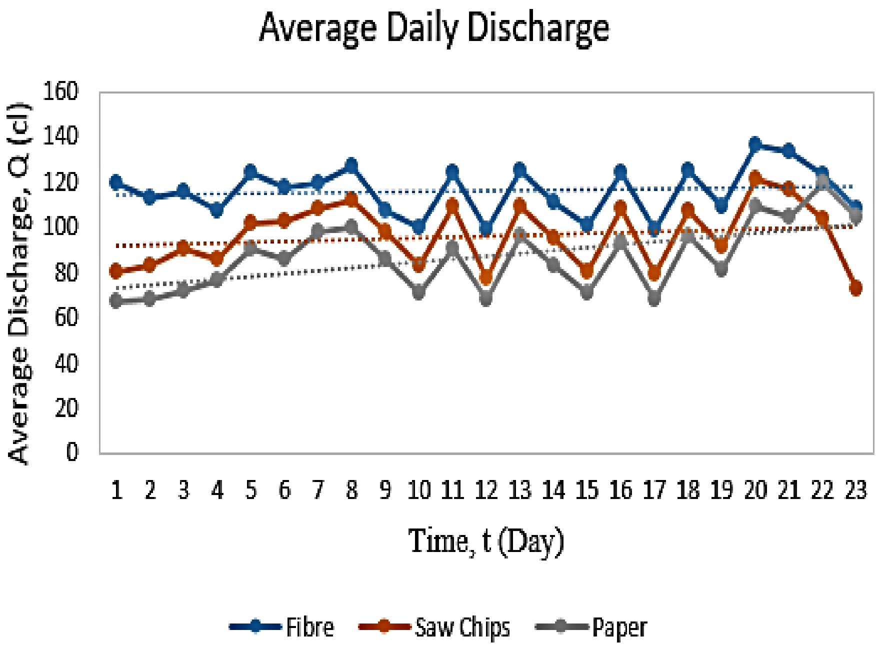


Fig.3: Average Daily Discharge from drains

From Fig. 3, Discharge, Q (cl) from the drains at any time, t (day) is given in equation (8), (9) and (10) for fibre, sawchips and paper respectively.

$$Q_f = 0.1848t + 113.87 \qquad (8)$$

$$Q_s = 0.4051t + 91.573 \qquad (9)$$

$$Q_p = 1.2717t + 71.783 \qquad (10)$$

Where Q_f and Q_s, and $Q_p$are discharges (cl) from fibre, sawchips and paper respectively; and t is time (day).

From the results, it was discovered that filter drains gave the highest propensity to discharge followed by saw-chips and lastly paper drains. It showed that filter drains had an edge to water discharge in an area of high water table compared to other used synthetic drains. Fluctuation in the readings of individual filters as shown in the data reflected change in water table as affected by precipitation. Absent of precipitation between a first and second readings gave rise to a lower subsequent reading.

IV. VALIDATION OF RESULTS

Catchment radar for the various filters were simulated using radar chart and the discharges were correlated by combination with respect to individual filter (see Fig. 4). The resulted discharge models by combination are given in (11), (12), (13), (14), and (15). The radar chart affirmed that drain filter drew most water from the catchment followed by saw-chips filter and lastly paper filter. The non-uniform shape of the individual filter radar line indicates the fluctuation in the catchment water table which resulted in discrepancies in the frequency of discharge as obtained in the reading.

$$Q_s = \frac{k}{0.715} Q_p, \ (0 < k < 1) \qquad (11)$$

$$Q_f = \frac{k}{0.866} Q_s, (0 < k < 1) \qquad (12)$$

$$Q_f = \frac{k}{0.703} Q_p, (0 < k < 1) \qquad (13)$$

$$Q_f = \frac{k^2}{0.619} Q_p, (0 < k < 1) \qquad (14)$$

$$Q_f = \frac{k^2}{0.609} Q_s, (0 < k < 1) \qquad (15)$$

Where k is termed filter discharge correlation factor which is a function of soil hydraulic conductivity.

$$k = \frac{\Sigma[\Sigma|Q_1 - \bar{Q}_1|^2 - \Sigma|Q_2 - \bar{Q}_2|^2]}{\Sigma|Q_1 - Q_2|^2} \qquad (16)$$

Where Q_1 and Q_2, and $\bar{Q}_1$ and $\bar{Q}_2$ are instantaneous discharges and mean discharges for any two different materials under correlation.

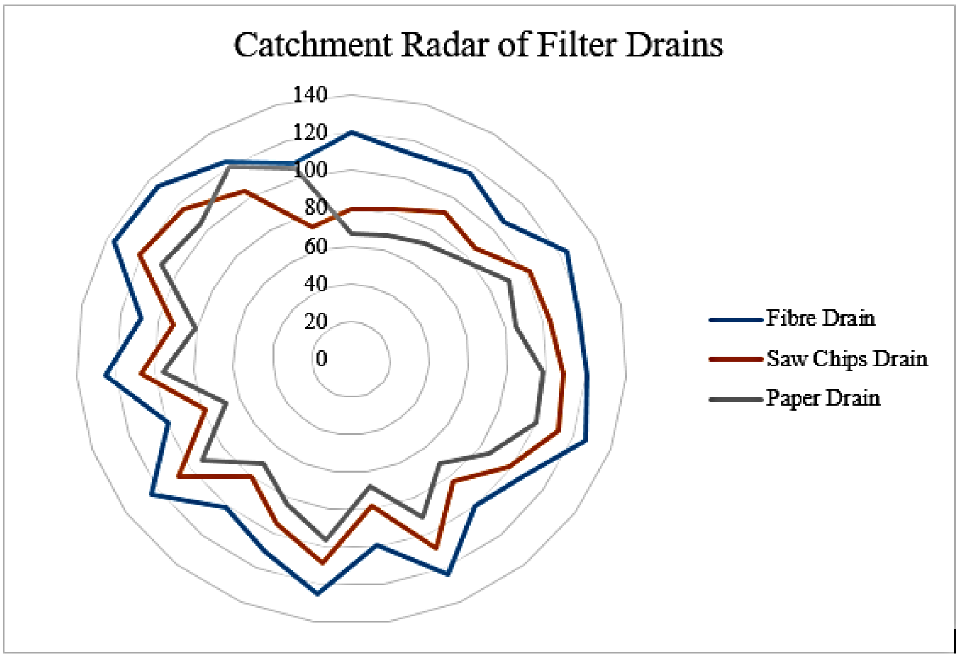


Fig. 4: Catchment Radar of Filter drains

V. CONCLUSSION

Filter moulded drains are most suitable in waterlogged areas or areas where one is trying to maintain a precise level of water table taking in mind the piezometery level of the catchment. Habitual clogging of filters though made their maintenance to be cost effective as there may be need for frequent change of the wrapped filters. Underground drainage using filter moles is better managed when the most suitable filter that would give desire results is adopted. Soils are of different intrinsic characteristics which made some to be slow to drains while some drain faster. The fast drain soils such as sandy soils would prefer high discharge ability filters such as fibre because of the faster rate of water percolation through the soil. Similarly, highly waterlogged catchment would also prefer high discharge filter because of the already stored water in the soil various profiles. Further research on other synthetic filters is recommended in other to give insights on their rate of discharge and give better drainage management.

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