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An assessment of geocomposite drain performance after long-term site use

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Abstract

The paper describes the test results for geosynthetic geocomposite drain (commercially known as Enkadrain) installed on the Edinburgh City Bypass in 1985 and removed and tested in 1995.

The durability of geosynthetic fabrics and geocomposites becomes an ever more important concern topic with their increasing availability and use. Information gained from installations undertaken some years ago have particular relevance in measuring how accurate Accelerated Laboratory Tests for Long Term Performance will be. A geocomposite drain which was installed as vertical structural drainage to a rail bridge in 1985 (as part of the A702, Edinburgh City Bypass, Sighthill Section) became available for testing in 1995 due to new roadworks (M8 Extension, Claylands to Edinburgh City Bypass). The sample which was tested after being retrieved from the site was taken from the base of an 8m high retaining wall, then compared with a sample of new unused drain composite material, manufactured to the same original standards.

The retrieved and unused drain materials were tested for water permeability, tensile strength of the filter fabric, and discharge capacity of the whole geocomposite. Also discussed are the selection of the geosynthetic and drain core and their performance given the nature of the surrounding backfill.

The original installation of the geocomposite drain was in conformity with the Department of Transport Regulations as implemented by the Scottish Development Department.

1.0 Introduction

The development and utilisation of geotextiles, geogrids, geomembranes and geocomposites in subsurface construction works have been nothing short of awesome. These products which are collectively called 'geosynthetics', have risen from a relatively minor and speciality product status to a world-wide, billion dollar industry in a short time span. No other specific items in civil engineering and related construction activities has had such a dramatic increase in such a short time span (Koerner 1990).

It is a well known fact that all geosynthetics are utilised for the five principal functions: these are reinforcement, separation, filtration, erosion control and fluid barriers (Cazzuffi et al 1995). Since they are truly international products, unified testing standards, and definitions have been attempted to be developed although some of the properties and mechanisms are still not yet fully understood. Nevertheless, the current situation is that these products are still growing at a very rapid pace and their future is very strong.

One of the most obvious uncertainties that makes designers often sceptical of their use, is their long term behaviour. European Standards are still in preparation and although certain design mechanisms have already been defined, durability is still a questionable parameter to the practising engineer in terms of his/her liability. The practising engineer is no longer looking for mathematical models, predictions and design mechanisms but for 'real' performance characteristics, such as histories and case studies on the long term behaviour of used geosynthetics.

2.0 Objectives

The aim of this project is to examine and compare the hydraulic behaviour between a ten year old used and reclaimed geosynthetic material to an identically manufactured unused (new) one.

The reclaimed piece of geosynthetic material that was chosen here is generically known as a "geocomposite drain" and was originally utilised for filtration and drainage. It is also commercially known as "Enkadrain" and is manufactured by Akzo Nobel Geosynthetics.

The reclaimed geocomposite drain was decommissioned during the construction of the new part of the M8 extension, off Newbridge roundabout, at Claylands to Edinburgh City Bypass). It was "retrieved" from the back of an approximately 8m high retaining wall, which formed part of the Railway bridge at the main railway line, Edinburgh and Glasgow, at the crossing with the A702, Edinburgh City Bypass, Sighthill Section. (See Figures 1 and 2).

Approximately ten years prior to its decommissioning (circa 1985), this particular reclaimed geocomposite drain was installed behind the retaining wall vertically orientated in horizontal strips, to act as a drainage medium between the concrete and the backfill material.

2.1 Backfill Material

Burnt oil shale (red blaes) has been used in this location as backfill material. From its particle size distribution shown in Figure 3, it can be noticed that the backfill resembles almost a slightly silty, sandy gravel.

The installation of the geosynthetic drain was obviously specified here to enhance the permeability characteristics of the backfill.

In the absence of in-situ permeability tests and other information, an attempt was made here to estimate the coefficient of the in-situ permeability (k) of the original backfill material prior to decommissioning.

The backfill itself, was probably placed at equal layers with the aim to achieve densities ranging from about 1700 to 1800 kg/m^3. These, according to Figure 12, for the range pressures of 25 to 200kN/m^2, correspond to a coefficient of permeability (k) ranging from 0.0002 to 0.40 m/s.

This can also be confirmed by using Hazen/Beyer formula; $k = \left(\frac{2.68}{U+3.4} + 0.55\right) d_{10}^2$.

Where U = Uniformity coefficient

d_{10} = The percentage passing expressed in cm.

$$k = \left(\frac{2.68}{U+3.4} + 0.55\right) d_{10}^2 \quad m/s$$

$$U = \frac{d_{60}}{d_{10}} = \frac{10}{0.15} = 67$$

$$k = \left(\frac{2.68}{67+3.4} + 0.55\right) 0.015^2 = 1.3x10^{-4} \ m/s$$

The above estimation is very close to the one of Figure 12 although it is based on granularity with no pressure taken into account.

The Hazen/Beyer formula is normally used for coarse sandy materials but by preference for soils with U<20.

If the measured minimum value for permeability of the non woven filter of the geosynthetic drain is of the order of 10^{-3}m/s; with a minimum soil permeability of 0.0013m/s;

$$\frac{0.001}{0.00013} = 7.69 \text{ (say8)}$$

and for a soil permeability of 0.002m/s;

$$\frac{0.001}{0.0002} = 5$$

Figure 1: A view of the ten year old reclaimed piece of geosynthetic retrieved from the back of the shown retaining wall after the excavation of the fill material at Claylands to Edinburgh City Bypass.

Figure 2: Another view of the exposed approx. ten year old geocomposite drain.

This means that the design rule,

$$k \text{ geosynthetic} \geq 10 \text{ k soil}$$

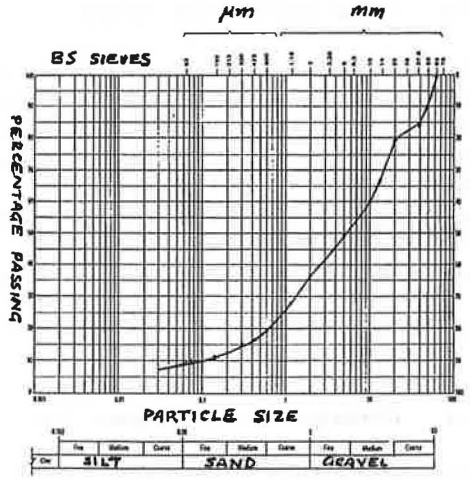

Figure 3: The particle size distribution curve of the backfill material (red blaes).

is almost valid here. Hence the initial idea of specifying a geosynthetic drain to enhance the permeability properties of the red blaes appears to be justifiable.

2.2 Properties of Geocomposite Drain

According to Figure 4, it can be seen that this particular drain is composed of a three-dimensional structured polyamide drain core sandwiched between two thermally bonded nonwoven polyester fabrics. The nonwoven fabric on the soil side acts as a filter allowing the passage of water but forming a barrier to the soil. The nonwoven on the wall side prevents the bituminous waterproofing layer from being damaged. The water is filtered through the fabric in contact with the soil, and runs downwards through the drain core. It is then collected and discharged via a pipe to the surface water drainage system.

During decommissioning, the backfill material was excavated by means of a mechanical excavator whose hydraulic "shovel" caused damage to many parts of the old geosynthetic drain, disturbing its original installation. The pieces that were chosen to be tested here however, were selected from areas that were not visible damage.

3.0 Testing of Geosynthetic Samples

The comparative testing exercise of the two materials (i.e. the "used" geocomposite drain and the "new" one) was carried out by the British Textile Testing Technology Group, BTTG. The objective of the exercise was to determine whether the ten years of "burial" had changed the hydraulic and mechanical properties of the "used" material.

The testing programme was as follows:-

3.1 Discharge Capacity: (In plane flow)

The measurements were made according to BS 6906 : Part 7, 1990, at three stress levels (25, 60 and 200kPa) and two hydraulic gradients (0.1 and 1.0) on three samples along their plane direction (See Figure 5). The pressure increment of 60kPa although not mentioned in BS 6906, was chosen to simulate the horizontal pressure behind the wall that corresponds to eight metres of depth. This was calculated as follows:-

$Ka\, \gamma\, H$

$0.4 \times 18 \times 8 = 58\text{kPa}.$

Where:-

Ka = Assumed coefficient of active soil pressure.

H = Height in metres.

γ = Unit of weight of soil kN/m^3.

To simulate the real retaining wall situation, the drain was tested using a 19mm thick rubber foam on one side and a rigid loading platen on the other. This corresponds to the soil and concrete wall surfaces respectively. Depending on the modulus of the nonwoven filter, the soil pressure and deformability and the distance between the draincore elements that support the nonwoven filters, the filter is more or less pressed into the draincore which consequently leads to a reduction of the discharge capacity. (See Figure 4). The results of the discharge capacity of the "used" and "new" geosynthetics are shown in Table 1 and Figures 8, 9, 10 and 11.

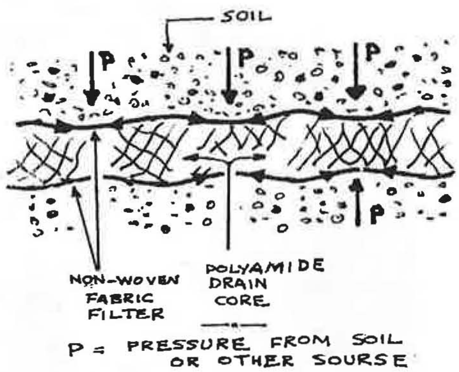

Figure 4: *A diagrammatic cross-section of the geosynthetic (geocomposite) drain.*

Table 1: *A comparison between the "in-plane flow" discharge capacity test results of the "used" and the "new" drains (in ℓ/m/s). These results are related to three pressure levels and two hydraulic gradients.*

Pressure (kPa)	Hydraulic Gradient	Specimen 1	Specimen 2	Specimen 3	Mean
"Used" Material					
25	0.1	0.99	0.916	1.38	1.08
	1	3.65	3.13	2.6	3.13
60	0.1	0.4	0.338	0.24	0.326
	1	1.45	1.45	1.06	1.32
200	0.1	0.053	0.075	0.11	0.0793
	1	0.25	0.275	0.3	0.275
"New" Material					
25	0.1	1.3	0.96	1.15	1.14
	1	4.1	3.17	3.65	3.64
60	0.1	0.42	0.32	0.32	0.353
	1	1.4	1.458	1.45	1.436
200	0.1	0.075	0.0783	0.07	0.0744
	1	0.263	0.309	0.32	0.297

3.2 Thickness

This was measured at various pressure (or stress) levels. The effect of pressure on thickness during discharge was only monitored during the duration of the testing (i.e. approximately ½ hour). The effect of creep of the geosynthetic in this way, was minimised. The pressure/thickness and flow/thickness results for the 'new' and 'used' materials are illustrated in Figures 10 and 11.

3.3 Permeability (Cross plane flow)

The test method employed here was also according to BS 6906 : Part 3. The permeability of the "new" and "used" nonwoven filter samples was assessed by directing the flow of water at right angles to the plane of the geosynthetic. (See Figures 6 and 7).

One set of tests was carried out on the outer filter-fabric of the drain alone (without the core) that was in contact with the soil and the other set with the core in place. In this way a better understanding of the flow mechanism of the geosynthetic product was established. (See Tables 2 and 3).
The difference in weight between the "used" and "new" materials before and after testing is shown in Table 4. The above difference occurred due to the fact that the old-used drain might have been partially "clogged" by very fine particles during the ten years of service. This "washed away" during testing.

Table 2: *A comparison between the "normal to plane flow" discharge capacities of the "used" and "new" drains with the core in place (in ℓ/m²/s).*

		"New"	"Used"
Specimen	1	264.8	264.8
	2	258.2	225.4
	3	209.5	207.3
Mean		244.2	232.4

Table 3: *A comparison between the" normal to plane flow" discharge capacities of the outer filter fabric of the "used" and "new" drains without their core (in ℓ/m²/s).*

		"New"	"Used"
Specimen	1	245	237.1
	2	205.5	214.4
	3	246.3	230.6
Mean		232.3	227.4

Table 4: *Weight losses of the specimens after testing of the outer filter fabric.*

"New"	1.6%	(Mean of 3)
"Used"	3.1%	(Mean of 3)

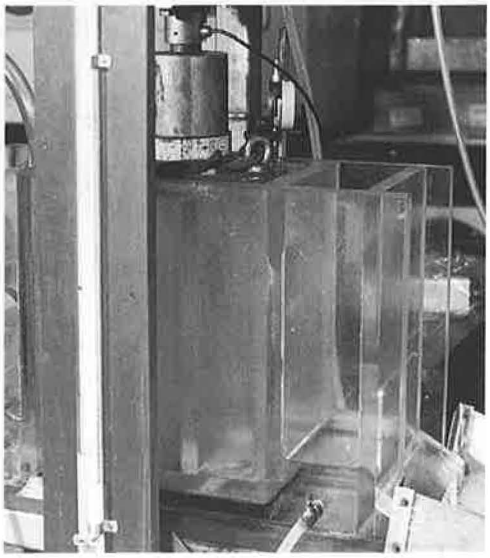

Figure 5: *A view of the "in-plane flow" testing apparatus.*

3.4 Tensile strength/elongation

Specimens of "new" and "used" drain materials were tested in both directions using a set of flat compression jaw faces on a Testometric 200kN tensometer following the method of BS 6906: Part 1. Here only the filter fabric of the composite geosynthetic material was tested. This was the one in contact with the soil. The other one in contact with the wall was rejected because it was covered with bitumen. The core was removed since it possesses negligible strength. The test results are given in Table 5.

4.0 Conclusions

The results from the previous comparative testing indicate that the long term of "burial" and functioning of this particular geosynthetic did not affect its hydraulic properties.

Figure 6: *A view of the "cross plane flow" testing apparatus.*

NORMAL TO PLANE RIGHT ANGLE FLOW TEST
BS 6906 PART 3 (MODIFIED)

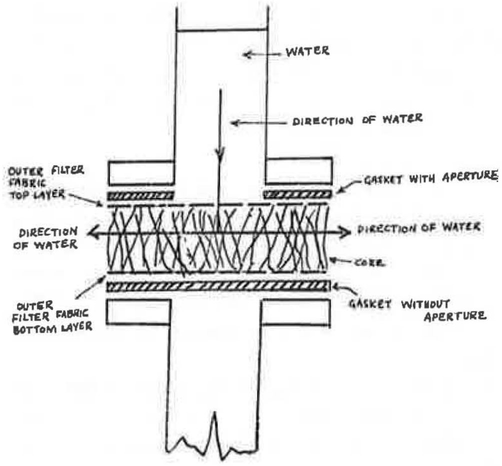

Figure 7: *A diagrammatic view of the "cross plane flow" testing apparatus.*

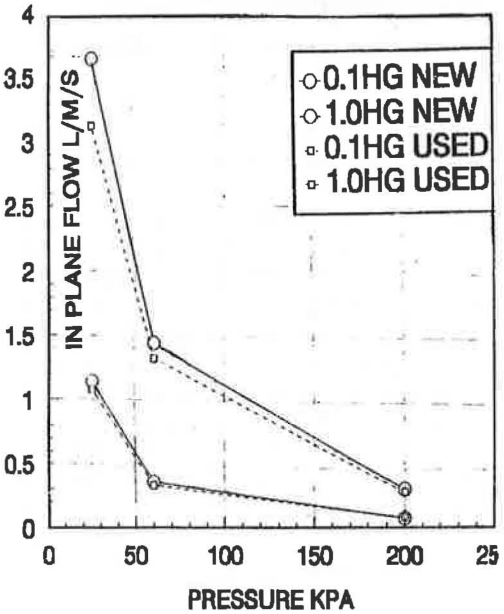

Figure 8: *Relationship between the "in-plane flow" discharge capacity and pressure of the "new" and "used" drains at two different hydraulic gradients.*

Table 5: *Tensile properties of "new" and "used" geosynthetic drains.*

Specimen	Direction	max.load kN/m	Extension at max load (%)
"New " Material			
1	Lengthway	7.00	28.6
2	"	8.50	37.6
3	"	8.70	35.0
4	"	9.60	41.6
Mean		8.45	35.7
S.D.		1.08	5.47
% CV		12.8	15.3
1	Crossway	8.10	39.6
2		8.70	46.1
3	"	8.85	40.9
Mean	"	8.55	42.2
	"		
S.D.		0.40	3.4
% CV		4.6	8.1
"Used" Material			
1	Lengthway	6.20	24.5
2	"	7.05	32.4
Mean		6.63	28.4
		0.60	5.5
S.D.		9.1	19.5
% CV			
1	Crossway	7.10	32.7
2	"	7.45	38.0
3	"	7.45	33.6
Mean		7.33	34.8
S.D.		0.20	2.8
% CV		2.8	8.1

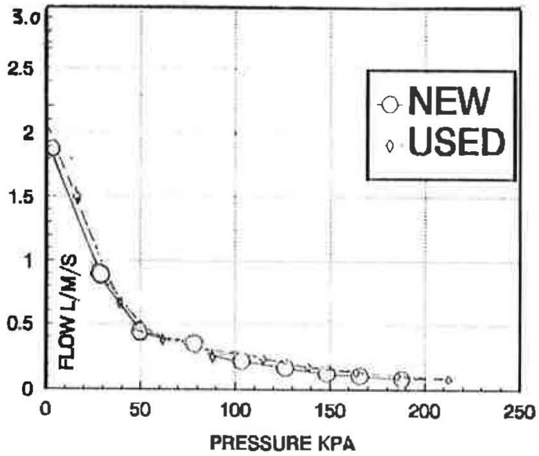

Figure 9: Relationship between the "in-plane flow" discharge capacity and pressure of the "new" and "used" geocomposite drains for one hydraulic gradient of 0.1.

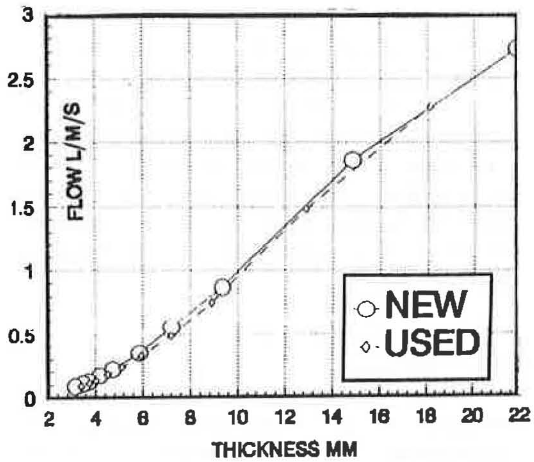

Figure 11: Relationship between the "in-plane flow" discharge capacity and thickness, with no external pressure applied.

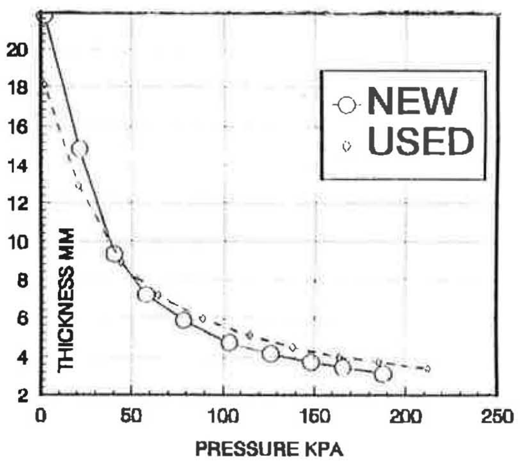

Figure 10: Relationship between pressure and thickness for both the "used" and "new" geocomposite drains.

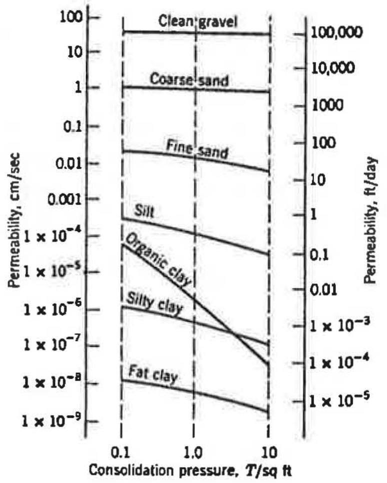

Figure 12: Permeability versus consolidation pressure (cited by Cedergren, 1977).

The relevant results indicate no significant difference in the hydraulic conductivity (i.e. discharge capacity) of the two geosynthetic drain materials. In other words, the difference in flow between "new" and "used" retrieved geosynthetic, is not significant at the 95% level.

The effect of pressure on flow and thickness is very similar for the two materials. The flow of the "used" sample is slightly lower at low pressure; (i.e. less than 20 kpa) as a consequence of the used material being somewhat thinner at low pressure.

The thickness/flow relationships of the "new" and "used" samples are identical.

The tensile strength of the "used" sample appeared to be slightly lower than that of the "new" one (around 20%). However, given the small number of specimens that were left to be tested for tensile strength (after the hydraulic testing was carried out), and the variability of the results, as well as the variations in the manufacturing processes, confidence in this finding is not high. It is certainly true to say that there is no evidence from these results, that the strength of the excavated sample has been seriously reduced after almost ten years of burial.

5.0 References

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