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Optimisation and testing of liner protection geotextiles used in landfills

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ABSTRACT: Having designed the non woven needle punched staple fibre geotextiles, specifically for liner protection, the author and colleagues have sought to optimise mechanical performance by adjusting production to produce the best weight (*and therefore cost*) / performance ratio. The aim has been to find links between standard index tests and site specific performance tests on site and in the laboratory. The now well established laboratory based "cylinder" performance test has been widely recognised in the UK as the nearest 'short term' (100 hours) duration test available. After having completed over 40 separate tests simulating, in most cases, actual sites, it has been possible to draw some meaningful conclusions on the performance requirements of the fabric. As a result of this research an additional index test, based on the cylinder test, has been proposed. This will hopefully give a comparative test for geotextiles and more readily simulate the action of a stone under pressure attempting to push through a protector and help to identify the key properties of the geotextile which assist protection.

1. INTRODUCTION

In the UK there has been a marked increase in the need for suitable land for landfill purposes. With much of the naturally lined sites used up and the raising of standards for protection of ground water and surface water the need for well engineered lining systems is essential. With the prospect of rising legislative costs site owners are ever more keen to find workable optimised designs and each engineered layer of a lined site is scrutinised.

To improve the performance of any given geotextile each process in manufacture needs to be improved.

2. THE MANUFACTURING PROCESS

It has been long established that the needle punched staple fibre non woven family of geotextiles has provided the most efficient protection to an HDPE liner. This is due to it's ability to cushion and spread load locally around an individual stone. To increase the efficiency of this cushioning effect rather than merely increasing the number of fibres beneath the stone there are other variables in the manufacturing process which can be optimised. These variables include:

a) Needles - needle spacing, frequency of needling, types of needles, needle shape, orientation of barbs on needles
b) Fibre - fibre diameter, mixes of fibre diameter,fibre length, fibre crimp, orientation of fibres, fibre elongation and tenacity
c) Fabric tension

3. INDEX TESTING

Index tests are used for comparison of geotextiles and for quality assurance they do not necessarily give an indication of how a geotextile performs in-situ. They are easy, repeatable, short term tests. The current index test which is closest to the action of a stone penetrating a fabric is the CBR puncture test common to most countries in Europe. It has also proved to be the most reliable test for quickly indicating a problem with production quality.

The CBR test was therefore used as the key index test to measure "improved" quality when varying the above manufacturing parameters. Table 1 lists a few of the fabrics typically used for basal membrane protection:

Table 1: Typical fabrics used in membrane protection

Trade Name	GG60	GP90	GP91	GP70	GP151
Polymer type fibre type	PP random fibre	PP selected fibre	PP selected fibre	PP selected fibre	PE selected fibre
CBR value	6500N	8500N	11000N	6500N	5500N
Weight/sq.m	1200g	1200g	1200g	750g	1200g
Typical Cost / sq.m.	£2.10	£2.80	£2.70	£1.80	£3.20

It can be seen for any given weight there can be a large variation in CBR value. The variation is due to the selection of fibre and the machining methods employed.

4. PERFORMANCE TESTING

The next step is to establish whether there is any link between the CBR index test and an empirical site test. The cylinder test or plate load test has been recognised in Europe as a good short term simulation of the static mechanical stresses imposed on the liner system by a stone drainage blanket. Figure 1 illustrates the typical set up simulating the base of a landfill. The actual stone, fabric and membrane intended for the site are used. A dense rubber sheet simulates a rolled clay surface underneath the membrane. The rig is loaded for 100 hours (4 days).

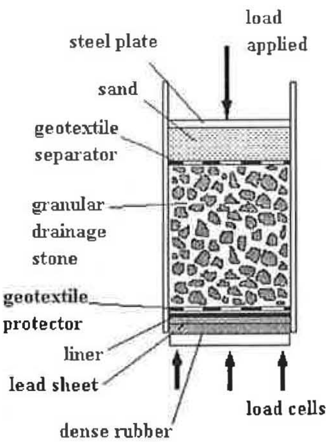

Figure 1 "Cylinder " Performance test

The load applied is factored up to take account of the likely increased temperature in the landfill and the duration of plastic deformation of the membrane.

This rig is frequently used in the UK to establish whether a combination of liner, protector and stone is allowable. The pass/fail criteria is based on the localised strain under an individual stone. As the membrane recovers after the load is removed a tell-tale lead plate is used under the membrane to give a permanent record of the fully loaded state. The plate is assessed for the three worst indentations and the local strain is measured.

The allowable strain is taken as 0.25%. This value was established by the German "Quo Vardis - Schutzlagen" working group. It takes into account plastic failure, possible biaxial strain of the membrane and possible settlements in the subsoil.

5. STANDARD EMPIRICAL TESTS

Over the last 3 years a large number of commercial tests have been carried out with various stone types and loading regimes. In order to try to cut down the variables but still stay close to a commercial site a programme of in-house testing was set up.

The possible variables for the cylinder test are:
a) Overburden load
b) Stone- type, diameter, grading, angularity, hardness
c) HDPE membrane - thickness, manufacturer (resin type), surface texture
d) Fabric - weight, CBR,

For the in-house tests the load, stone and membrane types were fixed at a typical level for the U.K.

Load - factored load equivalent of 30m deep landfill
Stone - 10-20mm subrounded/semiangular
Membrane - 2mm HDPE from a common single source

Figure 2 shows the plot of the average values of the fabrics shown above. As can be seen with increase CBR values for a given weight (1200g) there is an increase in protection.

Plotting CBR verses strain (see Figure 3) gives a characteristic curve. This would imply therefore that for this particular stone, membrane and load the optimum CBR value would be between 6000N-6500N. Therefore the most cost effective solution would be the 750g, 6500N fabric saving approximately £0.30 per sq/m. compared to the equivalent 1200g, 6500N fabric.

Whilst it is advisable to carry out a cylinder test for each site there are some general observations that can be made.

a) Single size stones are more damaging than coarse graded
b) Angular stones are more damaging than rounded although split rounded can cause a problem.
c) It is usually uneconomic to use a stone size above 30mm as the fabric costs increase disproportionately for higher CBR/weights for manufacturing reasons.

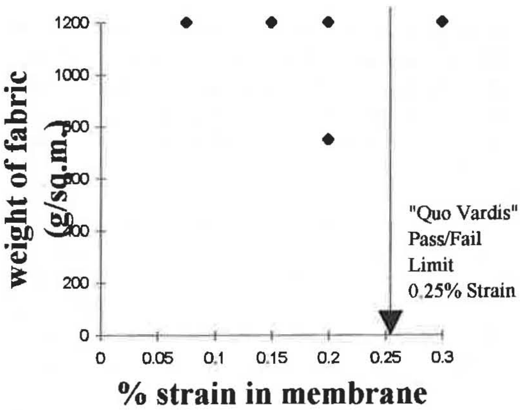

Figure 2
Weight of fabric verses % strain for membrane

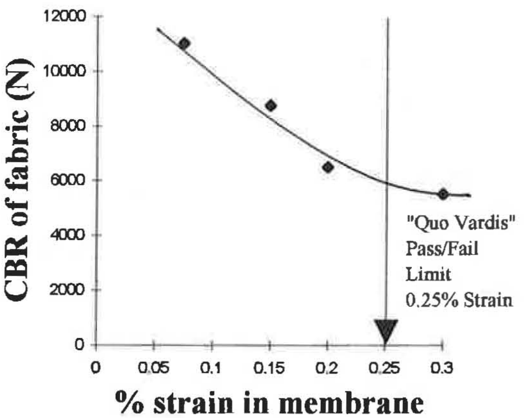

Figure 3
CBR of fabric verses % strain of membrane

6. INDEX CYLINDER TEST

Whilst the empirical cylinder test is a useful tool rapid comparisons of geotextiles is not possible. There is also too much variation in stone quality and type to establish hard and fast characteristic curves. The next step in establishing geotextile protection efficiency is to cut out even more variables and to try to isolate the geotextile. The cylinder is set up as shown in figure 4.

The aim is to establish a protective index for each fabric and relate this to the standard index tests such as CBR.

The rig contains M16mm nuts simulating a typical

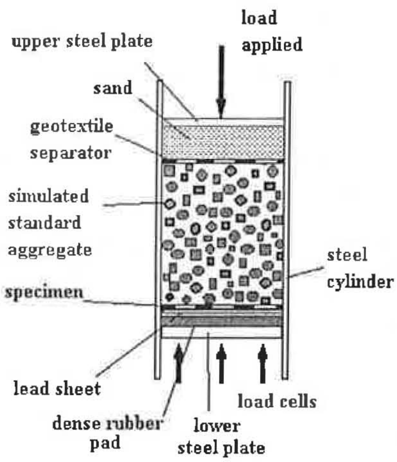

Figure 4 "Cylinder" Index Test

angular aggregate, the membrane is removed as this is now a comparative test for geotextiles alone. The only two variables now are the load and geotextile type.

The intention is to plot CBR of fabric verses strain. A best fit straight line will be drawn the gradient of which will give the "protection efficiency" of the fabric. This can then be used to compare protector geotextiles. To date the results lie on a good straight line. The work is on-going.

7. SITE DAMAGE TESTS

A number of site damage tests have been set up in the UK to check for site installation damage as well as long term puncture tests. These tests were consistent with the laboratory cylinder tests

For instance, on one site a trial panel was laid out using rounded sub angular stone with 2mm HDPE membrane on clay. Four types of geotextile were laid out varying from 325g/2700N CBR to 1200g/8500N CBR. After placement of stone a large excavator was positioned on two timber sleepers designed to give a footprint equal to the load of the finished landfill. The load was evenly distributed across the four geotextiles.

After careful removal of the load, stone and fabric a visual inspection confirmed that the 750g/6500N CBR fabric had protected the membrane from any visible indentations or scratches. Whilst the site analysis was somewhat subjective it was later confirmed with a cylinder test under the same loading conditions.

8. CHEMICAL IMMERSION TESTS

Whilst the base polymer for these fabrics is very stable the engineer should satisfy himself that there is no unusually noxious chemicals present in the leachate. Needle punched non woven staple fibre fabrics are normally produced in polypropylene or polyethylene fibres. Polyethylene has been considered the safest option and is consistent with the common use of HDPE in the liner. However there are some important considerations:

a) The PE and PP used to make membrane has a different molecular structure from the PE and PP used in fibre production.
b) For membrane production PE costs are *lower* than PP and for fibre production PE costs are *higher* than PP (see above costs in Table 1)

Having established that there is a link between CBR and protection performance it is important to establish that there is no break down in the CBR performance over time due to chemical attack.

There are many tests results available from the polymer producers on chemical resistance. These are useful but do not give an indication of the effect of a leachate "cocktail". Two long term tests were therefore set up along the lines of the EPA 90/90 test method, one with a typical domestic landfill leachate and the second with an aggressive leachate from an old coking plant.

Chemical analysis revealed that the coking plant leachate contained refined hydrocarbons, coal tars, polycyclic aromatic hydrocarbons, nitrified phenols and some PCB's. Other chemicals present included cyanides, various metals and oil based contaminants. The pH range was 1.4 - 14.

Samples of both PE and PP fabric and membrane were suspended in stainless steel tanks sitting on regulated hotplates.. The tanks were then sealed to create as near anaerobic conditions as possible. Individual samples were then removed at intervals, washed, allowed to dry and tested in the CBR rig.

The liner samples were tested according to the EPA 90/90 suite of tests. eg tensile, tear, puncture etc.

The results are as shown in figures 5 and 6.

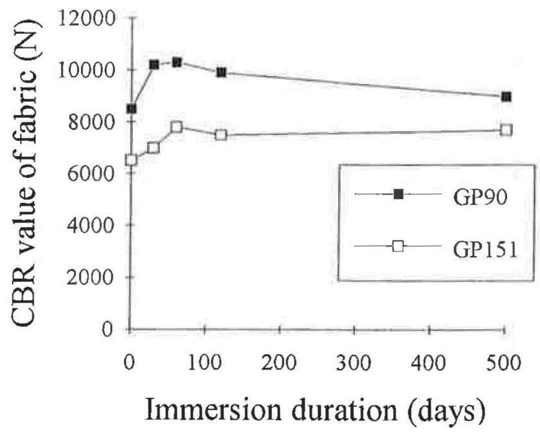

Figure 5 - CBR values for fabric immersed in leachate from a domestic landfill site

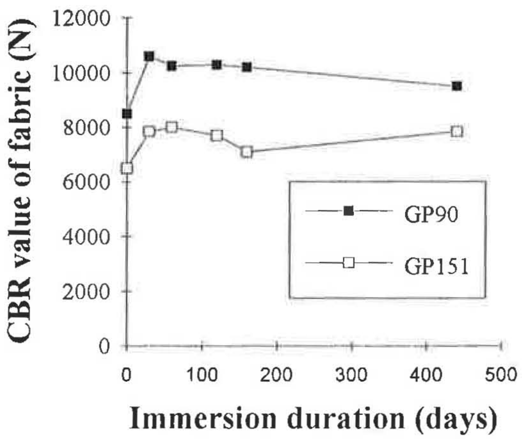

Figure 6 - CBR values for fabric immersed in an aggresive leachate from a coking plant

a) Both PE and PP fabrics have initially increased in strength in both tests and settled to approximately 120% of the production values. This is caused partly due to the stiffening of the fibres due to elevated temperatures and partly due to fine particles in the leachate which remain within the matrix of fibres.
b) The PE liner showed little change but the PP liner showed a marked drop in strength (20%) in the aggressive organic leachate from the coking plant.
c) Both PE and PP fabric have fallen from the initial peak value and have stabilised at a value higher than the control specimens.

This confirms that the PP fabric, which has higher mechanical strength and is less cost, is as stable as the PE fabric. It also shows that PP fibre reacts differently from PP liner due the difference in molecular structure.

9. CONCLUSION

Having taken an empirical rather than theoretical approach with the many variables which affect the mechanical performance of a protective geotextile it has been shown that :

a) Optimising the manufacture of these fabrics by changing, for instance, the mix of fibres to produce the highest CBR result for a given weight the most cost effective product has been produced.
b) The CBR puncture resistance is directly related to the % strain developed in the membrane
c) Stone type as well as size and grading is significant.
d) Whilst we are now in a position to make a good first guess for estimating purposes it is recommended that a cylinder test be carried out for each site to verify correct geotextile selection.
e) Polypropylene non woven staple fibre fabric give the best cost/performance and is chemically stable in typical domestic landfill environments. Whilst the fabric performed well in the aggressive organic leachate test it is recommended that a separate immersion test be carried out for such sites.

10. MINIMUM SPECIFICATION REQUIREMENTS

Having established the fabric required by a cylinder test the engineer needs to specify the most relevant currently used index tests for tender and quality assurance purposes. It is now apparent that specifying a protector fabric by weight alone is inappropriate and that the best indicator is the CBR value. There follows a suggested list of index values, in order of significance which the engineer should specify with a rationale for each parameter:

1. Minimum CBR Puncture resistance
If the CBR puncture resistance is key to the performance then this must mean that the interfibre friction is employed to spread the load of a protruding stone.
2. Maximum CBR displacement
This gives an indication of the stiffness of the fabric and the interfibre friction.
3. Minimum thickness (not less than 3mm)
There needs to be a minimum thickness to generate this load and cushion the stone from the affect of sharp edges to the aggregate.
4. Minimum tensile strength
This will be related to the CBR puncture resistance. These types of fabric have different values of tensile strength in the machine and cross machine directions and need to be able to withstand handling on site and being placed on slopes.
5. Maximum tensile extension
Again an indication of stiffness. Too much stretch will reduce thickness and therefore puncture resistance capability.

Apart from thickness the actual values of these parameters will be dictated from the CBR value.

REFERENCES

Brummermann K, Blumel W & Stoewahse C. 1994 "Protection Layers for Geomembranes: Effectiveness and Testing Procedures"

Fifth International Conference on Geotextiles, Geomembranes and Related Products
Singapore, 5-9 September 1994

Brummermann K.,1993
"Protection layers in combined sealing systems of German landfills."
University of Hannover, Germany

Saatoff F, Sehrbrock U.1994
"Indicators for selection of Protection Layers for Geomembranes"
Fifth International Conference on Geotextiles, Geomembranes and Related Products
Singapore, 5-9 September 1994

Soyez B, Delmas Ph & Jessburger H L 1994
"European Recommendations on Geotextiles and Geomembranes in Landfills"
Fifth International Conference on Geotextiles, Geomembranes and Related Products
Singapore, 5-9 September 1994

Shercliff D, 1994
"Membrane Protection in Landfills"
Polluted and Marginal Land - 94 , Conference of Re-use of contaminated land and landfills 28-30th June 1994, Brunel University, London

Seeger S, Muller W 1995
"Requirements and testing of protection layer systems for geomembranes"
Geosynthetics in Infrastructure enhancement and remediation - 9th GRI conference 12-13th December 1995, Drexel University, Philadelphia, USA

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