Performance of No-Filter Smooth Drain Pipe on Clayey Loam

Adeniran, K.A.
Department of Agricultural Engineering,
University of Ilorin, P.M.B. 1515,
Ilorin, Kwara State, Nigeria.
E-mail: *kadeniran_2003@yahoo.com*

ABSTRACT

The performance of smooth drainage pipes fitted with no-filter material as against those with nylon, rice husks and cowpea chaffs were investigated. The study was conducted on a clayey loam during the 2005, 2006 and 2007 rainy seasons. The experimental design was completely randomized design replicated three times. The treatments applied include drains installed with cowpea chaff, rice husks, no-filter and nylon drainage filter materials. The filter materials were compressed using locally available materials and installed manually to a soil depth of 25 cm using ASABE Standards (2006). The drainage area was about 180 m^2 (0.432 ha) with a buffer zone of 1m allowed in between the plots. The slope along the length was 3.90 % and across the length was 1.63 %. The soil physical characteristics like the texture, moisture content, field capacity and bulk density were determined. Properties such as load at peak, strain at peak, energy at peak, load at yield and energy at yield were highest for sand samples collected from no-filter treated pipes with recorded average values of 958.5 N, 36.53 Nm, 22.45 %, 195.63 N, and 0.93 Nm respectively. Nylon filter pipes gave the highest strain at yield recording an average value of 8.54 mm. Rice filter samples recorded the highest deformation at yield value of 9.29 mm. Results of the drainage yield showed that during the 2005 rainy season, plots treated with no-filter material gave the highest discharge of 56.3 l/day, while plots with rice husk gave a discharge of 44.8 l/day. For the 2006 rainy season, plots treated with no-filter material gave the highest discharge of 500.4 l/day, while plots with bean chaff gave the lowest discharge of 60 l/day. For the 2007 rainy season, for first 11 days plots treated with no-filter recorded the highest amount of discharge recording the highest value of 110.8 l/day while plots treated with rice husk gave the highest drainage yield for the remaining 19 days recording the highest amount of 120.9l/day. The results showed that for the same rainfall amount and pattern, plot with rice husk gave the highest drainage yield of 148.9l/day, while plot with control (no-envelope) gave the lowest drainage yield of 99.4 l/day. The plots treated with nylon-synthetic material produced the best water quality because it was free of debris, smell and the discharge was clear, while that of the others were loaded with debris and discharge has a foul smell. The study shows that drainpipes can be installed successfully in the area under study without using filter material because of the high drainage discharge and also because there is no decay of material with time.

1. INTRODUCTION

Drain filters are permeable materials placed around drains pipes to restrict silt and sand from entering the drain (Drablor and Melvin, 2001; Wright and Sands, 2001; Fouss, 2003). Schwab *et al*., (1993) and FAO (2005) reported that the following organic materials could be used as drain filters; saw dust, straw, corncobs, coconut fibers, bean chaff, rice husk and wood chips. Commercial filter materials include geotextiles, nylon and polypropylene. Non-organic filter materials include well-graded coarse soil and fine gravel (Schwab *et al.,* 1993). Some of these have many advantages as well as disadvantages. Most of these commercial types are costly and not readily available in areas needing subsurface drainage. Some of these materials like well-graded coarse soil and fine gravel are heavy and difficult to handle. For these reasons, substitute materials such assynthetic fabrics have been sought. Synthetic fabrics only provide a stable soil-drain interface that is very important in preventing sediment entry into drains, but they do not provide structural support to the drain tubes. FAO (2005) reported that the main advantage of smooth plastic pipes over clay and concrete pipes is their low weight per unit length which greatly reduced their transportation cost and the cost of labour required for installation. The objective of this study was to determine the effectiveness of no-filter material compared to those with nylon, cowpea chaff and rice husks used as drainage filter materials for smooth plastic drains.

2. MATERIALS AND METHOD

2.1   Location of Study

The study area is a portion of land within the Agricultural Engineering Department, University of Ilorin, Kwara State. The experimental plot used for the study was established on the Agricultural Engineering Research plots. The area has a climate with temperature ranging between 23^0C and 32^0C, throughout the year. Kwara State is located on latitude 08^030'N and longitude 04^035'E in the Southern Guinea Savannah zone of Nigeria. Kwara State being a transitional state between North and Western part of Nigeria is dominated by humid tropical climate except in the extreme Northeast, which is characterized, by tropical climate. Food crops commonly grown in the state are maize, cassava, yam and sorghum. The rain distribution pattern is biannual. The rainy season starts from the second week in March and ends around the first week of August. There is a period of long drought (dry season) from October to March.

2.2   Drain Filter Materials

The materials used for this project include no-filter (control), nylon, rice husks and bean chaff. The rice husk and bean chaff are agricultural waste materials, which are easily available and have low cost. Other materials used include: smooth polyvinyl chloride (PVC) pipes, collecting buckets, graduated cylinders. The land covered an area of about

180 m^2 (about 0.432 hectares). Field plots were developed using the three filter materials replicated four times. Each plot was 2 x 2 m^2 and a buffer zone with width of 1m was allowed between the treated plots. The experimental design was completely randomized design. The slope of the area was determined to be 1.63 % across the slope and 3.90 % in the direction of the slope. The experiment was conducted during the 2005, 2006 and 2007 rainy seasons (5th August to 3rd September).

2.3 Drains Installation Method

The procedure recommended by ASABE (2006) Standards was used in the installation of the drainpipes. Installation included digging to 25 cm soil depth, laying the pipes and backfilling after installing the filter material. The backfilling was done in such a manner that protects the pipe from damage. Smooth drains with an internal diameter of 10 cm (4 in) were used. Some precautions were taken in the course of installing the drain filter materials. These include placing the outlet of the pipe along the direction of slope to ensure optimum drainage and the available slope was used to best advantage. Also the general direction of waterway was followed and routes resulting in excessive cuts were avoided. The hydraulic conductivity, K, of the soil was determined using the auger-hole method. The method described by Michael (1999) was also used to determine the moisture content at field capacity. Field capacity was determined by allowing water to pond on the plots for three days. Soil samples were collected the third day, after the removal of gravitational water.

2.4   Drainage Filter Material Design

The pipe grade openings are 12.5 mm in diameter and the gradation of the foundation soil shows filter distribution curves nearly parallel to that for the soil. Using the United States Bureau of Land Reclamation (1987) Criteria;

$$D_{15(F)}/D_{15(B)} = 5 \text{ to } 40 \tag{1}$$
$$D_{15(f)}/D_{85(B)} \leq 5 \tag{2}$$
$$D_{85(F)}/\text{maximum size opening in pipe drains} \geq 2 \tag{3}$$

Where $D_{15(F)}$ = Sieve size that ensures 15% passing of the filter material,
$D_{15(B)}$ = Sieve size that ensures 15% passing of the base material,
$D_{85(B)}$ = Sieve size that ensures 85% passing of the base material,
$D_{85(F)}$ = Sieve size that ensures 85% passing of the filter material

The compression tests were carried out using the universal testing machine for the three filter materials.

2.5   Drain Spacing and Drain Depth

The experimental design of this project is based on non-steady state conditions because the rainfall pattern is not uniform but bi-modal and also because of the rapid removal of water from the plots even during periods with little or no-rainfall. In determining the

drain spacing, the non-steady state equation reported by Schwab *et al*. (1993) was used, and it is given by;

$$S^2 = 9Ktd_e/f\{[1nm_o(2d_e + m_o)]/[m(2d_e + m_o)]\} \tag{4}$$

Where S = drain spacing, (L),   K = soil hydraulic conductivity, (L/T)
    d_e = equivalent depth, (L),   m = height of water table after time (t)
    m_o = initial height of water table, (L),   f = drainable porosity,
    t = time in days for water to drop from m_o to m.

2.6 Drain Discharge

At the beginning of test, the same 1000 liters of water was applied until to each drainage area until the place is saturated. The discharge released by each pipe was collected on daily basis for a period of thirty (30) days at three-hour interval from 6:00am of one day to 6:00am of the next day. The drain discharge Q, through the pipe was expressed in terms of the drainage coefficient (q) and the drainage area (A).

$$Q = qA/(1000 \times 3600 \times 24) \tag{5}$$

Where Q is in m^3/s, q is in mm/day and A is in m^2. A is given by
    A = LS; L is the length of pipe drain, and S is the drain spacing.

2.7 Pipe Drain Size

The following equation was used to determine the size of pipe drain to be used;

$$Q = 50d^{2.71}i^{0.57} \text{ (for smooth pipe)} \tag{6}$$

Where i is the hydraulic gradient (slope) and d = pipe size (mm)
To take care of the problem of siltation and misalignment during installation, a factor of safety of 25 % was incorporated into the drain discharge.

$$Q_d = Q/0.75 = 1.896 \times 10^{-6}/0.75 = 2.526 \times 10^{-6}\,m^3/s \tag{7}$$

Where Q_d is the design discharge, d = 78.4 mm (from equation 6)

2.8 Determination of Loads on Conduits

The type of loading can be determined from the equations below:
For ditch and projecting conduits, the equations suggested by Schwab *et al*. (1993) were used:

$$W_c = C_dwB_d^2 \tag{8}$$
$$W_c = C_c$$
$$W_c = C_cwB_c^2 \tag{9}$$

for ditch and projecting conduits respectively.
Where
    W_c = total load on conduit per unit length expressed in kg/m
    C_d & C_c = load coefficient for ditch and projecting conduits respectively
    w = unit weight of fill material, kg/m^3
    B_d = width of ditch at top of conduit (m) and B_c = 24 cm and d = 56 cm (depth)
    H = d – B_c = 56 – 7.67 = 48.3 cm, H/B_d = 48.33/24 = 2.01 ≈ 2.0

Schwab *et al.,* (1993) reported that for ordinary clay, $C_d = 1.5$ and $C_c = 10.8$

$H/B_c = 48.33/24 = 6.30 \approx 6.0$, w = 18854.82 N/m

For ditch conduits; $W_c = 1.5 \times 18854.82 \times 0.24^2 = 1629.03$ N/m

For projecting conduits $W_c = 10.8 \times 18854.82 \times 0.0767^2 = 1197.94$ N/m

Actual load is 1197.94 N/m. Hence, ditch conditions apply. To allow for variations and bedding conditions, a factor of safety of 1.5 is included, resulting in a design load of 1197.94 N/m x 1.5 = 1796.91 N/m. Strength for ordinary bedding condition is 11673.9(1.5) = 17510.85 N/m which is sufficient to support the design load of 1796.91 N/m, since 17510.85 N/m > 1796.91 N/m.

3. RESULTS

3.1 Soil Physical Properties

The results from the laboratory processes on physical properties of soil used for the study are as shown in Table 1. The soil analysis indicated that the soil in the site contained 16 % sand, 22.6 % silt and 61.4 % clay, which meant that the soil was predominantly clay loam. The bulk density was 1.60 g/cm^3 and the amount of water holding capacity was 9.4 cm/m depth of the soil. The optimum moisture content out field capacity that the soil can hold was 11.06 %. Tables 2-5 shows the filter size limits for the soil, sand and gravel layers surrounding the filter materials used. That of no-filter was not determined because the sieve size that will fifteen and eighty-five percent passing (D_{15} and D_{85}) for filter is the same as those of the base soil. Tables 2-5 were also used to determine the maximum in pipe drain using equation 3. Table 4 showed that the size requirement that ensured fifty percent passing (D_{50}) and also the maximum opening pipe drain was highest with pipes fitted with nylon materials and lowest for pipes fitted with cowpea chaffs.

Table 1. Soil Properties

Characteristics	Value
Soil type	Sandy loam
Field capacity	9.42 %
Moisture content	8.45 %
Bulk density	1.60 g/cm^3
Porosity	35.47 %
Bulk density	1.71 g/cm^3
Available water	8.44 cm/m

Table 2. Particle size for the cowpea chaff filter materials

Layers	Layer size (Base)		D_{50} size requirement for filter (mm)		Max. Opening in pipe drain using eqn. 3 (mm)
	D_{15}(mm)	D_{85}(mm)	Using eqn. 1	Using eqn.2	
Soil	0.006	0.1	0.02-0.16	E0.3	0.08
Sand	0.15	2.4	0.65 – 3.9	E11.5	20.0
Gravel	3.5	50.0	16.5*	**	0.03

Note: *these materials gave distribution curves nearly parallel to that for the soil.
**Maximum permissible size is 76.2 mm at D_{100} for any filter material.

Table 3. Particle size for the rice husk filter materials

Layers	Layer size (Base)		D_{50} size requirement for filter (mm)		Max. Opening in pipe drain using eqn. 3 (mm)
	D_{15}(mm)	D_{85}(mm)	Using eqn. 1	Using eqn.2	
Soil	0.006	0.1	0.025-0.20	E0.4	1.00
Sand	0.15	2.4	0.70 – 4	E12.0	24.0
Gravel	3.5	50.0	17.0*	**	0.04

Note: where * and ** are as defined in Table 2.

Table 4. Particle size for the nylon filter materials

Layers	Layer size (Base)		D_{50} size requirement for filter (mm)		Max. Opening in pipe drain using eqn. 3 (mm)
	D_{15}(mm)	D_{85}(mm)	Using eqn. 1	Using eqn.2	
Soil	0.006	0.1	0.03-0.24	E0.5	1.20
Sand	0.15	2.4	0.75 – 6	E12.5	25.0
Gravel	3.5	50.0	17.5*	**	0.05

Note: where * and ** are as defined in Table 2.

3.2   Tensile Tests

Table 3 shows the tensile tests carried on the filter materials used. Properties such as load at peak, strain at peak, energy at peak, load at yield and energy at yield were highest for sand samples collected from no-filter treated pipes recorded average values of 958.5 N, 36.53 Nm, 22.45 Nm, 195.63 N, and 0.93 Nm respectively. Nylon filter pipes gave the highest strain at yield recording an average value of 8.54 mm. Rice filter samples recorded the highest deformation at yield value of 9.29 mm. Table 3 generally shows that all the materials are good drainage filter materials because they are very strong and can withstand heavy loads under conduit and projecting conditions (eqns 8 and 9).
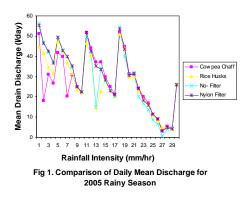
Table 5. Results of tensile tests carried out on the filter materials

Test	Filter Materials			
	Cowpea Chaff	Rice Husks	*No-Filter	Nylon
Thickness (mm)	50	50	50	50
Load at peak (N)	682.5	776.70	958.5	852.2
Deformation at peak (mm)	38.50	40.60	38.30	42.30
Strain at peak (%)	32.46	33.27	36.53	29.20
Energy at peak (N.m)	15.68	16.39	22.45	18.39
Load at yield (N)	158.30	165.50	195.63	187.00
Deformation at yield (mm)	8.75	9.29	8.56	3.33
Strain at yield (%)	7.08	7.15	8.54	7.29
Energy at yield (N.m)	0.45	0.56	0.93	0.81

*Soils collected on the plots with no-filter material.

3.3 Drain Discharge

Fig. 1 shows the daily mean discharge after the installation of the filter materials and the pipe for the 2005 rainy season. From Fig. 1, the drain discharge was highest for pipes with no-filter material, recording average values of 56.3l/day, while plots with rice husk gave a yield of 44.8 l/day. For the 2006 rainy season (Fig 2), plots treated with no-envelope material gave the highest of 500.4 l/day, while plots with bean chaff gave the lowest yield of 60 l/day. For the 2007 rainy season (Fig 3), for first 11 days plots treated with no-filter recorded the highest amount of discharge recording the highest value of 110.8 l/day while plots treated with rice husk gave the highest drainage yield for the remaining 19 days recording the highest amount of 120.9 l/day. The plots treated with nylon-synthetic material produced the best water quality because it was free of debris, smell and the discharge was clear, while that of the others were loaded with debris and discharge has a foul smell.

Fig 1. Comparison of Daily Mean Discharge for
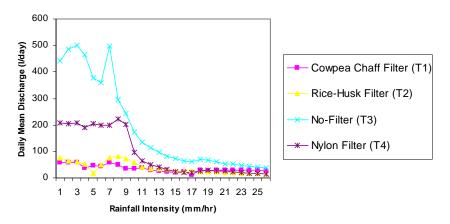2005 Rainy Season

Fig 2. Comparison of Mean Discharge for 2006 Rainy Season
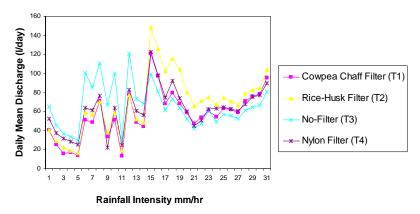

Fig 3. Comparison of Daily Mean Discharge for 2007 Rainy Season

4. DISCUSSION

Plots treated with no-filter material recorded high drainage discharge during the first period of study (2005 rainy season) because water flows freely through the pipe openings than the others. The same result was obtained during the 2006 and part of the 2007 rainy season. Also blockage of pipe openings was more rampant for the plots treated with cowpea chaffs and rice husks. This is why water discharge by these pipes contained more debris than those of nylon and no-filter materials. Rainfall pattern were not the same during the period of study, although the study was conducted between the same periods of the year, 5th August to 3rd September, of the 2005, 2006 and 2007 rainy seasons

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respectively. More rain fell during the 2007 rainy season than that of 2005 and 2006 seasons.

5. CONCLUSION

For the four-drainage filter materials used; cowpea chaff, rice husks, no-filter pipes and nylon drainage materials, the study shows that no-filter drainage pipes performed best for the three rainy seasons. For the same degree of compaction and rainfall amount, clogging of pipes will likely occur with rice husks and cowpea since there are biological materials; they will decay with time or be consumed by termites. The advantage of nylon filter over no-filter is that the water discharged was white and free of odour and debris unlike that of no-filter pipes. The study confirmed the idea that drainage pipes can be successful installed on some soils in the humid tropics without using filter material.

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