Evaluation of Textile Filter in Field Drains

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ABSTRACT

The role of drain in agricultural lands is to remove excess surface and subsurface water to create a good environment for root growth and to increase crops yield. The main objective of this research was to evaluate the performance of closed drains when using textile filter instead of crushed gravel filter. The research has been executed in the laboratory using a sand tank model and by using two types of the soil. One of soils was light soil (sandy soil) and the other heavy soil (loamy soil). The tests were classified into four cases; each case was supplied discharge during 10 days. The results showed that the amount of out flow when using graded crushed gravel filter is greater than the amount of out flow in case of using textile filter for the same soil; and the amount of sediment in applying graded crushed gravel filter for the two types of soils was greater than using textile filter. The entrance resistance for textile filter was greater than graded crushed gravel filter and the entrance resistance increase for the two types of filters with time. From the results it can be concluded that the graded crushed gravel is more efficient than the textile filter in sandy soil, while when using the two types of filters with loamy soil the results showed that the two types of filter exhibited low work efficiency.

Keywords: graded crushed gravel filter; textile filter; sand tank; sediment; entrance resistance**.**

تقييم اداء الفلتر النسيجي في المبازل الحقلية

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الخلاصة

تلعب شبكات البزل انتاج دورا مهما في افراغ الماء السطحي وتحت السطحي الزائد عن حاجة النباتات لتهيئة بيئة ملائمة لنمو الجذوروبالتالي زيادة المحاصيل الزراعية. أن الهدف الرئيسي من الدراسة هو تقييم استعمال الفلتر النسيجي بدلا من فلتر الحصى المدرج المكسر للمبازل المغلقة بأستخدام نوعين من التربة احداهما تربة خفيفة (رملية) واخرى ثقيلة (مزيجية). تم تقسيم التجربة الى اربعة حالات ولكل حالة يتم اطلاق تصريف لمدة10 ايام. اوضحت النتائج ان كمية التصريف الخارج للفلتر الحصى المكسر اعلى من التصريف الخارج للفلتر النسيجي ولكلا النوعين من الترب, وكمية الرسوبيات للفلتر الحصى المكسر اكثر من الفلتر النسيجي لكلا النوعين من التربة ايضا. واما مقاومة الدخول للفلتر النسيجي فكانت اعلى من فلتر الحصى وتزداد هذه المقاومة مع الزمن, لكلاالنوعين من الفلتر. من النتائج نستطيع ان نستنتج ان الفلتر الحصوي المكسر مرغوب اكثر في التربة الرملية اما في التربة المزيجية فكان كلا الفلترين كفاءة العمل واطئة.

الكلمات الرئيسية: فلتر الحصى المدرج المكسر، الفلتر النسيجي،خزان رمل، رواسب، مقاومة الدخول.

1. INTRODUCTION

Subsurface drainage can be executed by installing an artificial conduit to create a flow path under the water table which means the hydraulic head of the soil to be drained is higher than the head through conduit. The purpose of sub surface drainage is to serve one or more of the following purposes:

- Improving the environment of root zone for vegetative growth by controlling the level of water table and ground water flow by creating a hydraulic gradient towards the drain due to the hydraulic head differential. This phenomenon is to create phreatic line (free water surface) in the vicinity of the conduit.

- Preventing and intercepting water movement into moist areas in order to remove it at the downstream end of the conduit, consequently preserving a flow system.

- Removing runoff water and sewage surface water in order to improve the stability of the appropriate internal slope and to reduce soil erosion.

Many researchers have applied several experiments and research studies by developing drainage criteria to improve the drainage process, and to show that the filters are important to improve and maintain drainage system. Improving the permeability around drain and increasing soil stabilization as the main objective of drain filter. The other playing role of porous material placed around a subsurface drain is to protect the drains from sedimentation of fine soil particles in the drains and to improve hydraulic performance to control the water table. There are several types of filters, including granular mineral materials that consist primarily of coarse sand, gravel and fine crushed stone, located beneath and around the drain pipe. There were many types of organic materials that were used as drain filters including straw envelope, flax straw, rice straw, cereal straw, bamboo, heather bushes, cedar leaf, wood chips, corncobs reeds, flax stems, linen, and sod grass. The other filters used are made from special fabric material such as paper, burlap, or fabric textile material that can be produced from polyamide (PA) and polypropylene (PP) or polyester (PETP) and polyethylene (PE).

1.1Specifications for Gravel Envelopes

United States Army Corps of Engineers **USACE, 1941** used the first criteria that was proposed by Terzaghi for drain envelope which were:

$$D_{15\,filter} \geq 4D_{15\,soil} \tag{1}$$
$$D_{15\,filter} \leq 4D_{85\,soil} \tag{2}$$

where:

$D_{15\,filter}$ = size of particle in filter material, 15% passing sieve.
D_{15soil} = size of particle in soil, 15% passing sieve.
D_{85soil} = size of particle in soil, 85% passing sieve.

SCS, 1971 combined results of envelopes research with specifications to evaluate drainage and granular materials artificially classified for use as drain envelopes. **SCS, 1988** replaced these specifications to distinguish between envelope and filter. Recommendation for using the natural materials or about the mixing these materials that can be used as envelope are:

$D_{100\ filter} \leq 38\ mm$ (3)
$D_{30\ filter} \geq 250\ \mu m$ (4)
$D_{5\ filter} \geq 75\ \mu m$ (5)

where:

D_x = is size of particle in filter material, x is percent % passing sieve.

1.2 Specifications for Prewrapped Loose Material (PLM) Envelopes

In 1994, many scientists and engineers in Europe developed a classification system for the prewrapped loose material **(**PLM). **FAO, 2005** presented three categories of envelopes, depending on the opening size of pores and effectiveness (O_{90}) as follows:

PLM- extra fine $100\ \mu m \leq O_{90} \leq 300 \mu m$ (6)

PLM- fine $300\ \mu m \leq O_{90} \leq 600 \mu m$ (7)

PLM- standard $600\ \mu m \leq O_{90} \leq 1100 \mu m$ (8)

The following minimum thicknesses are required:

- Minimum thicknesses for Synthetic fibrous PLMs are equal to 3 mm as PP fibers.
- Minimum thicknesses for Synthetic granular PLMs are equal to 8 mm as polystyrene beads.
- Minimum thicknesses for Organic fibrous PLMs are equal to 4 mm as coconut fibers.
- Minimum thicknesses for Organic, granular PLMs are equal to 8 mm as wood chips and sawdust.

The following retention criteria for both geo-textiles and PLMs can be accepted:

$1 \leq O_{90}/D_{90\ soil} \leq 2.5$ for envelope thickness ≤1 mm (9)

$1 \leq O_{90}/D_{90\ soil} \leq 3.0$ when envelope thickness (1 to 3) mm. (10)

$1 \leq O_{90}/D_{90\ soil} \leq 4.0$ when envelope thickness (3 to5) mm. (11)

$1 \leq O_{90}/D_{90\ soil} \leq 5.0$ when envelope thickness ≥ 5 mm. (12)

$O_{90} \geq 200\ \mu m$. (13)

In order to reduce the risk of mineral clogging, it is advisable that the ratio of $O_{90}/D_{90soil} \geq 1$; moreover, envelopes containing O_{90}/D_{90soil} ratios near the maximum limit of the proposed range of values are mostly preferred **FAO, 2005**.

1.3 Review of Literatures

Many researchers studied the effect of filter type on the behavior of flow pattern and on flow through drains. **Lennoz, 1989** studied the influence of envelopes on flow patterns close to a drain pipe and he designed a rectangular sand tank and installed a drain in the central. The aim of the study was to diagnosis the clogging hazard for different soil types, and to choose the most effectives envelope material. He found that all kinds of geo-textile tested were good for sandy soils, but in the case of using fine textured soil (silts and clay), the envelope material needs to have effective properties. He found that, for a sandy soil all envelope materials commercially available were suitable.

Sheard, et al., 1999 used geotextile materials as drain envelopes with three types of soil. The results showed that the clay soil formed a film over geotextile material and clogged the porous of envelope and reduced drainage efficiency. He found that a drain without an envelope, the clay particles were not trapped and needed to be flushed out during the next full flow period.

Agar, 2011 conducted a laboratory research using tub permeameter to compare three types of geotextile filters (woven and non-woven) with gravel and sand filter under the extraordinary hydraulic gradient regarding clogging and preventing siltation in laboratory condition. He used two types of soils (clay, silt loam). All geotextiles functioned better than sand-gravel envelopes in preventing the siltation and their clogging level, and did not affect hydraulic conductivity.

Lal, et al., **2012** studied the performance of geo-synthetic filter materials as a drain envelope in land reclamation in Haryana, north India. The study showed that geo-synthetic envelope materials with O90values >300 μm and woven filters with 60 mesh size could safely be used on lateral and collector drains, respectively, and for medium textured soils.

Nooreldeen, 2013 evaluated the efficiency of crushed gravel and graded gravel filter around field drain, by using sand tank model 70 cm wide, 50cm long and 80 cm deep. She used a pipe drain 5 cm diameter and two types of soils, loam, and sandy loam. The results of the study showed that the crushed gravel filter can work similar to a graded gravel filter after a certain time from the beginning of experiment. It was also found that the discharge and sediment for the case of graded gravel filter were very close to crushed gravel filter and sometimes gave the same results.

2. ENTRANCE RESISTANCE

Total resistance of seepage to subsurface drains consists of four components: horizontal, vertical, radial, and resistance to entry. The first two depend on the porous medium, while the last two depend on both soil and types of drain and envelope. Using the envelope around drainage pipe is to reduce the hydraulic gradient, and reduce the entrance resistance. Equipotential lines become circular and concentric to the drain pipe, which means that full flow through the drain is attained. So, the total head losses due to different resistances can be expressed by:

$$h_T = h_v + h_h + h_r + h_e \qquad (14)$$

where:

h_v = head loss due to vertical flow (L),

h_h = head losses due to horizontal flow (L),

h_r = head loss due to radial flow (L), and

h_e = head loss due to resistance of entry (L).

The movement of water from the soil into drain passing through the filter around the pipe contributes to loss apart of the flow effort. These head losses can be measured by knowing the difference in the head of two piezometers, one inside pipe drain and the other in the soil at the edge of trench in which the pipe drain is placed. Several researches evaluated the performance of subsurface drainage materials depending on studying the entrance resistance. The total head losses were always preferred to be a value close to zero in order to facilitate the movement of water from the soil into the drain, and can be calculated as follows **ILRI, 1979**.

$$h_e = \alpha \frac{q}{K_F} \qquad (15)$$

where:

α = Resistance coefficient (dimensionless),

[(0.4-0.6) for smooth pipe],[(0.5-1)for corrugated pipe],

q = drain discharge per unit length (L^3/L.T), and

K_F = hydraulic conductivity for envelope drain (L/T).

3. The LABORATORY WORK

A sand tank was manufactured by using acrylic material, with 60 cm wide, 50cm long and 80 cm deep according to advices of **Luithen, 1965**, **Luthin and Haig, 1971** and **Lennoz, 1989**. The experiments of our research were run included testing two types of filters, graded crushed gravel filter, and textile filter type (pp400) and using two types of soil. The numbers of executed tests were four and these are:

1. Graded crushed gravel with soil No.1 (sandy soil).
2. Textile filter with soil No.1 (sandy soil).
3. Graded crushed gravel with soil No.2 (loamy soil).

4. Textile filter with soil No.2 (loamy soil).

Three piezometers were installed around the outlet of drain, one of them (A) was inside the drain, and (B) was adjacent to the drain, and (C) was away in about 15cm from (B) as shown in **Figs. (1-5)**. In order to test working efficiency of the two types of filter and for a long time water was supplied during 10 days for 24 hours. During the continuous time of supplying water, the variation of piezometer for the piezometers A, B and C, were recorded and the discharge of drain was measured. The readings of piezometers A,B, and C were used to observe the variation of entrance resistance for the filter during time of test **Vlotman, 2000**. This work was repeated for the two filters using two types of soil. For all runs some sediment appeared at the beginning of test and disappeared at the end.

3. 1 Textile Filter

To evaluate the performance of a textile filter used in the laboratory, textile filter with the characteristics (ASTM D5261) shown in **Table 4** was used.

Note: since the drain is 5 cm diameter and textile filter of this size is not available, the textile material was weaved around pipe to surround the pipe drain and this was done, by taking textile material from the weaved pipe with 10 cm diameter as shown in **Fig. 12** and **Fig. 13**. The filter was checked by office of engineering constructions/ University of Technology. The date of test was 11-9- 2014.

4. RESULT AND DISCUSSION

4.1 Drain Discharge

The discharge of drain pipe is an important component of any design procedure for a drainage system. This parameter was used to compare between graded crushed gravel filter and textile filter by using two types of soil. The duration of the discharge measurement was 10 days and for both filters and for two types of soil. The results showed that in case. No.1 for sandy soil, the rate of discharge when using crushed gravel filter was approximately constant 3.5 l/min during four days and then decreased to 3.2 l/min and continued to decrease until becoming 2.8 l/min. In case No.2, the value of discharges when using textile filter and after two days of measurements, the discharge decreased from 3.5 l/min to 3.15 l/min and then fell to 2.4 l/min and settled on 2.4 l/min until the end of test. The results are for the two types of filter obtained using sandy soil. **Fig. 6** shows the trend of discharge variation for the two filters and it can be noticed, that the performance of the two filters decreased after four days and this was due to the filling of soil particle the void between crushed gravel particles. Also appeared in textile filter more affected compared with graded crushed gravel in sandy soil.

The other step of laboratory work was to use loamy soil with graded crushed gravel filter (case No.3). The results showed that the amount of out flow when using the graded crushed gravel filter was approximately constant for the first two days and then decreased from 1.2 l/min to 0.85 l/min and continued to decrease to 0.68 l/min and settled at this value. The amount of discharge for textile filter in case No.4 was less than the graded crushed gravel filter in case No.3, and the value of flow rate for textile filter was approximately constant for three days and decreased from 0.85 l/min to 0.4 l/min after some time, and almost settled on this value as shown in **Fig.7** and **Table.1.** But when comparing the performance of filters in the same soil indicates that the graded crushed gravel filter gave an amount of outflow more than when using textile filter and for two types of soil.

4.2Entrance Resistance

The results showed that this value of entrance resistance increases with time for the two types of filter. When comparing the results of entrance resistance for the two types of filter and during the same period of time 10 days, for the same type of soil, it can be found that the entrance resistance of textile filter is higher than that of the graded crushed gravel filters **Fig. 8**.

The entrance resistant in loamy soil, using the two types of filters was high, but the difference between them was small. The results showed that this type of soil had a major impact on the performance due to soil particles size which were small and which may move and settle between the voids of filters and decrease the permeability which means an increasing in the entrance resistance as shown in **Fig. 9** and **Table. 2**.

4.3 Sediment

The sediment is another parameter that can be used to evaluate the performance of a drain filter, because it affects the performance efficiency of drain due to the sedimentation of soil particles in the pipe. The amount of sediments in flow through graded crushed gravel was greater than with textile filter. In the case of using textile filter, the appearance of sediment decreased very strongly and disappeared after 6 hours from.

This appearance of sediment indicates that the two filters follow the same behavior about the carrying of sediments during the first five hours but after six hours, the sediment disappeared in the case of using textile filter (case No.2), but in the case of using graded crushed gravel filter (case No.1), the sediment continues to appear eleven hours as shown **Fig.10**

When using loamy soil, the amount of sediment for graded crushed gravel (case No.3) was higher than when using textile filter (case No.4) as shown in **Fig. 11**. While the amount of sediment when using textile filter was small and decreased with time and disappeared after 7 hours.

This means that the textile filter retained soil particles more than the crushed gravel filter because of the different size of pores for the filters. A high velocity and large discharge in the graded crushed gravel lead to the accumulation of a large amount of sediment which affects soil stability and increases soil erosion. **Table. 3** shows the measured values of sediments for each case.

5. CONCLUSIONS

1. The amount of drain discharge when using graded crushed gravel was greater than the amount of discharge when using textile filter for the same soil. But for the case of using sandy soil, the performance of the two filters gives approximately the same especially at the end of the run.

2. The entrance resistance for textile filter is greater than that of graded crushed gravel filter for all stages. And the entrance resistance for the two types of filters increased with time when using sandy soil would be less, so it is concluded that the emigration of fine particles into filter clogged the filter therefore the head loss of entry increased which increased entrance resistance.

3. The amount of sediment for graded crushed gravel when using the two types of soil was greater than that when using textile due to the characteristics of the opening size of textile filter which is equal to 400 (µm) which is very small as compared with crushed gravel filter.

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NOMENCLATURE

$D_{15Filter}$	= size of particle in filter material ,15 % passing sieve, L,
$D_{5Filter}$	= size of particle in filter material , 5 % passing sieve, L,
$D_{30Filter}$	= size of particle in filter material , 30% passing sieve, L,
$D_{100Filter}$	= size of particle in filter material , 100% passing sieve, L,
D_{15soil}	= size of particle in soil material ,15 % passing sieve, L,
D_{90soil}	= size of particle in soil material ,90 % passing sieve, L,
h_T	= total head losses due to different resistances, L,
h_v	= the head losses due to vertical flow, L,
h_h	= the head losses due to horizontal flow, L,
h_e	= entrance resistance, L,
K_F	= hydraulic conductivity of the envelope drain, L/T,
PLM	= prewrapped Loose Material,
O_{90}	= opening size pores for envelope, L,
Q	= discharge, L^3/T,
q	= drain discharge into unit length of drain per unit time, $L^3/L.\ T$, and,
α	= resistance coefficient.

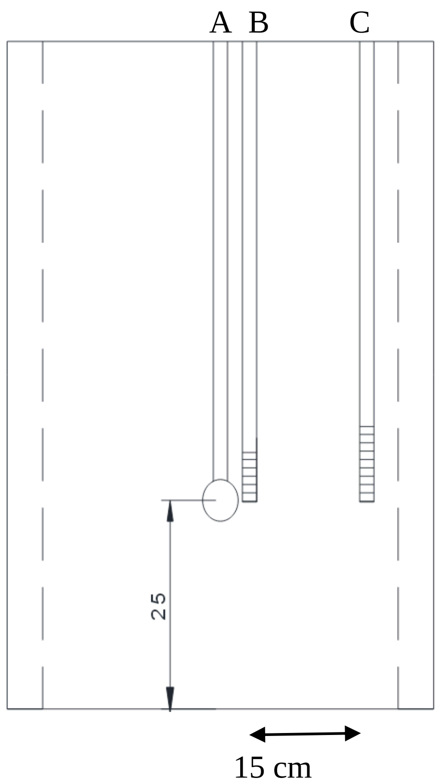

Figure. 1. The location of the piezometers to measure the entrance resistance.

Figure.2. Graded crushed gravel filter with sandy soil, case No.1.

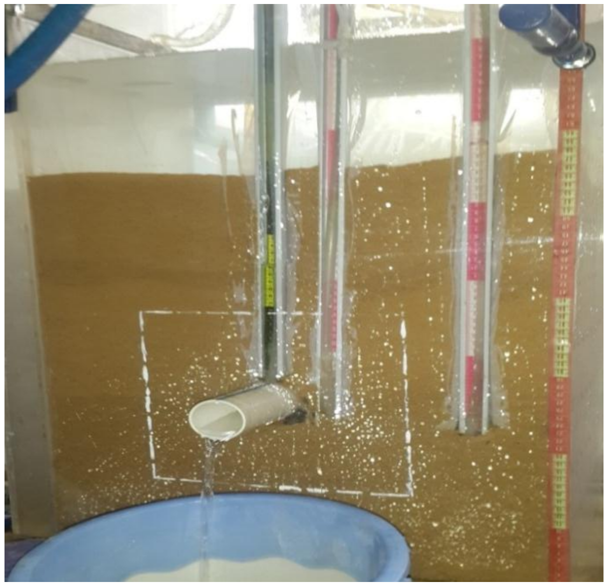

Figure. 3. Textile filter with sandy soil, caseNo.2.

Figure.4. Graded crushed gravel with loamy soil, caseNo.3.

Figure.5. Textile filter with loamy soil, caseNo.4.

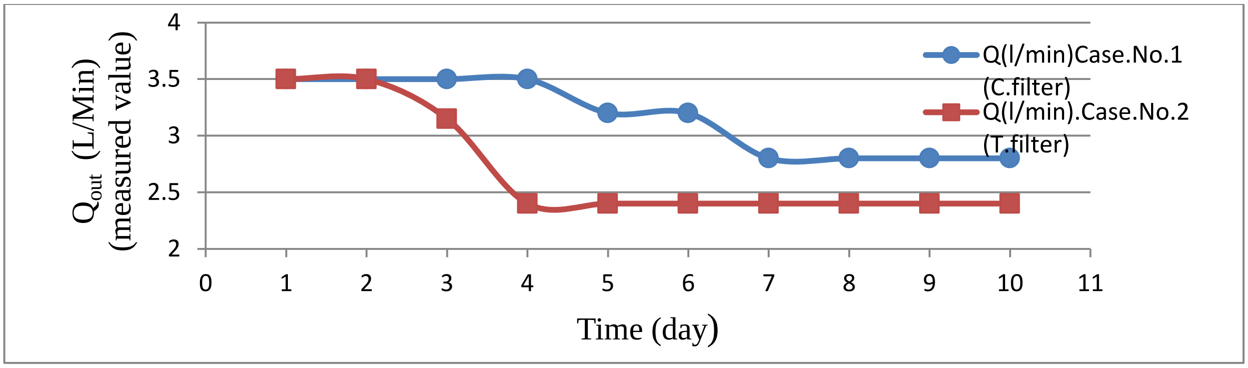

Figure.6. The variation of discharge flow during test time for the two filter using sandy soil

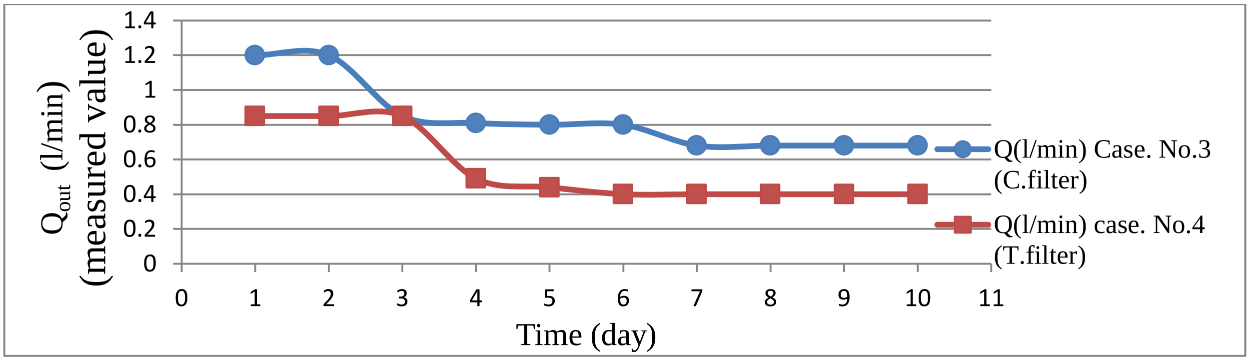

Figure. 7. The variation of discharge flow during test time for the two filters using loamy soil.

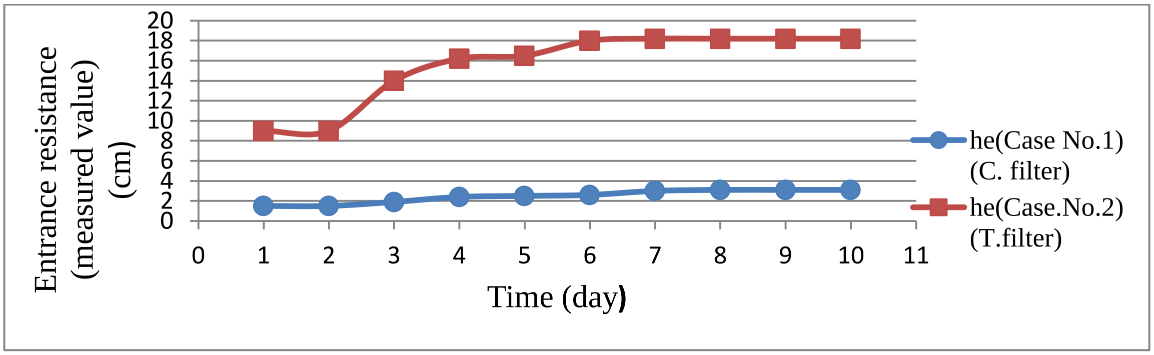

Figure. 8. The variation of entrance resistance with time for two filters, using a sandy soil.

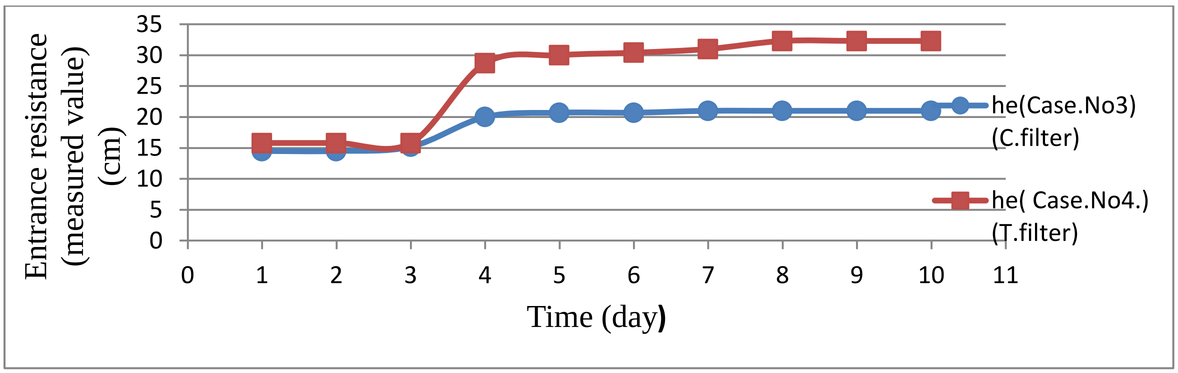

Figure. 9. The variation of entrance of resistance with time for the two filters type when using a loamy soil.

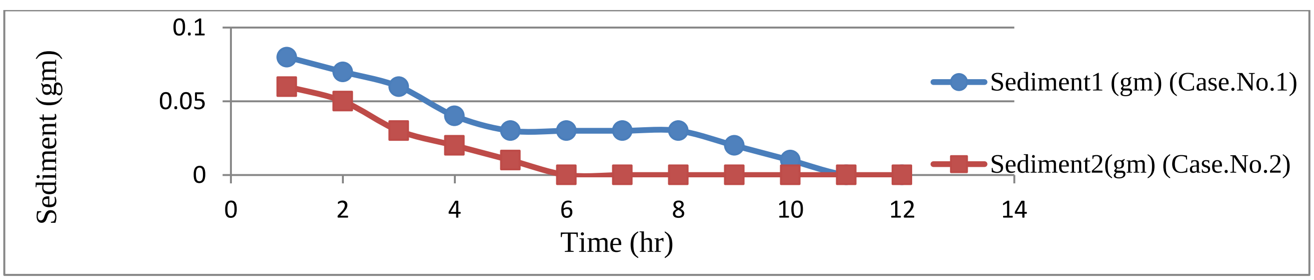

Figure.10. Comparison between the amounts of sediment when using graded crashed gravel, (Case No.1) and textile filter with a sandy soil (Case No.2).

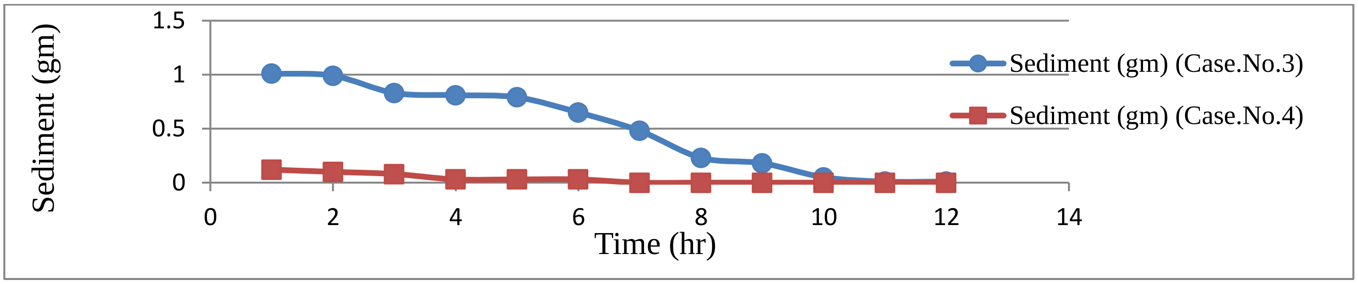

Figure. 11. Comparison between the amounts of sediment when using graded crashed gravel, (Case No.3) and textile filter with a loamy soil (Case No.4).

Figure 12. Pipe drain (5cm) with weaved textile

Figure 13. Laying the drain pipe in the sand tank

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Table. 1. Measured of values of outflow discharge for each case.

Time (day)	Case.No.1 (C. filter) Q(l/min)	Case.No.2 (T. filter) Q(l/min).	Case. No.3 (C. filter) Q(l/min)	Case. No.4 (T. filter) Q(l/min)
1	3.5	3.5	1.2	0.85
2	3.5	3.5	1.2	0.85
3	3.5	3.15	0.85	0.85
4	3.5	2.4	0.81	0.49
5	3.2	2.4	0.8	0.44
6	3.2	2.4	0.8	0.4
7	2.8	2.4	0.68	0.4
8	2.8	2.4	0.68	0.4
9	2.8	2.4	0.68	0.4
10	2.8	2.4	0.68	0.4

Table. 2. Measured values of entrance resistance for each case.

Time (day)	he (cm) (Case No.1)	he (cm) (Case.No.2))	he (cm) (Case.No.3)	he (cm) (Case.No4)
1	1.5	9	14.5	15.8
2	1.5	9	14.5	15.8
3	1.9	14	15.2	15.8
4	2.4	16.2	20	28.7
5	2.5	16.5	20.7	30
6	2.6	18	20.7	30.4
7	3	18.2	21	31
8	3.1	18.2	21	32.3
9	3.1	18.2	21	32.3
10	3.1	18.2	21	32.3

Table. 3. Measured values of sediment for all cases.

Time (hr)	Sediment (gm) (case.No.1)	Sediment (gm) (Case.No.2)	sediment (gm) (case.No.3)	sediment (gm) (case.No.4)
1	0.08	0.06	1.01	0.12
2	0.07	0.05	0.99	0.1
3	0.06	0.03	0.83	0.08
4	0.04	0.02	0.81	0.03
5	0.03	0.01	0.79	0.03
6	0.03	0	0.65	0.03
7	0.03	0	0.48	0
8	0.03	0	0.23	0
9	0.02	0	0.18	0
10	0.01	0	0.05	0
11	0	0	0.01	0
12	0	0	0.01	0

Table.4. Textile filter characteristics

Filter material	It consist polypropylene fibers pp400
O_{90} - range	400 µu
Filter transmittance	The filter curb 90% of the particles that bigger than 400µu.
Description	The drain pipe was wrapped 5.8 mm thickness of polypropylene fiber.
Specific weight	425 g/m^2
The histological examination filter to meet international standards ASTMF800 and specification results ASTM D 5261	