ExcelPlas Independent Materials Testing

Performance-based testing for assessing the puncture protection of geomembranes (ASTM D5514)

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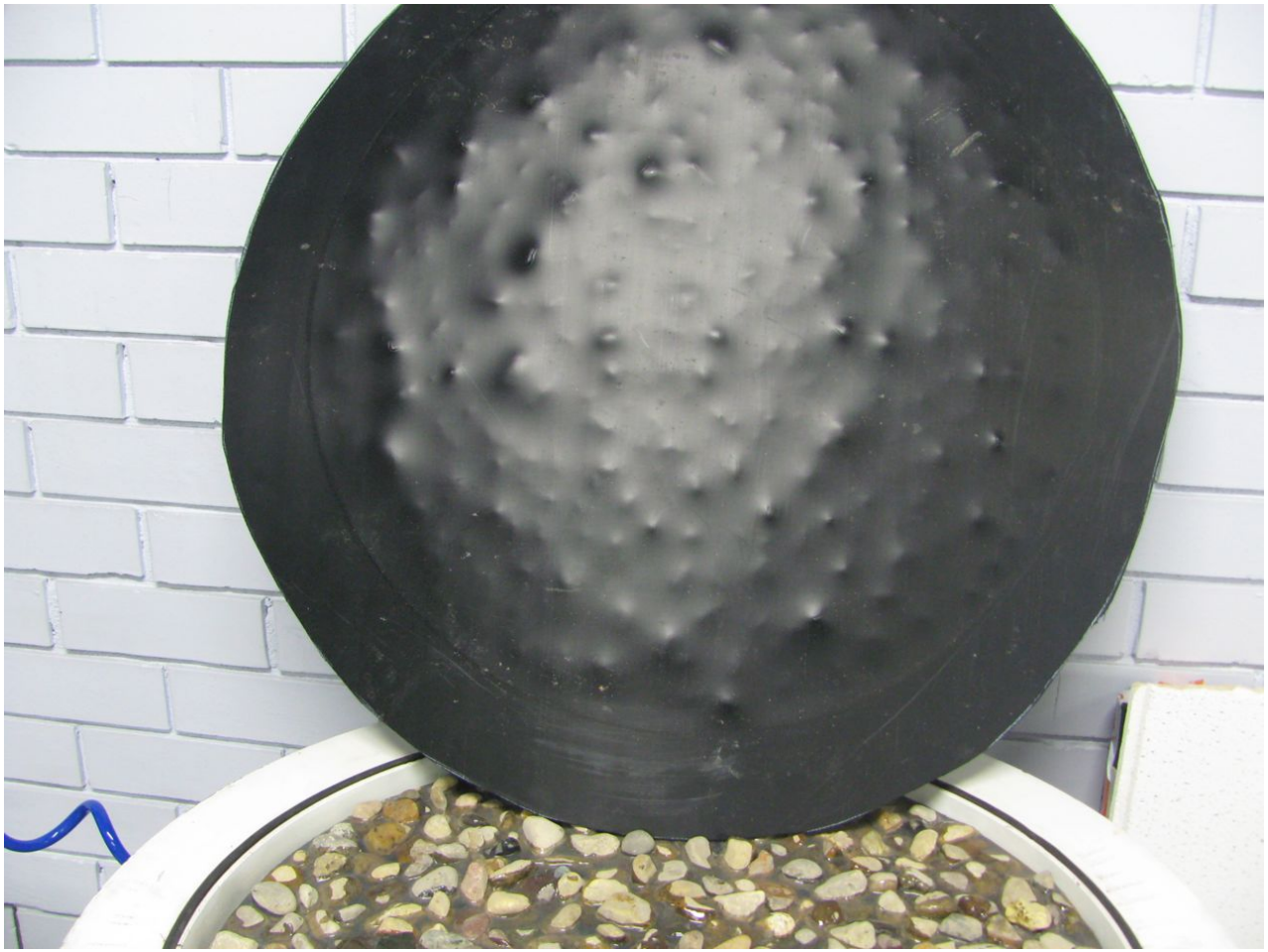
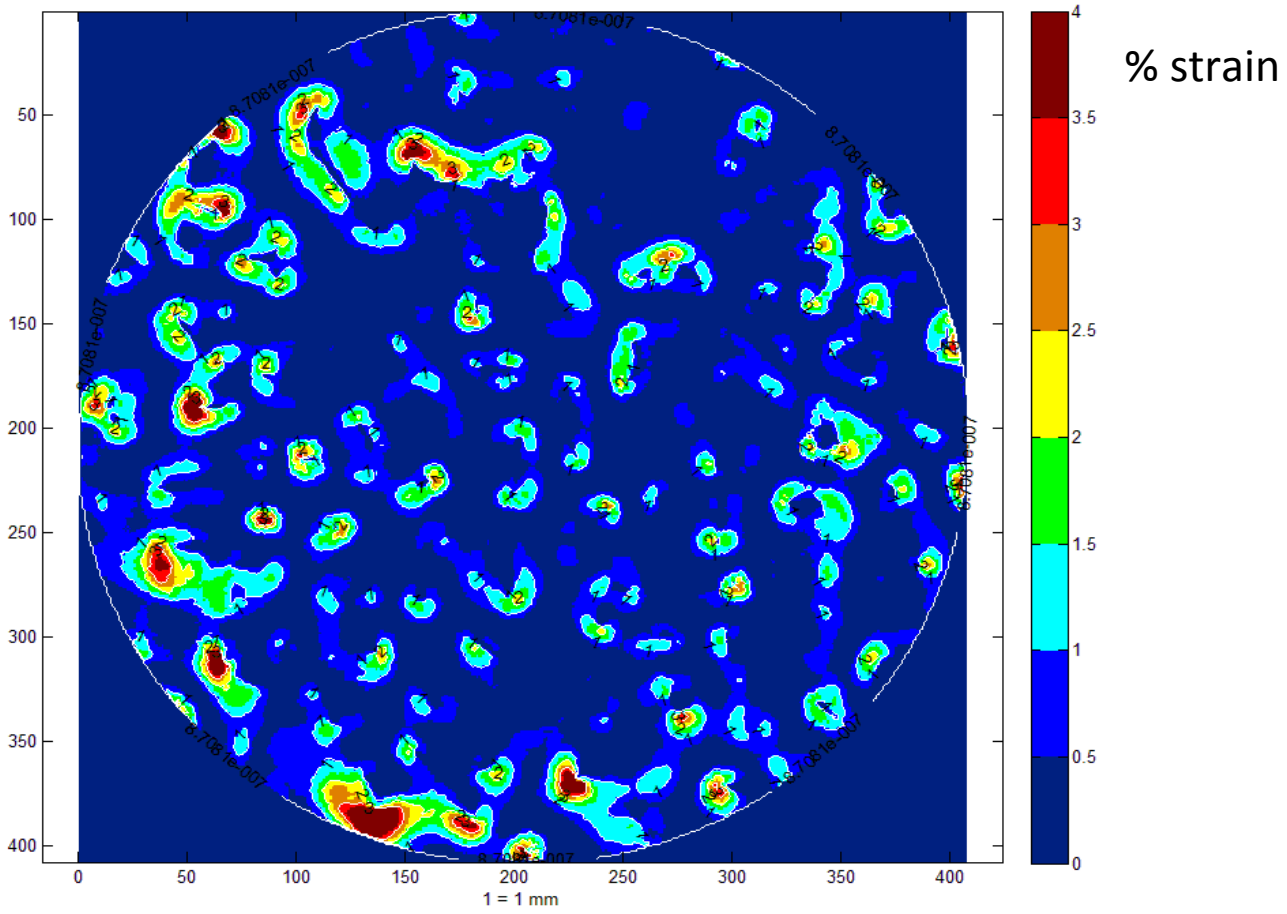
Example of Aggregate Damage on HDPE Geomembrane

Rock Pizza Testing Rig

Damage to HDPE Geomembrane



Laser Scanning for Local Strain Levels



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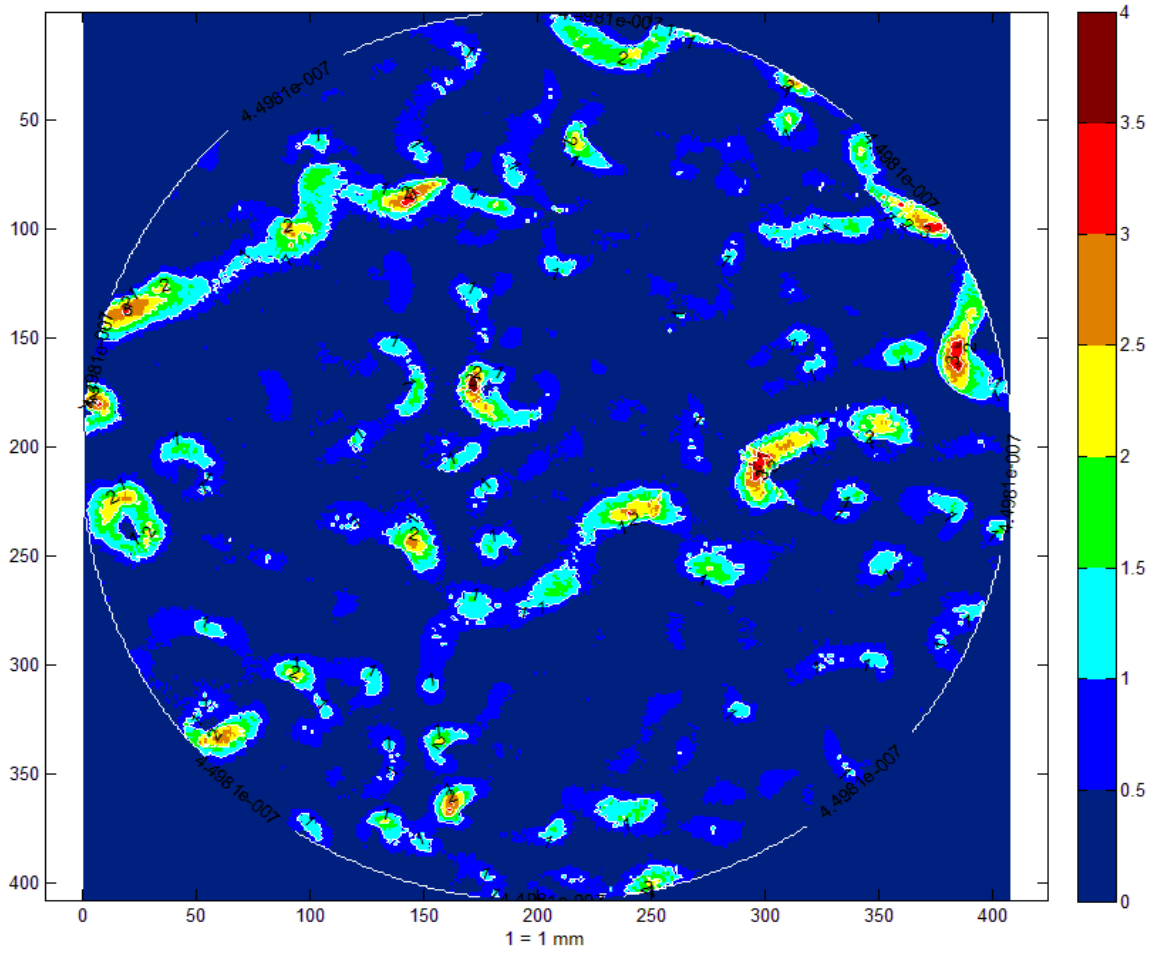


% strain

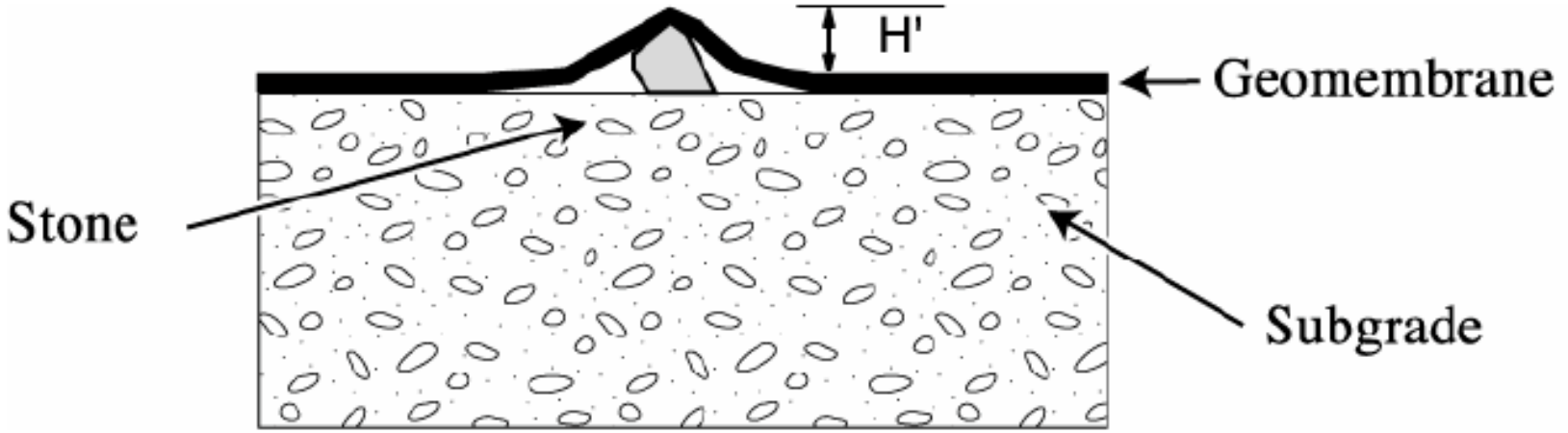
Stresses on Geomembranes

The real life stress situations on a geomembrane include:

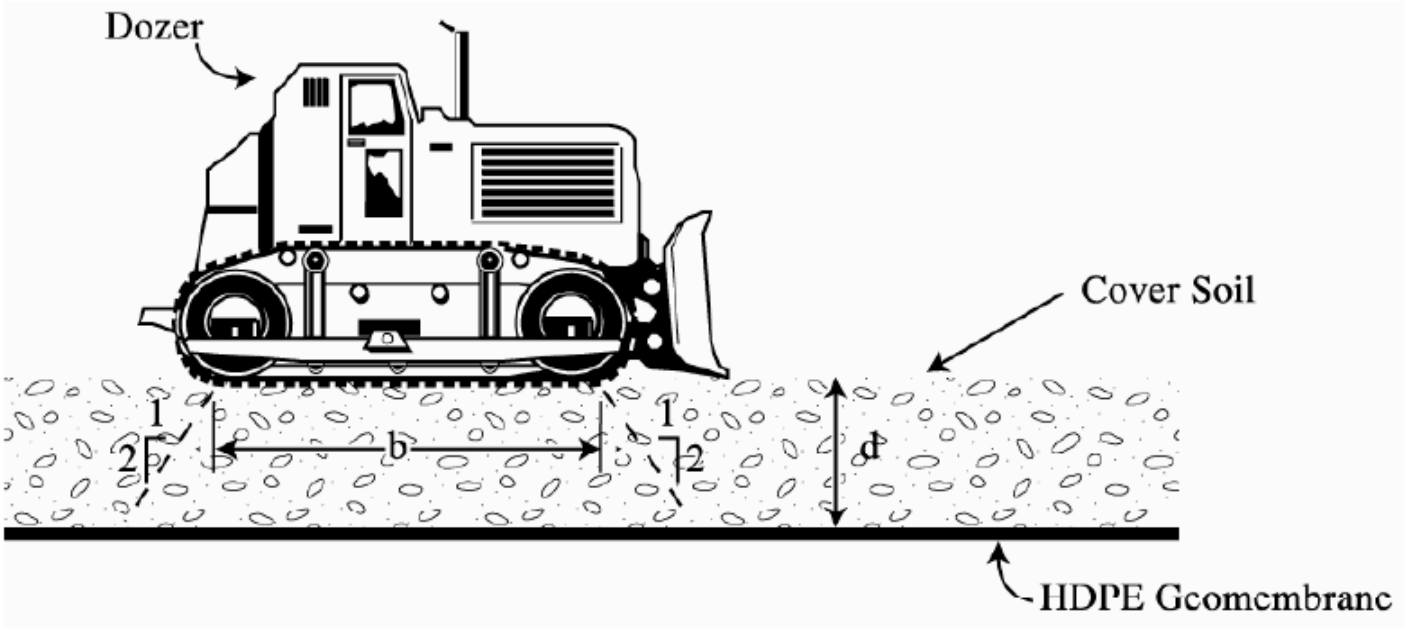
(1) Damage during installation (dynamic) and

(2) Long term static stress from the load of the cover soil or from the waste in a base seal application) and this could be very high. In both cases the use of actual drainage material is critical as opposed to the use of nuts or selected general stone size.

Angular Rocks

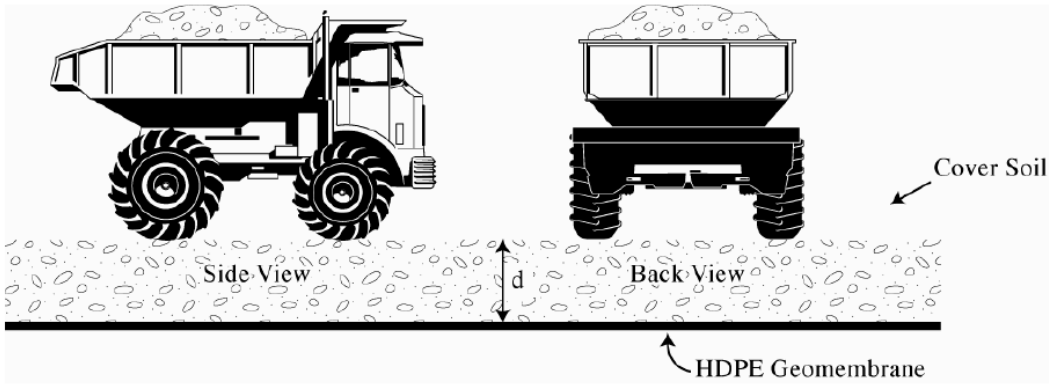


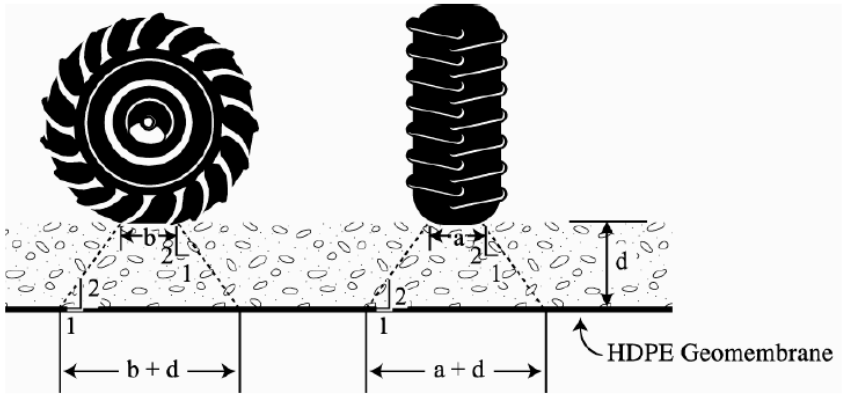
Forces on the Liner



By far the most damage to a geomembrane is done during installation, particularly during covering (placement of the cover material). Stone punctures are the most frequent forms of damage with equipment damage the next. Relatively little new damage appears to occur during service. Thus protection systems have to be more effective during construction. The nature of the drainage layer over the geomembrane is critical.

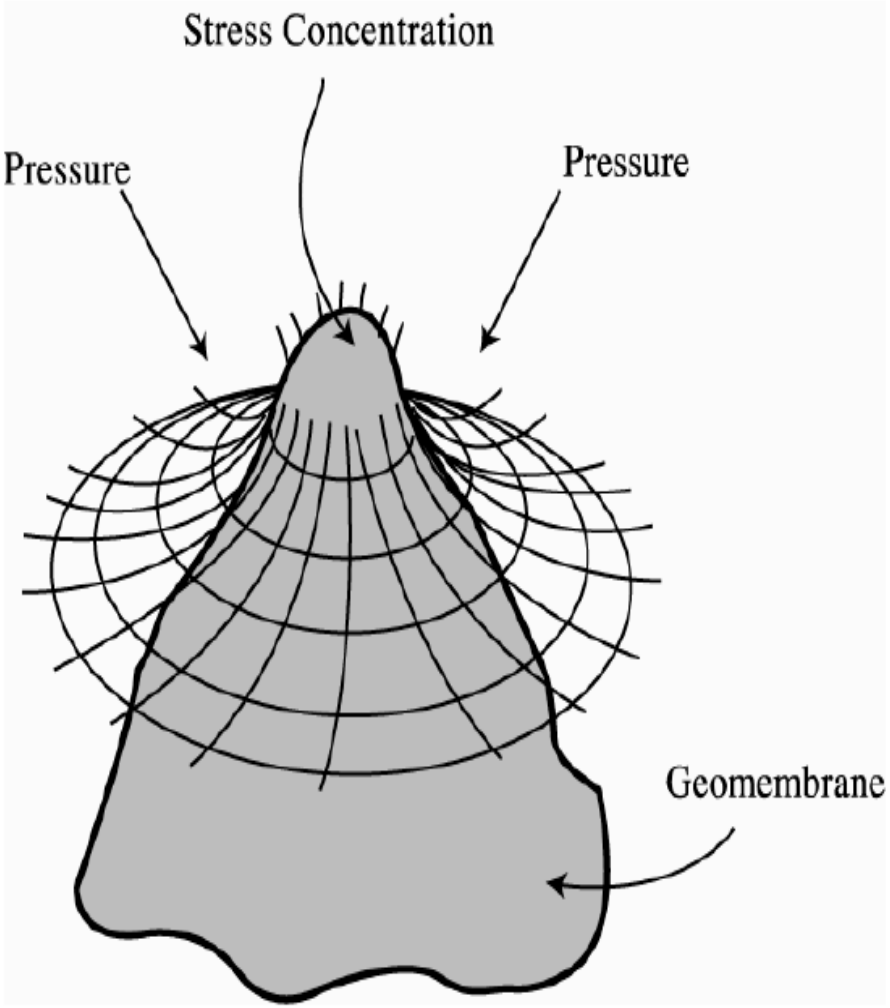
Forces on the Liner





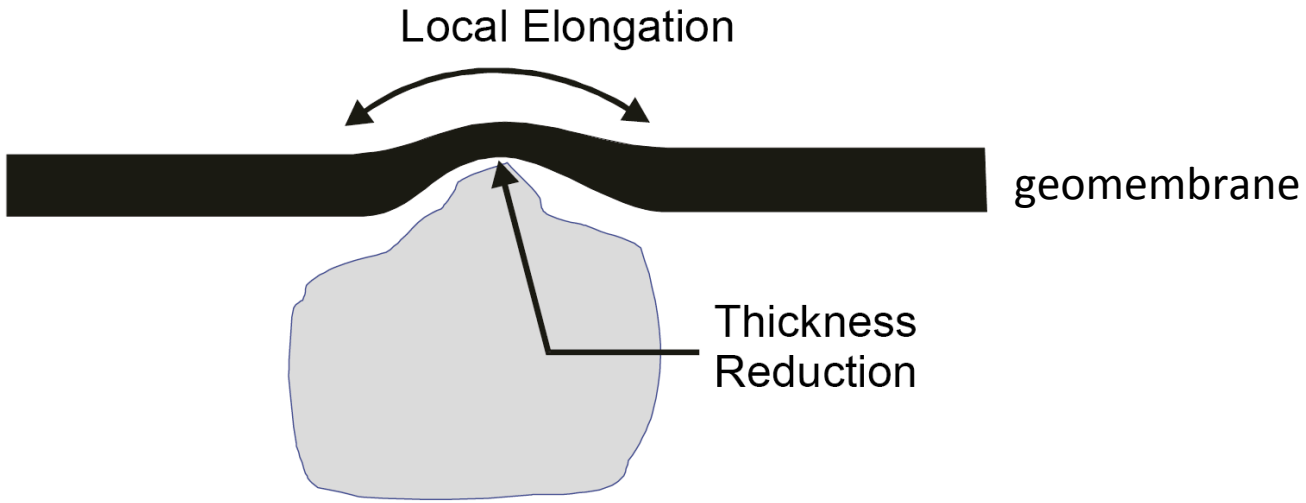
Hydrostatic tests can be performed with the site-specific material, the supplied geosynthetics and the loads of the vehicles which really will be used on site

Angular Subgrade



Damage is done to the geomembrane well before a leak/hole/puncture might occur in it. Therefore, damage can be done during installation that does not become a leak until later. Hence, the strict limitations on general (3%) and local (0.25%) strain imposed in Germany, and hence the thick/heavy geotextile and other protection systems.

Puncture by Angular Rocks



The puncturing/cutting stresses on the geomembrane imposed by angular rocks and aggregate are significant in the field situation. The ASTM D5541 test is a very useful test for comparing puncture protection performance of different geotextiles with site specific stone and geomembranes. The test can determine whether or not a geomembrane is punctured, or deformed such that it will leak over the longer term. The concern, particularly with HDPE, is not whether it is punctured in the test, but whether it is stressed sufficiently to induce stress cracking in the longer term. This, in fact, is the reason for the use of much heavier/thicker puncture protection layers in Germany.

Puncture Protection

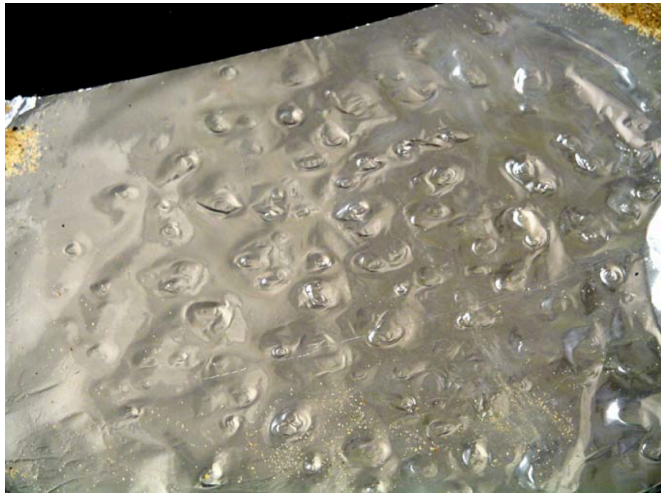
- Puncture protection of geomembranes is becoming more important as interest in the maximum allowable strains in different geomembrane materials increases. Mass of cushion geotextile is an important parameter.

- Solution provides the geomembrane with a new "artificial soil base" for puncture protection and drainage. Puncture protection was only one part to solve the problem. The other part of the solution to the problem, is the selection of the right geomembrane that will work with this protection.

Elastic Recovery

- Simply looking at a geomembrane specimen when it has been exhumed is not sufficient, since elastic recovery occurs. We need to know the stress in the geomembrane in service, not when it has recovered after being exhumed. Nor does strain alone, even in situ, indicate the stress situation since stress relaxation occurs in these viscoelastic materials.

- Tell-tale plate of aluminium or lead sheet can be used to measure deformation. Best to conduct these tests with the soil and rock materials to be used in the job



Weight of Geotextile Required for Protection

- Question: Will a 500 gsm nonwovens protect a geomembrane from 4 inch angular rock when German regulations require of the order of 2000 gsm?

- Answer: Geotextiles of 1,200 gsm are known to provide good protection against 16 to 32 mm coarse gravel but 500 g/sqm geotextiles can leave the geomembrane looking like a sieve.

Case Example

- **Problem**: a job, where the protection of the geomembrane was critical, due to the slope conditions: 45° and with angular rocks showing everywhere

  Original design done by a Consultant was: Geotextile 400 gsm with a HDPE Geomembrane 1.5mm.

  Improved Design: 1000 gsm geotextile , a geocomposite: Geotextile-geonet-Geotextile (Geotextile 300gr/m^2 each and the Geonet 5mm thick), and a 1.0mm fPP geomembrane non reinforced.

Puncture Testing

- The whole system (protection system and geomembane) should be tested with site specific materials in order to ensure that the deformation of the protection system will not cause a damage in the geomembrane.

  The challenge is not to protect only from puncture, but also that this protection should prevent stresses that will induce a failure in longer term by stress cracking in the case of HDPE.

ASTM D5514

- The ASTM D5514 test, procedure B is the best way to assess geomembrane protection without overdesign. It consists in the application of an air pressure over the whole sandwich, reproduced with the materials to be installed (Stone / GX / GM - even other layers if requested). The air pressure applied on top of the sandwich can be adjusted to a sufficient level in order to consider not only short term pressure (equipments or service stress) but also long term effects with application of safety factors (based on literature).

ASTM D5514

- To analyze the results of ASTM D5514 we simply consider the number of plastic deformations, which can be easily observed visually, and report this number per square meter (a good system giving 'zero' as the reported result). Considering that the typical / actual yield strain of HDPE geomembranes is somewhere between 10 and 12 %, this means we tolerate a typical total deformation of 10 to 12 % under a test stress chosen as a multiple of the service stress. It is not as critical as the 0.25 % proposed by German regulation, but it is critical if the test duration and stress level are adequately selected to simulate long term exposition (actually, we are comparing 6% ultimate deformation in Germany to 10-12 % ultimate with D5514).

Geotextiles

- The Pyramid Puncture test is potentially misleading on other products such as staple fibre.

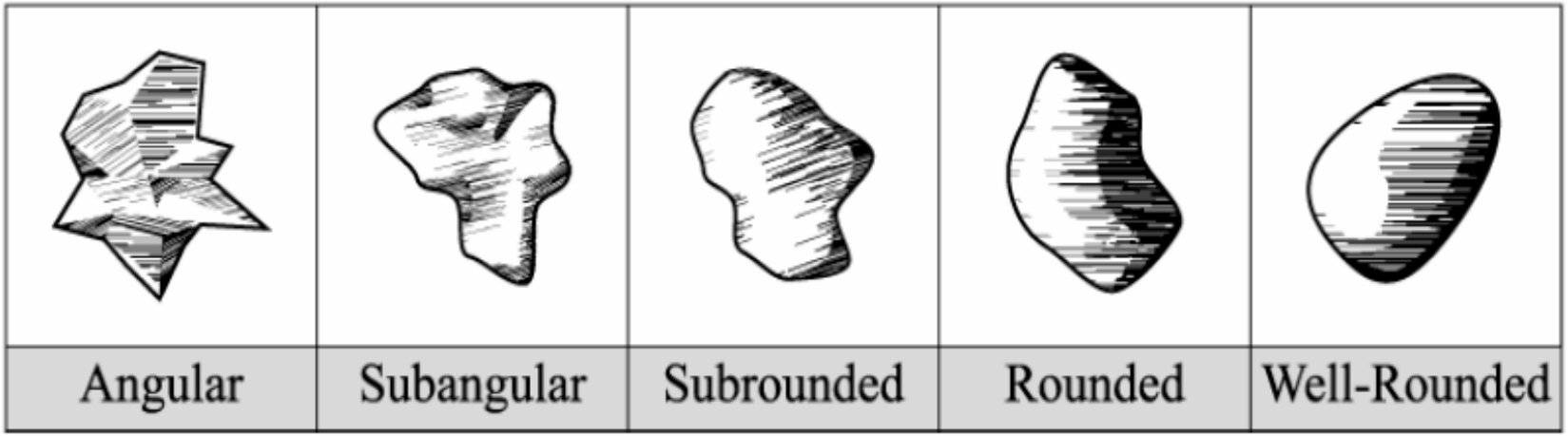
  Not all needle punched non-wovens are the same - one can engineer enormous performance differences based on the fibre length, thickness (denier), stiffness and crimping, needling process and intensity, and the use of supplementary bonding.

  Heat bonding the upper surface of a staple fibre product produce a skin that makes it more difficult for a rock to penetrate to the softer core of fibres.

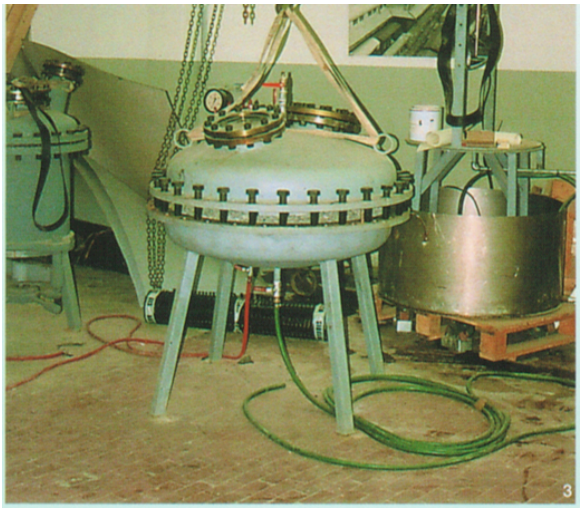
Aggregate geometry

The use of site-specific aggregate can overcome variability in stone properties (angularity, mineralogy, etc.), in the same way than it it commonly done for GS/GS or Soil/GS shear resistance.

The particle size of the stones in the drainage layer is a trade-off. The smaller the aggregate the better it is for the geomembrane but the more clogging one will see.

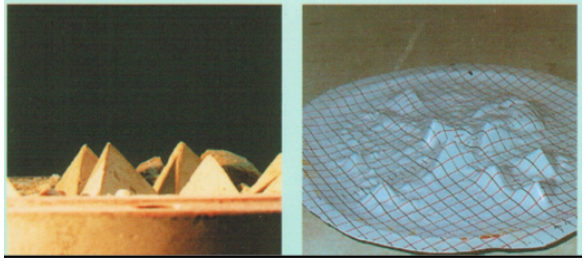


Rock Pizza



4 - Different types of substrates are used in the pressure vessels, they vary from very agressive (exceeding actual installations) to test extreme performance or substrates exactly replicating real conditions.

5 - A PVC geocomposite after puncture/burst testing at 100 meter head. The geomembrane is still intact maintaining its water tight integrity. PVC elasticity will allow almost total recovery of deformation after less than 1 hour.



ASTM D5514 is an excellent test if conducted and analyzed properly since it is the best possible way to design protective layers, because it is not over-conservative but gives sufficient information to make sure the liner will not end-up sieving wastes instead of confining them.

Critical Failure Situation

- The critical failure situation for a geomembrane is not the damaged hole situation, where a angularity penetrates through the geomembrane. Far earlier than this the geomembrane is already damaged. According to German perspective the maximum allowable strain is 6 %. Taking a safety factor of two into account this then decreases to 3 % and since this is a long term value Germans only allow 0.25 % (percent) deformation during installation. The rest will occur in the life time. Reasonable approach in a landfill base where one does not want to excavate 30 m of waste if a failure occurs. Well that means the protection layers are 1,200-2,000 gsm are required for a guarantee of safety safety.