Third International Conference on Geotextiles, 1986, Vienna, Austria

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GEOTEXTILES IN TUNNEL CONSTRUCTION
GEOTEXTILIEN IM UNTERTAGEBAU
GEOTEXTILES DANS LES TRAVAUX SOUTERRAINS

The application of Geotextiles in tunnel construction is a standard technology today. The purpose of this paper is to describe the various applications in protection and drainage methods and the function of Geotextiles in connection with waterproofing systems. A schedule of the mechanical, chemical and hydraulic minimum requirements, as well as some practical findings complete this paper.

The application of Geotextiles in tunnel construction must be considered. The functions of protection and drainage as well as separation and filtration justify the large scale application of Geotextiles in tunnel construction.

1. APPLICATION POTENTIAL

Long term post installation functions
- Protection and drainage on the rock face side of the waterproofing membrane.
- Protection layer for waterproofing surfaces placed in the in-side of the cavity and on reinforced rings or concrete balks.
- Protection and filtration layer between the waterproofing membrane and tunnel cavities that occur when using the open engineering method.
- Separation, slide and drainage layer between the concrete and the rockface or shotcrete.
- Protection layer with rebound reduction properties in membrane sealed tunnel constructions with a shotcrete inner lining.
- Sound deadening separation layer in the construction of railway tunnels.

Applications during construction stage
- Protection layer for the sealing off of frontal boards at the end of each concrete section.
- Use as counter form-work for shotcreted anticlines.
- Insulation layer for interface boarding of heat treated concrete.

2. WATERPROOFING

Geotextiles are applied as a waterproofing layer between the rockface and the inner concrete ring (illustration 1). The sealing system comprises the shotcrete layer, the Geotextile protection layer fixed to the shotcrete with a special type of rondell on which the geomembrane is welded.

Illustration 1: waterproofing in a tunnel, by means of a protection layer and PVC-sealing boards.

The fastening system is primarily designed according to the requirements of the waterproofing membrane. Usually about 3 rondells per m2 are required for loose overlapping of the Geotextile.

A predecessor to current protection layers was the use of non-wovens consisting of regenerated fibres. These however proved to possess lesser protection qualities.

3. REQUIREMENTS

Geotextiles used in conjunction with waterproofing membranes need to satisfy the following requirements:

mechanical protection and
in-plane drainage ability.

Both these requirements have to be fulfilled for the design life of the construction - which for tunnels is estimated to be a period of 100 years.

Although permanent protection against mechanical damage caused by the coarse shotcrete during shotcreting and slope deformation or shifting as a result of creeping, shrinkage and temperature changes in the concrete can be successfully prevented by various Geotextiles, impediment of the drainage function brought about by sintering will ultimately occur.

Before installing the ultimate lining pre-sealing, diversion or draining off of water ingress has to be undertaken to ensure that lateral drainage pipes cast into the lining continue to function (cleaning access eyes every 50 m to 100 m maximum).

To fulfill the requirements of the Geotextiles the mechanical, chemical and hydraulic properties outlined in schedule 1 have to be met.

3.1 Mechanical properties:

The thickness of various Geotextiles are comparable only under specified stress ratings, and a certain post compression thickness is absolutely necessary.

Pressure values of fresh concrete on formwork in tunnel construction lie according to Kurzmann (1) between 0,9 bar horizontal and 1,68 bar vertical.

Comparative ratings for example between Polypropylene endless fiber spun bonded Geotextiles and Polyamid (Nylon) spun drainage mats shown in table 2, prove, that thicknesses at a pressure load of 0,01 bar vary considerably (spun drainage mats 17 mm, Polypropylene fleece 500 g/m2 3,9 mm), whereas under 1 bar load pressure they are almost equal.

Table 2: Thicknesses of Geotextiles according to pressure

	Thickness mm	
Pressure in bar	Polypropylene fleece 500 g/m2	Spun Nylon drainage mats
0,02	3,9	17,0
1,00	2,2	2,5
2,00	1,8	2,0

In addition in a stress situation the spun nylon drainage mats show small holes which can mean reduced protection for the waterproof membrane on surfaces covered with rough shotcrete.

Table 1: Minimum requirement for Geotextiles in tunnel construction

Properties		Test	Values	
mechanical	rated surface weight	DIN 53854	500 g/m2	700 g/m2
	thickness	DIN 53855/3 at 2,0 bar	1,8 mm	2,5 mm
	CBR-Test X-S	DIN 54307	2800 N	3500 N
	Strip tensile strength	DIN 53857/2	800 N/5cm	1000 N/5 cm
	Extension at break min/max	DIN 53857	50 % / 130 %	50 % / 130 %
Chemical			fully resistant against solubility in p_H-range between 2 and 13 at temperatures 0^oC and 30^oC	
hydraulic	water permeability at fleece level	acc. Franzius Institute Hannover	k = between 10^{-1} and 10^{-2} cm/s; the permeability k is to be rated on a one-ply test piece of 0,1 m width which is to be placed in a vertical position to the Geotextile with a pressure of 2 bar and hydraulic gradient of I = 1,0	
	type of fibre		smooth, unruffled, hydrophobe (round cross-section)	

The strength and elasticity of the Geotextiles must be compatible with the type of sealing membrane and must also comply with requirements under high pressure.

3.2. Chemical properties (2):

The protection function of the Geotextile has to be absolutely permanent therefore chemical and rot resistance are necessary. Most shotcrete has a constant p_H-rating of approx. 12,0. Residiual strength tests (carried out at HOECHST) after long term storage of Polyester in alkaline solutions (for example calcium Hydroxide p_H-value 12,4) show an effective drop in strength after 6 months down to 29 % and down to 0 % after 12 months. Tests with concrete show a more rapid decomposition. It is for this reason that Polyester fibre raw materials can be practically excluded from an application in tunnel construction (see information leaflet of the German Research Association for Roadways and Transportation of Geotextiles in excavations under "Resistance to the aging process").

Natural and viscose fibres also do not show any resistance to long term aging. In contrast Polypropylenes show no reduction of strength in contact with concrete.

However, there do exist some problems, especially with Polypropylene, concerning resistance to light. This can be prevented through the use of stabilisers but it is recommended to take precautions against UV-rays during storage.

Long term, the Geotextiles must be compatible with the geomembrane (i.e. no stimulation of plasticiser migration from the geomembrane). In addition environmental compatibility must also be provided (no contamination of mountain water sources which must remain drinkable).

3.3 Hydraulic properties:

To prevent sintering in Geotextiles the smoothest possible fibre surface is essential. However, viewed long term, Geotextiles can only reduce the rate of sintering but not completely prevent it. This process depends on the hardness of the mountain water, the content of calcium in concrete aggregates and the free calcium content in the cement (calcium hydrate) of the shotcrete, as well as the carbonic acid content of the surrounding air and the release of water together with the pressure. The greater the porosity of the Geotextile the more carbonic acid is available and the faster the process of sintering.

The in-plane permeability of the Geotextile is only of importance when the Geotextile is subject to concrete pressure. Manufacturers data concerning uncompressed permeability is of little interest as the draining-off capacity is reduced considerably by increased pressure. Mechanically stabilised Geotextiles possesses greater water permeability than the thermally stabilised Geotextile types.

4. PRACTICAL FINDINGS

Practice shows that the composition and coarseness of the shotcrete surface often provokes discussions on the method of payment for construction work and the liability for the performance of sealing systems.

Additional costs for high mass per unit area Geotextiles are in no way comparable with the costs of additionally applied layers of shotcrete.

Geotextile costs of approx. ATS 60,--/kg (i.e. about ATS 30,--/m2 for 500 g/m2 Geotextiles or approx. twice this amount for spun nylon drainage mats) compared with the cost of about ATS 200,--/m2 for 5 cm of shotcrete.

Generally, it can be said that for the purpose of waterproofing no protective Geotextile under 500 g/m2 ought to be applied. The economical limit for the manufacture of single ply endless fibre Geotextiles lies at approximately 700 g/m2. Over and above that limit it is recommended to apply composite Geotextile backing. Desired additional thickness can be obtained by needling stable fibre products to the continous filament Geotextile. Required minimum properties will also be maintained by means of this process. The upper limit for the Geotextile mass lies at approximately 2000 g/m2.

For applications in shafts, it is advisable to use a Geotextile of 1000 g/m2.

The above mentioned waterproofing systems have not only proved reliable in areas of low hydrostatic pressure, but have also been successfully used in tunnel sections subject to high hydrostatic pressures.

Fire characteristics seem to be a problem for a number of Geotextiles (inflammibility, vapour emmission, dripping). It should however be possible to achieve fire classification B2 (normally inflammable) in accordance with DIN 4102, Part 1.

The application of Geotextiles, without geomembranes has proved successful as a sliding and drainage layer between the inner concrete lining and the rockface, and/or shotcrete. Movement ability ensures that a reduction of shrinkage stress and temperature stress cracking can be achieved.

This application is suitable for tunnel sections with a minimum of watersilt, since the drainage effect can be reduced through the penetration of cement lime into the Geotextile, unless special compound material is used. Geotextiles have been used on a test stretch of the Arlberg Tunnel West (3). No findings have as yet been published. At the same time it must be mentioned that most satisfactory findings are available on the application of Geotextiles in the separation of the outer and inner formwork on the Eichbergtunnel on the newly built stretch of the FRG-Railways between Hannover and Wuerzburg.

By this means the cracking may almost be completely prevented (4).

From experience on many Austrian tunnel constructions, it can be concluded, that waterproofing of the total tunnel track has proved to be satisfactory. All factors considered this method appears to be the most economical, compared to the maintenance works necessary on construction sections which have not been waterproofed, as well as the operation and maintenance of the underground constructions. It must also be emphasised that this method is financially more economical than construction methods using impermeable concrete, as clearly shown by comparative calculations for tunnel construction works in Austria.

According to the regulations of the FRG-Railways (5): "For the tunnel sections which lie in frost and/or thaw interacting areas it is preferable to use one of the available waterproofing materials than to use impermeable in-situ concrete".

In keeping with today's technological developments, the best material for the manufacture of Geotextiles for tunnel construction applications is Polypropylene.

In order to ensure steady quality of the fibre raw materials, it is preferable to use filament fibre Geotextiles (endless fibre) as compared to stable fibre Geotextiles.

A glance at the world market shows that in 1985 more than half of Geotextiles used were produced from endless fibre Polypropylene, more than any other material.

The author takes this opportunity to place on record a request to all Geotextile manufacturers to please produce literature using unified terminologies and values in order that the user (customer) may be in a position to make immediate comparisons.

(1) Federal Ministry for Building and Technology
Schaden Karl Dipl.Ing.Dr., Vienna
"Waterproofing Systems in Constructed Tunnels"
Research Proposal 919, Brochure 274

(2) Zitscher Fritz-Ferdinand Prof.Dr.Ing, Kiel
"Recommendations for the use of Synthetic Materials in Excavations and water-ways constructions". The Building Technology, Brochure 5, May 1982, page 145

(3) Bilewicz Dieter Dipl.Ing., Innsbruck
"Synthetic Fleece - an alternative to Common Tunnel Insulation".
BM-News 1977 (BM-Mitteilungen 1977)

(4) Semprich Stephan Dipl.Ing.Dr., Mannheim
"Research Findings on Inner Form Works of impermeable Concrete for Tunnel Constructions in Rock Formations". Lecture on the occasion of the STUVA-Congress 1985 in Hannover

(5) Waterproofing of Constructions in Underground Railway Tunnels. FRG-Railways
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