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## Distribution of inflowing water by using geotextile

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April 2014

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*Keywords:* Geotextile, Bentonite, Backfill, Pellets, Water inflow, KBP1003.

This report concerns a study which was conducted for SKB. The conclusions and viewpoints presented in the report are those of the authors. SKB may draw modified conclusions, based on additional literature sources and/or expert opinions.

A pdf version of this document can be downloaded from www.skb.se.

# Abstract

The work described in this report has been done on behalf of SKB (Swedish Nuclear Fuel and Waste Management Co) and Posiva (Finnish company responsible for the final disposal of spent nuclear fuel of the owners).

This report describes an investigation regarding the usage of geotextiles as a solution to distribute inflowing water during the installation of backfill. The purpose of the method is to distribute the inflowing water more evenly in the pellet filling, and to mitigate local erosion of the backfill. One objective with the project was to achieve a method that should be functional as long as the deposition tunnel is open and another that the adverse effects of the method regarding the long term safety of the repository should be minimal.

The project was divided into three parts:

1. Laboratory scale test.
2. Half-scale steel tunnel tests.
3. Fastening tests.

The purpose of the laboratory scale tests was to test the potential of the geotextile fabrics in water distribution between the rock and the bentonite pellets. In laboratory scale the rock surface was replaced with a Plexiglas tube.

Based on the laboratory scale tests, a typical polypropylene geotextile was used in the ½-scale steel tunnel tests. Three separate tests were done in the steel tunnel:

- Reference test without geotextile and with an inflow of 0.25 l/min.
- The first test with geotextile and with an inflow of 0.25 l/min.
- The second test with geotextile and with an inflow of 0.5 l/min.

The fastening tests were performed independently from the laboratory scale and ½-scale steel tunnel test. The fastening tests were done at three separate occasions and the tested methods were express nails, two different types of glues and cement.

The results from the tests show that geotextiles have high ability to distribute inflowing water over a large area and by that increase the pellet fillings capability to store water. The mounting of geotextiles on a rock surface is preferably done by using express nails.

# Sammanfattning


Det arbete som beskrivs i denna rapport har utförts på uppdrag av SKB (Svensk Kärnbränslehantering AB) och Posiva (finskt företag som är ansvarigt för slutförvaringen av använt kärnbränsle).

Denna rapport beskriver det arbete som gjorts med syfte att undersöka om det går att använda geotextil för att fördela inflödande vatten i samband med installation av återfyllning i deponeringstunnlarna. Tanken är att det inflödande vattnet ska fördelas mer jämt över pelletsen som därmed kan lagra större vattenvolymer och minska effekterna av lokal erosion av bentonit. Den teknik som har testats har till uppgift att vara i funktion så länge som deponeringstunneln är öppen. Den negativa påverkan som geotextilen eventuellt kan ha på långtidssäkerheten ska vara minimal.

Projektet kan delas in i tre delar:

1. Laboratorieförsök.
2. Halvskaleförsök i en ståltunnel.
3. Monteringstester.

Syftet med laboratorietesterna var att testa att de olika geotextilerna fungerade som tänkt när det gällde att fördela inflödande vatten över en större yta. I laboratorietesterna användes plexiglasrör för att simulera bergytan.

Baserat på resultaten från laboratorieförsöken valdes en polypropylene-geotextil ut för att användas i halvskaletesterna. Tre tester gjordes i denna skala:

- Referenstest med ett inflöde på 0.25 l/min, utan geotextil.
- Test med geotextil och ett inflöde på 0.25 l/min.
- Test med geotextil och ett inflöde på 0.5 l/min.

Monteringstester gjordes vid tre olika tillfällen. Metoderna som testades var spikplugg, olika typer av lim samt cement.

Resultaten från testerna visar att geotextiler av de testade typerna har god förmåga att fördela inflödande vatten över en större yta och därmed öka pelletsfyllningens förmåga att lagra inflödande vatten. Montering av geotextil på en bergvägg görs lättast med hjälp av s.k. spikpluggar.

# Contents

# 1 Background and scope

SKB and Posiva develop and tests different designs of the KBS-3 concept for a final repository for spent nuclear fuel. The work described in this report is a part of the cooperation between the two organizations.

The main alternative for the backfill design considered by both SKB and Posiva includes emplacement of pre-compacted blocks into most of the tunnel volume together with bentonite pellets that are filling up the spaces between blocks and tunnel walls. Pellets will also be placed on the tunnel floor (in the SKB concept while Posiva is planning for an in situ compacted bed) in order to even out the rough rock surface and by that provide a suitable surface on which the backfill blocks can be piled. One of the main identified problems is how the water inflow to the tunnels should be handled during emplacement. Depending on flow rates and how the inflow points are distributed in the tunnel the inflowing water may affect the stability of the backfill installation and also cause erosion of the backfill.

Earlier tests performed at different scales (e.g. Dixon et al. 2008a, b, Sandén et al. 2008) have shown that the bentonite pellet filling has the potential to store a large quantity of water. Tests have also been made in order to optimize this property of the pellet filling (Andersson and Sandén 2012). The tests have also shown that even if the storing capacity of the pellet filling is large, there will still be large pellet volumes that will remain dry during the time immediately following backfill placement and which not are providing water storage during this period. Several alternatives have been proposed to improve early water storage in the pellet fill and the idea showing greatest promise is to distribute the inflowing water over a larger area by use of geotextiles (Sandén and Börgesson 2014).

In order to test and show the geotextiles ability to improve the water storing capacity of the pellets the following tests were planned:

1. Laboratory tests. The aim with laboratory tests was to test the function of some different types of geotextiles regarding their possibility to distribute inflowing water to a pellet filling over a larger area.
2. Tests in half scale (steel tunnel tests at Äspö). The aim with the half scale tests was to test the function of geotextiles in large scale.
3. Fastening tests (Fortums low- and intermediate level waste repository at Loviisa). It must be possible to fasten the geotextiles on the rock walls in an easy way. The aim with these tests was to test different methods for fastening.

This report describes the results from these tests.

# 2 Geotextile materials

## 2.1 General

According to the historical record, it is believed that the first applications of geotextiles were woven industrial fabrics used in 1950's. One of the earliest documented cases was a waterfront structure built in Florida in 1958. Then, the first nonwoven geotextile was developed in 1968 by the Rhone Poulence company in France. It was comparatively thick needle-punched polyester, which was used in dam construction in France during 1970. (Huang and Gao 2004)

According to the definition of ASTM 4439, the geotextile is defined as follows:

*"A permeable geosynthetic comprised solely of textiles. Geotextiles are used with foundation, soil, rock, earth, or any other geotechnical engineering-related material as an integral part of human-made project, structure, or system."*

Geotextiles make up one of the two largest groups of geosynthetics, the other one being geomembrane. These synthetic fibres are made into a flexible fabric by standard weaving machinery or are matted together in a random, or nonwoven, manner. The fabric is porous to water flow across its manufactured plane and within its plane. There are at least 80 specific applications for geotextiles, but the fabric always performs at least one of five discrete functions: separation, reinforcement, filtration, drainage, or barrier to moisture. (Huang and Gao 2004)

Geotextiles used in drainage purpose are usually made out of plastic fibres, and therefore the availability of glass fibre based geotextiles for the application is limited. Glass fibres are added into geotextiles when higher mechanical stability is desired. Usually pure glass fibre is used in geomats, which are used to stabilize road foundation and increase soil freezing durability.

## 2.2 Geotextile materials used in the tests

Due to the limited availability and long delivery times of the glass fibre geotextiles, the steel tunnel tests at Äspö were done with typical, widely available, plastic geotextile developed for drainage purpose.

### 2.2.1 The plastic geotextile

The plastic geotextile was selected on a basis that it was familiar geotextile from previous projects and it's easily available. The geotextile was Fibertex F-1000M/Fibertex F-1000M White, the only difference being that the later one is white in colour and is delivered in smaller packages. Fibertex F-1000M White was used for the fastening tests. The material of the geotextile is pure polypropylene. The datasheet for the Fibertex F-1000M is provided in Appendix 1.

### 2.2.2 The "thin" glass fibre geotextile

The "thin" is manufactured by Osnar Chemical Private Ltd. in India and represented in Europe by TeleTextiles AS. One version of the textile was received for testing, but due to poor mechanical stability of the fabric it wasn't tested outside the laboratory. The fabric is non-woven 1.058 mm thick weighting 105.9 g/m$^2$. Also small sample of duple layer was received, but not used in tests. The material of the geotextile is pure E-glass (borosilicate glass). The amount of available data regarding the thin glass fibre geotextile is very limited, and no data sheet was provided by the representative.

### 2.2.3 The insulation type glass fibre fabric

The third fabric tested in the project is not technically geotextile, but it has suitable properties to be tested. The material is manufactured by Valmieras Stikla Skiedra which is fully owned by P-D Interglass Technologies Ltd. for heat insulation purposes. The fabric, Needle mat AF800-6, is non-woven and manufactured in Latvia. The fabric is referred to as type II glass fibre geotextile in this document. The fabric thickness is 6±1 mm and the weight is 800 g/m$^2$. The datasheet for Needle mat AF800-6 the can be found in Appendix 2.

# 3 Laboratory tests

## 3.1 General

The aim with the laboratory tests was to test different possible geotextile materials and to ensure their function as water distributor before testing in larger scale. Originally two types of tests were planned, tube tests and tests in an artificial slot. However, after having performed the tube tests it was decided that the results from these were enough in order to assess the function and also to take a decision regarding the quality of the geotextile that should be used in the larger steel tunnel tests.

The work was carried out in accordance with the activity plan AP TD KBP1003-12-032. The activity plan is one of SKB's internal controlling documents.

## 3.2 Method

The test equipment consists of a Plexiglas tube which can be filled with pellets, see photo provided in Figure 3-1. In both ends perforated steel plates are mounted in order to keep the pellets in position but still allow water to leak out. At the mid height it is possible to apply a water flow on the wall. The tests can be performed with the pure pellet filling but it is also possible to place a piece of geotextile over the inflow point. The Plexiglas makes it possible to study the wetting behaviour from the outside of the tube. Tests have been performed both with vertical standing tubes, simulating a wall inflow, but also with horizontal laying tubes simulating the case with ceiling inflows.

The tests were performed by applying a constant flow at the inflow point. The achieved water pressure needed in order to keep the water flow constant was measured during the test time. In addition, the wetting front of the pellet filling was studied from the outside. Photos were taken at predetermined intervals.


*Figure 3-1. Photo showing the test equipment used in order to study the function of geotextiles as water distributer.*

## 3.3 Test matrix

The wetting behaviour of different pellet types has been studied earlier and reported in Andersson and Sandén (2012). One main conclusion from these tests was that one pellets type, 6 mm extruded, and made of either Asha or Ibeco materials was superior regarding water storing capacity.

In order to minimize the number of test parameters, the following was decided:

- **Material**. All tests were performed using extruded pellets made of IBECO RWC BF 2010. The pellets have a diameter of 6 mm and a length of 5–25 mm. The pellets were manufactured at Äspö HRL in a rented pellet manufacturing equipment.
- **Salt content in water**. All tests were performed using water with a salinity of 1% (50/50 Na/Ca).
- **Water flow rate**. Two different flow rates were tested, 0.1 and 0.01 l/min.

Three different types of geotextile were testes, see detailed description in Chapter 2:

1. Standard type of geotextile with a certain content of organics (which should be minimized in a disposal facility). Thickness about 6 mm.
2. Fibreglass fabric (borosilicate glass) type I. This material contains no additives that can be harmful for the disposal from a long term safety perspective. The fabric is, however, very thin and the strength is low.
3. Fibreglass fabric (borosilicate glass) type II. This material contains no additives that can be harmful for the disposal from a long term safety perspective. This fabric is thick and seems to be more suitable for a full scale test.

### 3.3.1 Results

#### *General*

In total nine tests were performed, see compilation in Table 3-1.

#### *Vertical direction, 0.1 l/min*

Only two tests were performed with a flow rate of 0.1 l/min (test no. 1 and 4 in Table 3-1). This flow rate was afterwards assessed to be too high for this rather small test equipment and the rest of the tests were therefore performed with a flow rate of 0.01 l/min. The results from the water pressure measurements are provided in Figure 3-2 and photos taken during test time are shown in Figure 3-3.

The theoretical time for filling up all macro voids in the pellet filling inside the tube with a water inflow of 0.1 l/min is about 40 minutes. There was, however, a leakage downwards in the beginning of both tests which sealed after different times. The reference tests sealed the downwards leakage after 35 minutes and the geotextile test after about 50 minutes. This is logical since the geotextile shortens the distance to the outlet. The water pressure measurements shows a difference in behaviour but a part of that difference depends on the different time before sealing of the downwards flow. The geotextile seems, however, to distribute the inflowing water according to the plans but no conclusions can be made after these two initial tests.

**Table 3-1. Compilation of tests performed in the Plexiglas tubes.**

| Test no. | Material | Water flow rate | Geo-textile | Test direction | Remark |
|---|---|---|---|---|---|
| 1 | IBECO RWC BF 2010 | 0.1 | no | vertical | reference |
| 2 | IBECO RWC BF 2010 | 0.01 | no | vertical | reference |
| 3 | IBECO RWC BF 2010 | 0.01 | no | horizontal | reference |
| 4 | IBECO RWC BF 2010 | 0.1 | Standard | vertical | |
| 5 | IBECO RWC BF 2010 | 0.01 | Standard | vertical | |
| 6 | IBECO RWC BF 2010 | 0.01 | Fibre glass I | vertical | |
| 7 | IBECO RWC BF 2010 | 0.01 | Standard | horizontal | |
| 8 | IBECO RWC BF 2010 | 0.01 | Fibre glass I | horizontal | |
| 9 | IBECO RWC BF 2010 | 0.01 | Fibre glass II | horizontal | |

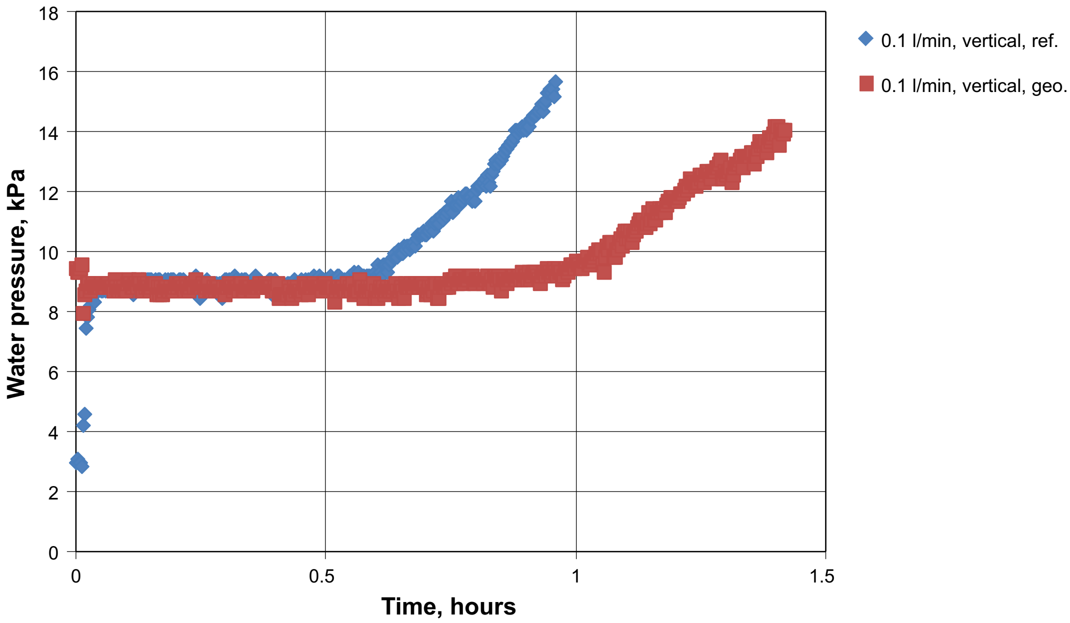



***Figure 3-2.*** *Water pressure plotted versus time for the two tests performed with a flow rate of 0.1 l/min.*

***Figure 3-3.*** *Photos taken after 50 minutes test time. The left photo shows the reference test and the right sows the test equipped with geotextile.*

### *Vertical direction, 0.01 l/min*

Three tests were performed with a flow rate of 0.01 l/min and in vertical direction (test no. 2, 5 and 6 in Table 3-1). The results from the water pressure measurements are provided in Figure 3-4 and photos taken during test time are shown in Figure 3-5.

The theoretical time for filling all macro voids in the pellet filling with a water inflow of 0.01 l/min is 6 h 40 min. All three tests started with water flowing downwards but the pellets sealed before any water leaked out. The water pressure measurements shows clearly that in the reference test there is a water pressure build up, but in the two tests with geotextile the water can flow without any resistance which means that the water can be distributed over a larger area without any risk for forming a piping channel or a water filled pocket. The results from these tests indicate that both tested geotextiles will work as distributor of water. The thin fibre glass fabric was, however, very fragile especially after wetting.

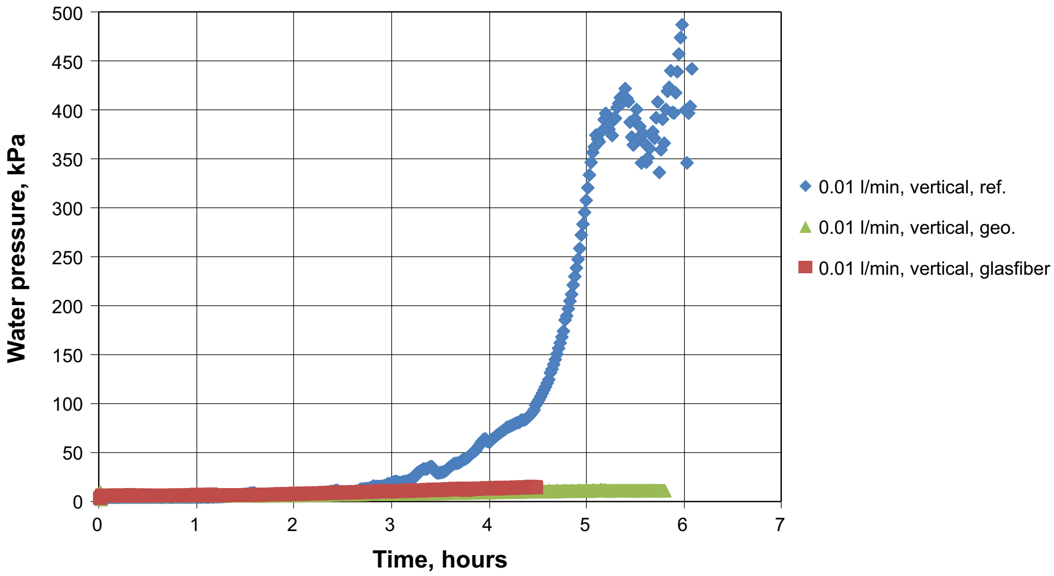



***Figure 3-4.*** *Water pressure plotted versus time for the three vertical tests performed with a flow rate of 0.01 l/min.*

***Figure 3-5.*** *Photos taken after 4 to 5 hours test time. The left photo shows the reference test, the middle photo shows the test performed with standard geotextile and the right photo shows the test performed with fibre glass fabric I.*

### *Horizontal direction, 0.01 l/min*

In total four tests were performed with a flow rate of 0.01 l/min and in horizontal direction (test no. 3, 7, 8 and 9 in Table 3-1). The results from the water pressure measurements are provided in Figure 3-6 and photos taken during test time are shown in Figure 3-7. One test was performed without any geotextile (reference test) and the other three were performed with the three different types of fabrics.

The theoretical time for filling all macro voids in the pellet filling with a water inflow of 0.01 l/min is 6 h 40 min. The wetting was for all four tests proceeding uniformly around the inflow point. The behaviour of the three tests performed with different geotextiles was very similar, showing a delayed water pressure increase compared to the reference test, and an even distribution of the inflowing water.

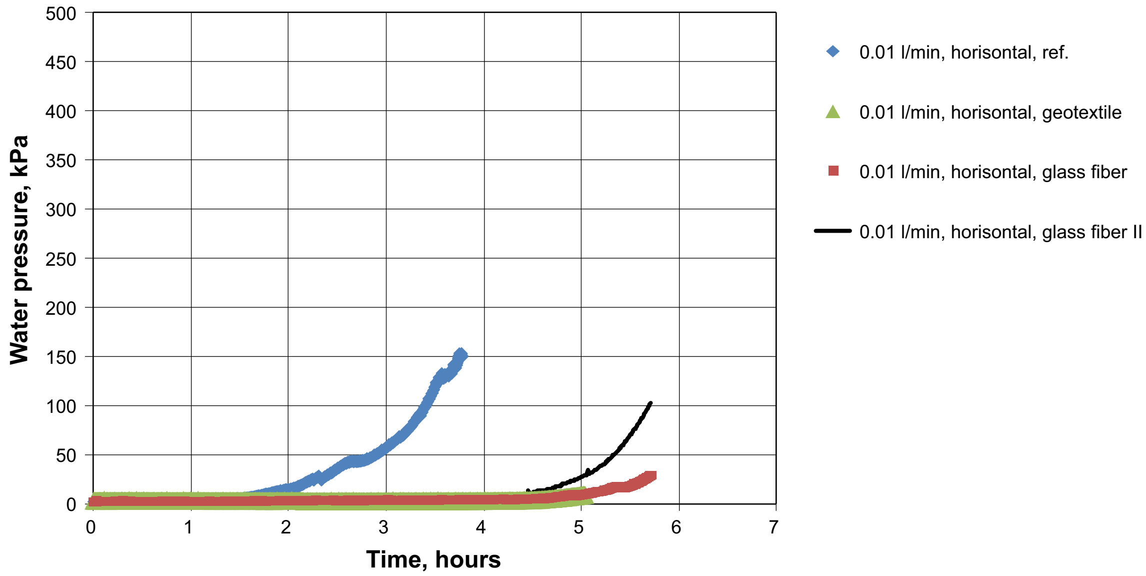



***Figure 3-6.*** *Water pressure plotted versus time for the four tests performed with a flow rate of 0.01 l/min and in horizontal direction.*

***Figure 3-7.*** *Photos showing the tests performed in horizontal direction with different fabrics.* ***Upper left****: Reference test* ***Upper right****: Test with geotextile of standard type* ***Lower left****: Test with fibre glass fabric* ***Lower right****: Test with thicker fibre glass fabric.*

### 3.3.2 Summary of results

The performed tests show very clearly that all tested qualities of geotextiles distributed inflowing water well. There was no obvious difference between the tested geotextiles regarding this property. It was, however, noticed that the thin fibre glass fabric was very fragile, especially after wetting and it is therefore not recommended that this quality is used in the planned large scale tests in the steel tunnel equipment. The fibre glass fabric type II was thicker, with higher strength and seemed to be more suitable for use on rock walls.

# 4 Steel tunnel tests

## 4.1 General

The objective of the ½-scale tests was to verify and demonstrate the functionality of the inflow handling system. The functionality of the geotextiles was tested in laboratory scale, see Chapter 3, before the ½-scale tests started. Since the ½-scale steel tunnel tests are time consuming (4–5 weeks/test) and therefore more expensive, only the best suitable components from the laboratory scale have been tested. Due to the availability of the glass fibre based geotextiles and the desire to finish the tests before the end of the year, the plastic based geotextile was selected for the ½-scale tests.

The work was carried out in accordance with the activity plan AP TD KBP1003-12-033. The activity plan is one of SKB's internal controlling documents.

## 4.2 Test description

### 4.2.1 Materials

**Backfill blocks** were manufactured within the SKB project System Design of Backfill. The block size is about 300×150×75 mm. The blocks will presumably not play a big role in this relatively short test, therefore the specific block material installed is not a key parameter for the test. Due to their availability, blocks manufactured of Asha NW BFL-L 2010 were used in the steel tunnel tests.

**Pellet**. Pellet properties will be essential for test results. A pellet optimization project has been ongoing during 2011–12 as a subproject within System Design of Backfill, and as a result 6 mm extruded pellets manufactured of either Asha NW BFL-L and IBECO RWC BF pellets have been evaluated to be the best suited types. The Asha pellets were more easily available, so those were used in the steel tunnel tests. The pellets were used as-delivered i.e. the fines were not removed.

**Geotextile.** All of the tested geotextile materials performed well in the laboratory scale tests. Due to availability the polypropylene geotextile was selected for the ½-sclae tests. The geotextile was positioned according to the drawing provided in Figure 4-1. The width was 0.5 m in all tests.

No floor material was used in the ½-scale tests.

### 4.2.2 Attachment of the geotextile onto the steel tunnel wall

The attachment of the geotextile onto the steel tunnel wall was done independently from the fastening tests.

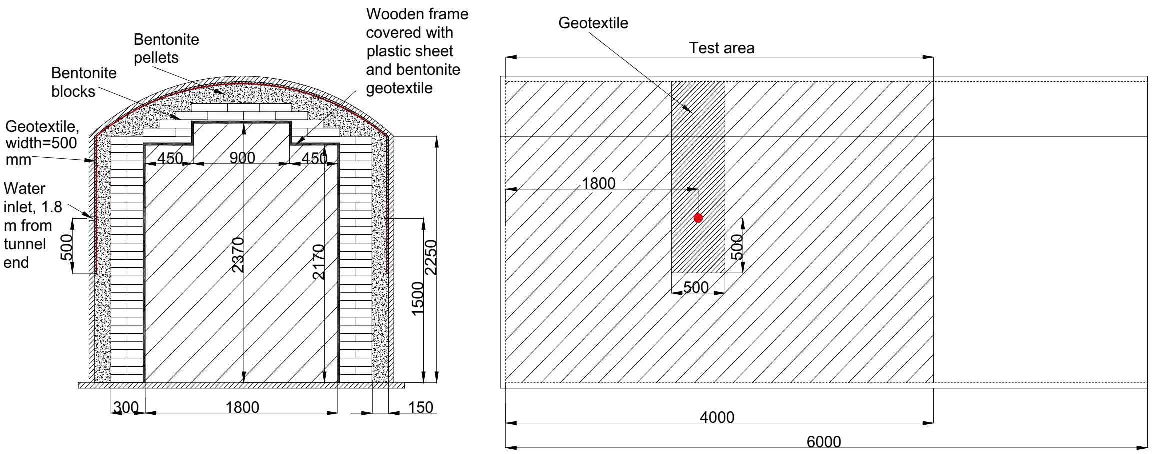



*Figure 4-1. Schematic of the ½-scale test tunnel.*

The geotextile was glued over the water inlet point, so that there was adequate (not necessarily equal) amount of fabric on both sides of the inlet point. The lower edge of the geotextile was approximately 0.5 meter under the water inlet nozzle, and extends all the way to the same height on the other side of the tunnel.

## 4.3 Test setup

### 4.3.1 Steel test tunnel

The test tunnel in Äspö bentonite laboratory is made out of steel. The nominal cross section of the tunnel is 7.1 $m^2$, and usable length for the tests is 4 m. The tunnel walls are not able to withstand the full swelling pressure of the fully backfilled tunnel. Therefore, instead of backfill in the centre of the tunnel, there is a wooden framework designed to deform and fail mechanically, if the swelling pressures becomes too high. The wooden frame was covered with a bentonite geotextile mat to control the movement of any water that managed to penetrate both the pellet and block materials. The blocks were mounted two layers deep (300 mm thickness) against the inner frame. The gap between the blocks and the wall (about 150 mm) was filled with pellets.

### 4.3.2 Circulating the water feed

The water used in the tests had 1% salinity (TDS 10 g/l), thus half of the salt is in $Ca^{2+}$ and the other half is in $Na^{+}$ salt. The purpose was to mimic the salt content in the repository conditions at the time of the operations.

The salt was mixed into water in big tanks. Special metering pumps were used in order to pump water at a determined flow rate into the decided inflow point on the steel tunnel, see Figure 4-1. In the tests, only one inflow point was used (the red dot in Figure). The geotextile was placed over the inflow point and then the whole way up to the roof and down on the other side of the tunnel. This design made it possible to study how well the inflowing water could be distributed also to the other side by the geotextile.

The water coming out of the test tunnel, flows into a container which mass is constantly monitored. By weighing the out-flowing water and measuring the water level in the container, the amount of eroding material was determined. This method gave a rough estimation of the total amount of eroded material.

### 4.3.3 Installation of the backfill into the steel test tunnel

The backfill blocks (300×150×75 mm) were installed by hand against the inner wood frame. The blocks were assembled to a cross pattern 300 mm deep, that can be seen in Figure 4-2.

The gap between the backfill blocks and the steel wall was filled with pellets. The pellet filling was done by blowing the pellets into the slot with shotcrete equipment. The pellet blowing is really dusty work, and therefore the pellets were sieved in the last test, to remove the smallest particles, for the last test. In order to construct a vertical wall out of the pellets some water was added at the final stages of the pellet blowing. In the first and the second test the amount of water used for the blowing was around 90 litres. The third test needed more water since the pellets were lacking out of the smaller particles, resulting in a water usage of 106 litres. The difference of the amount of water added is assumed to not affect the performance of the test system. The test construction can be seen in Figure 4-3.

### 4.3.4 Measuring and observation recording

In order to evaluate the water storing capacity of the pellet filling, the difference between inflow and outflow water volume was measured. Also the time to the first outflow was recorded. These are the simplest and most reliable measurements to determine the functionality of the geotextile.

During the dismantling of the tests, samples were taken according to the chart in Figure 4-6, at 0.6 m intervals. Photos were also taken in 0.6 m intervals in order to create visual records of the test; example of the sampling can be seen in Figure 4-4. The water content of the samples was measured by use of a standard laboratory oven, drying the samples at 105°C for 24 h.

***Figure 4-2.*** *The backfill blocks, before the pellet installation.*

***Figure 4-3.*** *The backfill front during a test.*


*Figure 4-4.* *Photo of the sampling during, the test 2.*

## 4.4 Test matrix

In total three tests were performed in this scale, see Table 4-1. The construction of the test setup takes around one week and the dismantling and sampling takes also around one week. The actual test duration for each of the tests was two to three days.

The registration of data was started when the water inflow was started and was stopped when the water inflow was stopped. After observation of the first outflow at the front the test was continued until the outflow and inflow were roughly the same.

Small changes were made to the third test based on practical reasons (the dusting of the pellet spraying) and on the results from the previous test (moving the geotextile 0.2 m backward but with the water inlet point in the same position). Due to the excessive dusting in the first two tests, the pellets were sieved and the small particles were removed for the last test.

The first test was a reference test performed without geotextile and with a water inflow of 0.25 l/min. In the second test a geotextile was added but the water inflow was the same as in the reference. In the third test the water inflow rate was increased to 0.5 l/min.

The tests were performed in the bentonite laboratory at Äspö HRL where the temperature was kept relatively stable so no temperature measurements were made during the tests.

**Table 4-1. The test matrix for the ½-scale steel tunnel tests.**

| | Geotextile | Number of inflow nozels | Inflow rate [l/min] |
|---|---|---|---|
| 1. Reference test | no | 1 | 0,25 |
| 2. | yes | 1 | 0,25 |
| 3. | yes | 1 | 0.5 |

## 4.5 Results

### 4.5.1 Reference test, 0.25 l/min

- The test started at 11:00 the 5th of September 2012.
- The test was stopped at 13:00 the 7th of September 2012.
- First outflow was registered after 30.4 hours. The outflow rate was soon close to the inflow rate.
- The pellet filling managed to store approx. 460 l of water. The theoretical available space was around 2,500 l.
- The test was terminated approx. 50 hours after start.

During test time, the water pressure needed to keep the inflow rate at a constant level was increasing with time, see Figure 4-5. The pressure peaks shows that the different flow paths in the pellet filling seals a large number of time, piping occurs and the water starts to flow again, either in the same channel or in another direction. After 30.4 hours, when water started to flow out at the front, the water pressure decreased to a lower level and no new pressure peaks occurred.

After termination of the test, the pellet filling was sampled in order to get information regarding the wetting pattern. The sampling was made according to the positions shown in Figure 4-6. The figure also shows very roughly the wetting of the pellets in the section closest to the inflow point.

Figure 4-7 shows the wetting pattern,(calculated by use of excel data sheet), from the water content determinations for the reference test. The wetting has reached the top of the roof and almost over to the next corner. There are however still dry areas both on the wall where the inflow point is situated and also at parts of the roof.

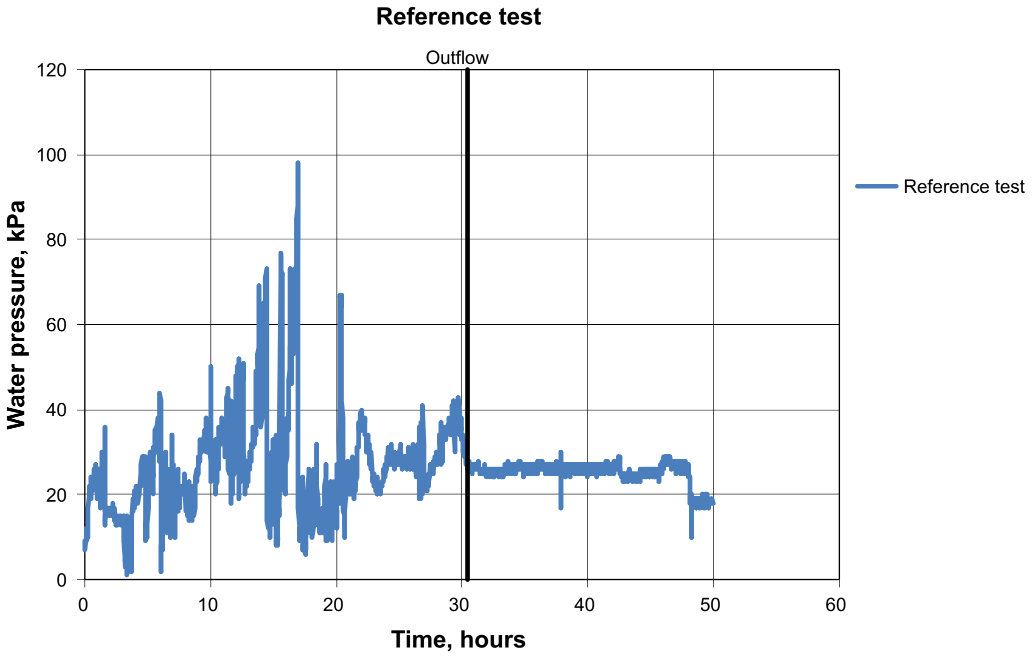



*Figure 4-5. Water pressure needed in order to keep the water inflow rate at a constant level plotted versus time for Test 1 (reference test).*

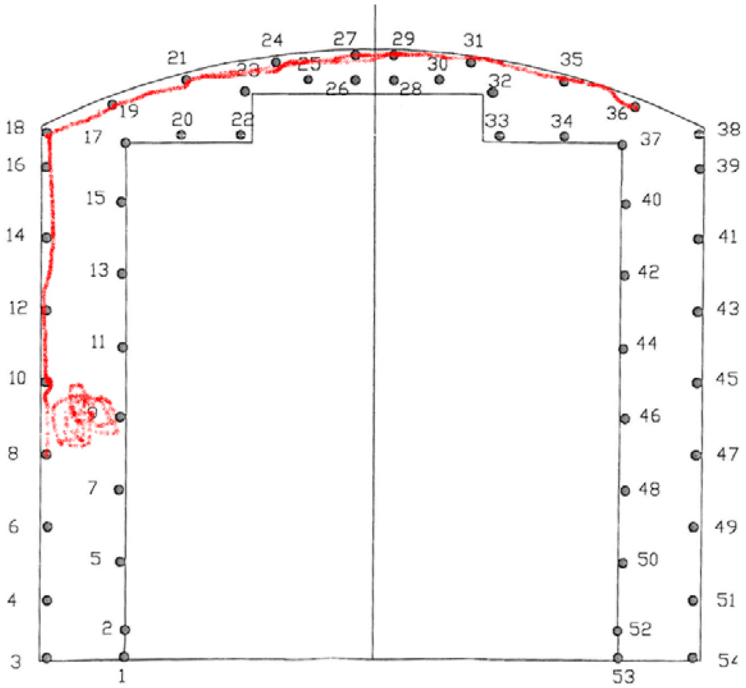



***Figure 4-6.** Overview of the sampling positions. The sampling pattern was then repeated for every 0.6 m of the test length.*

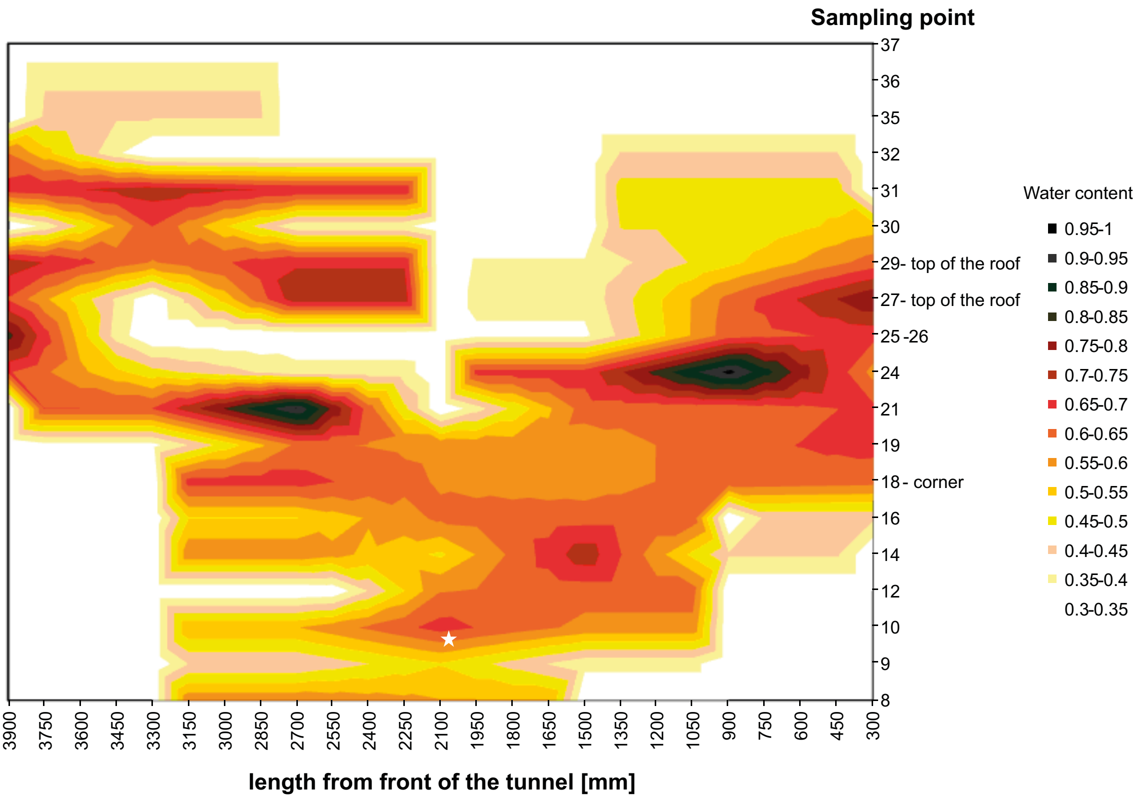



***Figure 4-7.** Wetting pattern of the pellet filling in the reference test. The picture shows a top view of the roof with the left tunnel side downwards. The star marks the place of the inflow point.*

### 4.5.2 Test with geotextile, 0.25 l/min

- The test started at 11:30 the 16th of October 2012.
- The test stopped at 14:45 the 18th of October 2012.
- The first outflow occurred after 26 hours (in the lower corner opposite to the inflow side). The outflow was small and lasted for about 45 minutes before sealing. No evident reaction of the outflow could be seen on the pressure curve.
- New outflow occurred after 39.5 hours close to the middle of the roof. The outflow increased over time and it took around nine hours to reach the inflow rate.
- The pellet filling managed to store approx. 588 l of water. The theoretical available space was around 2,500 l.
- The test was terminated 51 hours after start.

During test time, the water pressure needed to keep the inflow rate at a constant level was increasing with time, see Figure 4-8. There were no similar pressure peaks present as in the reference test without geotextile. After the first small outflow (which cannot be seen in the pressure curve) the water pressure continued to increase. About five hours before the final outflow starts, the water pressure decreased somewhat, but remained at a rather high level. This pressure level, 80–90 kPa, remained almost constant until test termination, indicating that parts of the inflowing water still was stored in the pellet filling.

The sampling of the pellets was made according to the positions shown in Figure 4-9. The figure also shows very roughly the wetting of the pellets in the section closest to the inflow point.

Figure 4-10 shows the calculated wetting pattern for Test 2. The pellet filling was wetted on both sides i.e. the filter has worked as a distributor of the inflowing water. Parts of the total area are, however, still dry especially on the wall where the inflow point is positioned.

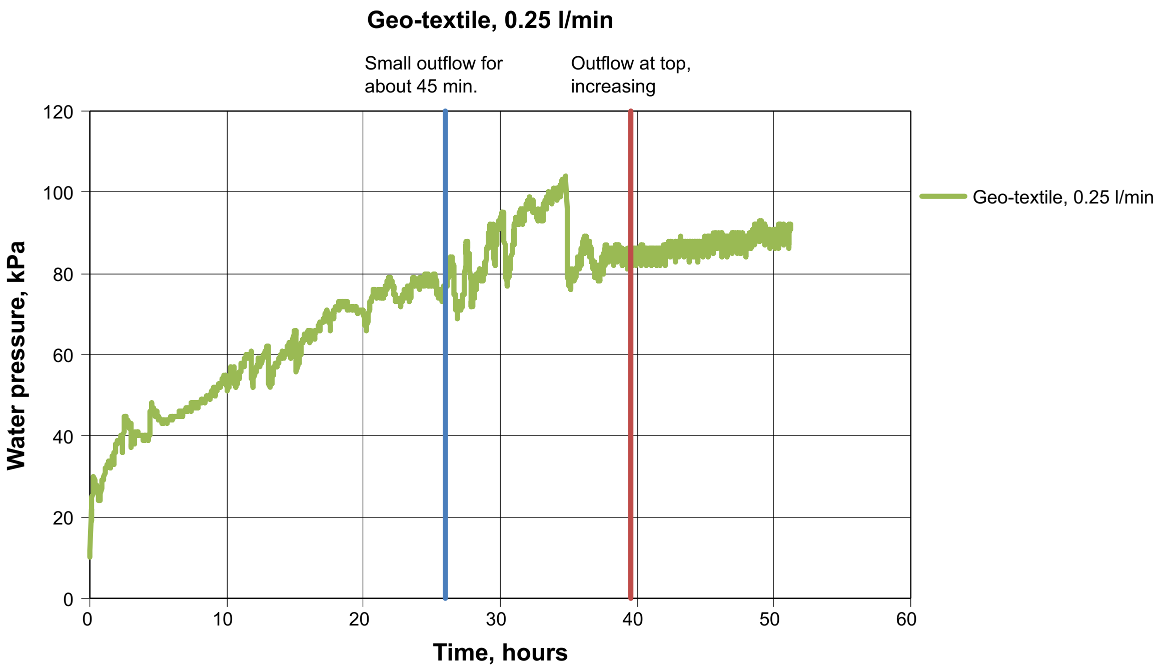



***Figure 4-8.*** *Water pressure needed in order to keep the water inflow rate at a constant level plotted versus time for Test 2.*

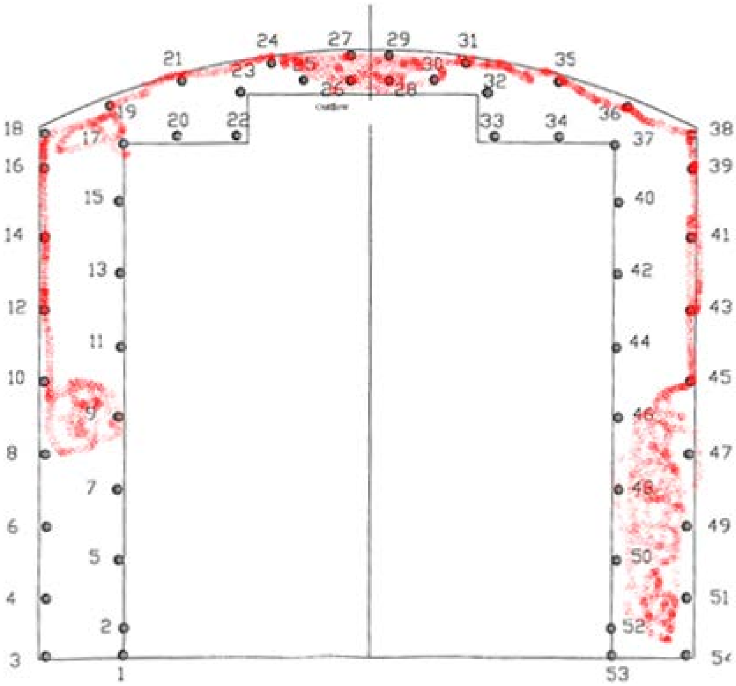


*Figure 4-9. Overview of the sampling positions. The sampling pattern was then repeated for every 0.6 m of the test length.*

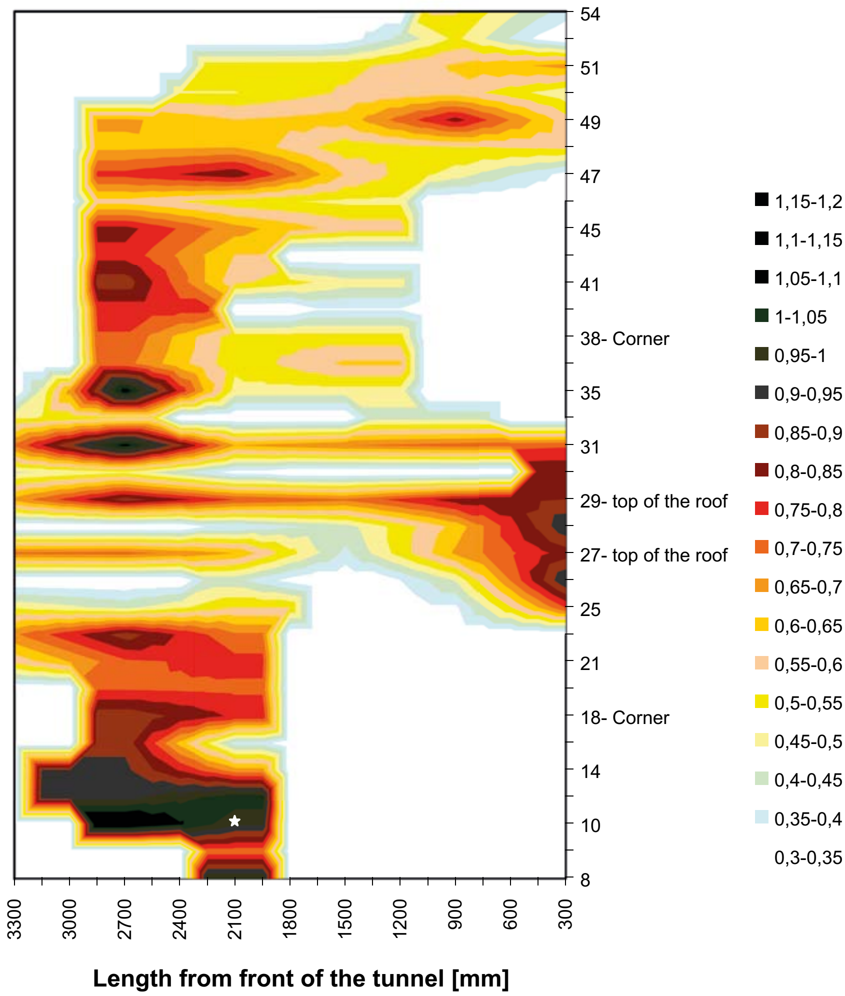



*Figure 4-10. Wetting pattern of the pellet filling in Test 2 (with geotextile). The picture shows a top view of the roof with the left tunnel side downwards. The star marks the place of the inflow point.*

### 4.5.3 Test with geotextile, 0.5 l/min

- The test started at 12:05 the 4th of December 2012.
- The test was stopped at 12:20 the 7th of December 2012.
- The first outflow occurred after 53.3 hours. The outflow was "explosive" and fist size clumps of clay flew a few meters from the outflow point close to the middle of the roof. This behaviour depends probably on that air had been trapped and compressed within parts of the filling.
- The pellets used in the third test were sieved, and by that lacking the smallest particles. The change in the pellet filling may have affected the performance of the system. Sieving of the pellets removed approximately 5% of the material based on average weight of the pellet bags before and after the sieving.
- The test was terminated 72 hours after start.
- The pellet filling managed to store almost 1,600 l of water. The theoretical available space was around 2,500 l.

During test, the water pressure needed to keep the inflow rate at a constant level was increasing over time, see Figure 4-11. The pressure had much more random variation during the test, than in the test 2. The pressure was also significantly higher (over 150 kPa) than in test 2. When the outflow started the pressure dropped to 70–100 kPa and remained at that level until the end of the test. The high pressure caused a relatively large outflow hole that can be seen in Figure 4-12.

The sampling of the pellets was made according to the positions shown in Figure 4-6. Samples were taken from the tunnel at 0.6 m intervals. Figure 4-13 shows the wetting pattern for the test 3. Despite the extensive wetting of the pellet filling, there were still dry spots in random places. The dry spots may be caused by the relatively short test time, and also the test tunnel geometry.

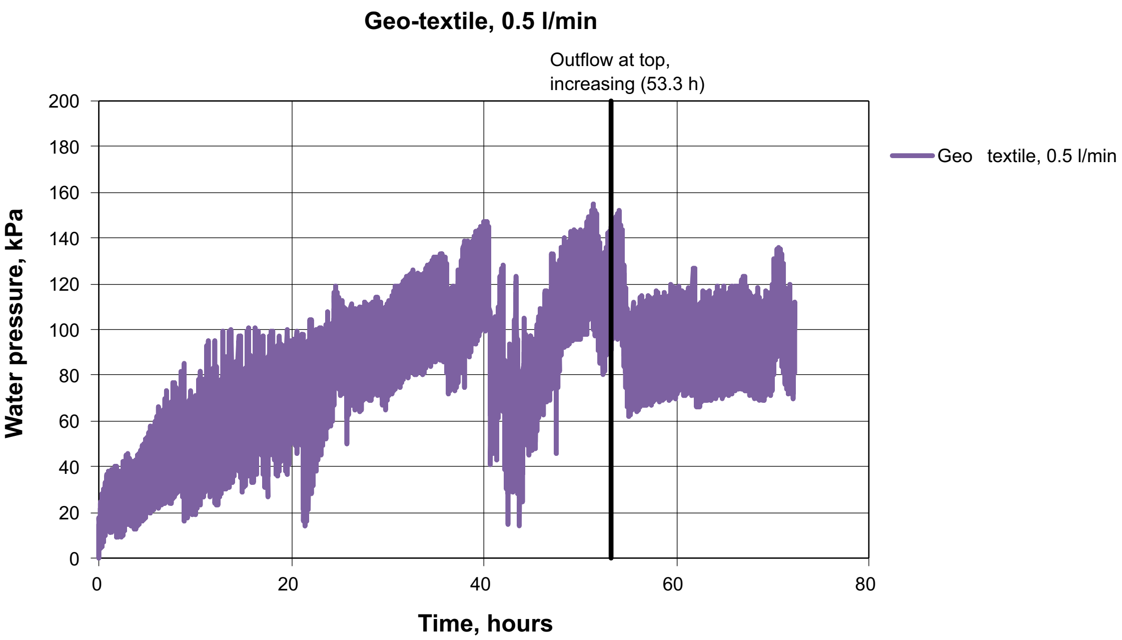



*Figure 4-11. Water pressure needed in order to keep the water inflow rate at a constant level plotted versus time for test 3.*

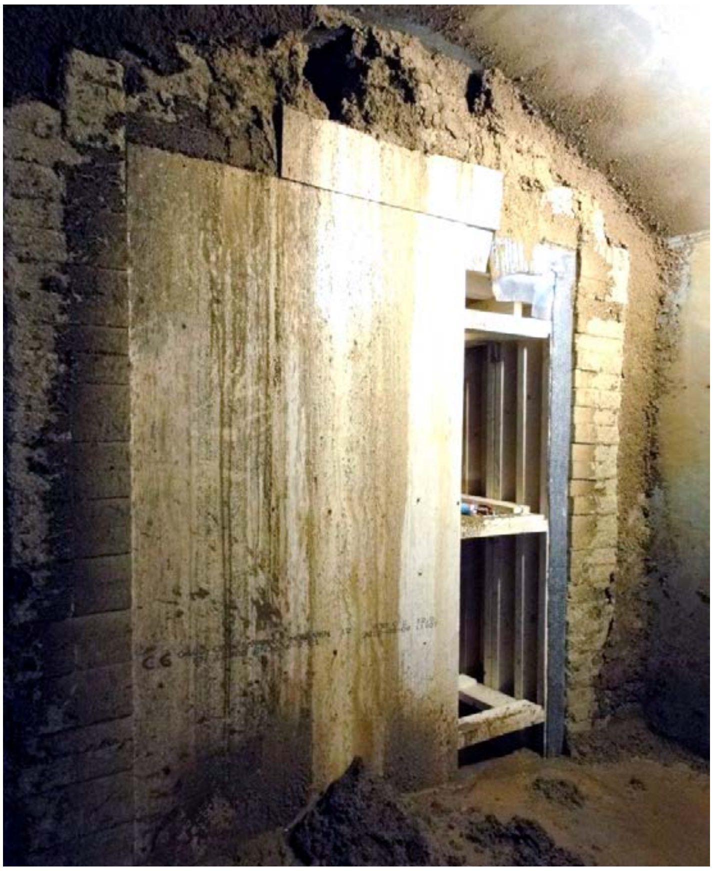


***Figure 4-12.*** *The outflow spot after closing of the inflow.*

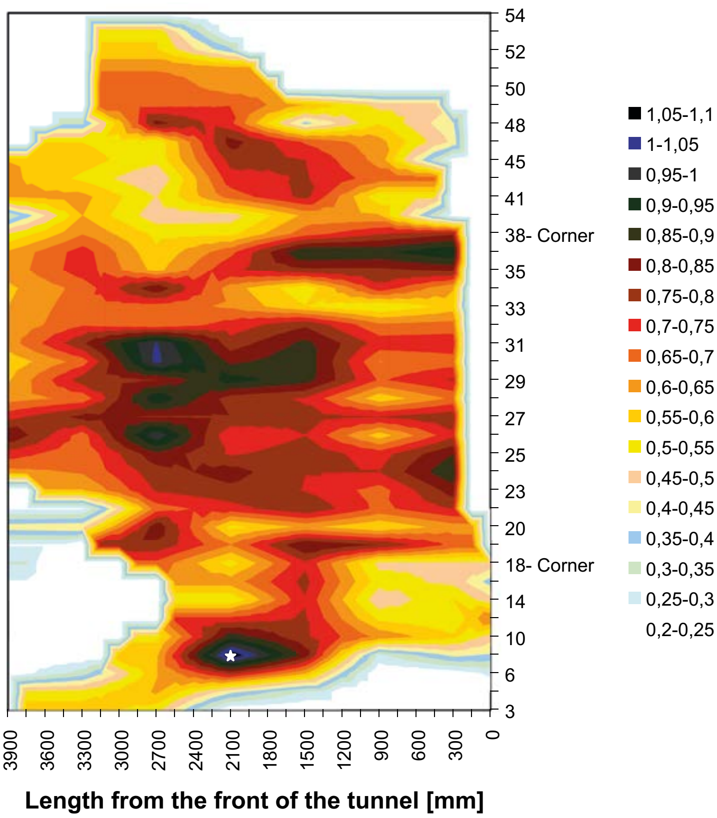



***Figure 4-13.*** *Wetting pattern of the pellet filling in the test 3. The picture shows a top view of the roof with the left tunnel side downwards. The star marks the place of the inflow point.*

## 4.6 Discussion

A compilation of the results from the three tests is provided in Table 4-2. The total space available in the macro voids in the pellet filling was calculated to approx. 2,500 litres. In the last column of the table the amount of voids filled with water i.e. stored in the pellet filling, before outflow is given in percent of the available volume.

The accumulated water volume stored within the clay mass at termination for the two performed tests with an inflow rate of 0.25 l/min is shown in Figure 4-14. In test 1, about 460 litres of water was stored in the pellets before water started to flow out at the front. Corresponding figure for test 2 is 588 litres (it was estimated that the flow rate at the outflow that occurred after 26 hours and lasted for 45 minutes was 0.1 l/min i.e. totally 4.5 litres leaked out during this time). Thus about 28% more water was stored when geotextile was used in the test setup.

The third test stored a greater amount of water (almost 1,600 l) into the pellet filling, than the two first tests. The influence of sieved pellets is not known, but may have influenced the result. However, it's also possible that geotextile works better with higher inflow rates when it spreads the inflow to larger area.

Some comments to the presented test results:

- The pellet type used in the three tests stores water very well. In the reference test it took more than 30 hours before any outflow occurred. It should be considered that this long time to outflow was reached with a rather high inflow (0.25 l/min) and in a test which, concerning the available pellet volume is much smaller than in the full scale.
- The geotextile distributes water as expected. Pellets were wetted on both sides of the tunnel and at the roof, compare Figure 4-10 and 4-13. The distance from the geotextile to the front is, however, limited and the risk of outflow early in the wetting process is therefore high.
- The water storing in the test performed with geotextile and with an inflow of 0.25 l/min, increased about 28% compared to the reference test. This is somewhat lower than desired but depends probably on the scale i.e. the distance to the front from the geotextile is limited.
- The water pressure measurements show that the water pressure developed is higher in the tests that include geotextile. This depends probably on the fact that the textile is filled rather quickly and that the pellets closest to the filter get some extra time to swell and seal.
- During the excavation of Test 2 it was found that the geotextile had loosened from the wall on the same side as where the first outflow occurred, see Figure 4-15. This position is quite close to the floor and also to the front and this could maybe explain this first early outflow.
- The sieving of the pellets may have affected the performance of the pellet filling, and therefore jeopardise the comparability with the reference test. The geotextile was also moved 0.2 m backwards in order to delay the first outflow.
- The geotextile had a width of 0.5 meter in all three tests and was positioned with the objective to lead the inflowing water to the other side of the tunnel. The width and positioning can probably be optimized in the full scale e.g. it will probably be possible to also lead water backwards in the tunnel.
- A wetted wall of pellet was ending all three tests. This may also have increased the pellet fillings possibility to store water. When the flowing water reaches the wetted wall it will probably turn and flow against drier parts of the filling instead of through the tight wall. The technique with building a tight wall of wetted pellets can be used also in full scale and should be further investigated.
- The geotextile seems to work better with higher inflow rates. The number of tests performed is limited and includes a number of uncertainties which means that more testing is required in order to confirm the water storing properties. Especially the effect of removing of the fine material should be investigated further.
- It is difficult to explain the large difference between test 2 and test 3. The figures indicate some random behaviour.

**Table 4-2. Results from the ½-scale steel tunnel tests.**

| Test, no. | Geotextile | Inflow rate [l/min] | Time to first outflow, h | Water stored before outflow, liters | Water stored before outflow, % |
|---|---|---|---|---|---|
| 1. Reference test | no | 0.25 | 30.4 | 460 | 18.4 |
| 2. | yes | 0.25 | 39.5 | 588 | 23.5 |
| 3. | yes | 0.5 | 53.3 | 1,600 | 64.0 |

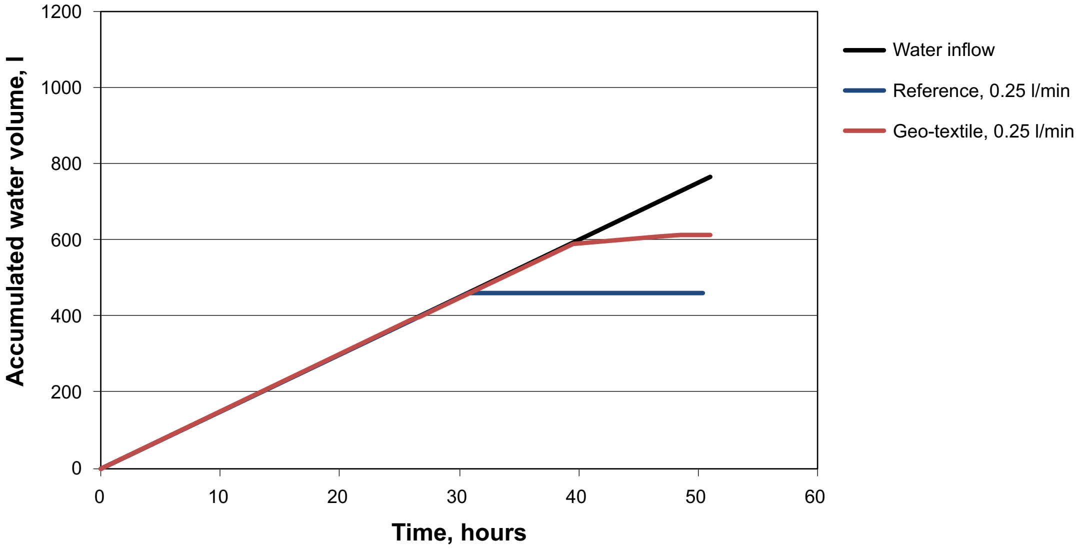



*Figure 4-14. The accumulated water volume plotted versus time for Test 1 and Test 2.*


*Figure 4-15. Photo of the loosened geotextile.*

# 5 Fastening tests

## 5.1 General

The fastening of the geotextile onto wet rock surface was tested in Loviisa Low- and intermediate level waste repository, which is excavated into crystalline rock to 110 meters depth. The location was chosen for its accessibility for Fortum's employees, as well as its suitable clean and wet rock surfaces.

The methods tested in the project are designed to be suitable also regarding the fact that some materials have to be left in the deposition tunnels. At this point of testing, only the functionality of the fastening methods has been tested.

## 5.2 Test matrix

The cleaning and preparing of the rock surface was kept at its minimum. The rock surfaces were naturally wet, and no artificial wetting was used.

The primary object was to fasten a one meter wide and 1–3 meters long sheet of geotextile onto the rock wall.

## 5.3 Results

### 5.3.1 Express nails

In the first fastening test the geotextile was attached with nails. The test section was one meter wide and about 3 meters in height. Fastening was done onto wet un-cleaned rock surface. The express nails were 40 mm long and had a diameter of 6 mm. Two different types of fabrics were tested with 10 months between, however the nails and the washers were similar in both tests.

#### *Plastic geotextile*

The distance between the nails was about 0.1–0.5 meters, depending on the actual shape of the rock. Attachment of the geotextile was started from the top. The first three holes were drilled directly into the rock and after that the holes were drilled through the geotextile. The drilling was done with a battery operated rock-drill hammer. The attachment proceeded downwards by drilling a few holes at the time. Washers were used to get better attachment because the nail heads were very small.

**Table 5-1. Test matrix for the fastening tests.**

| Fastening method | Plastic geotextile | Insulation type glass fibre fabric |
|---|---|---|
| Express nails | July 2012 | May 2013 |
| Glue type 1 | November 2012 | no |
| Glue type 2 | November 2012 | no |
| Cement paste | no | May 2013 |

**Table 5-2. Basic test data.**

| Geotextile | | Nails | | Washers | |
|---|---|---|---|---|---|
| Wide | 1 m | Diameter | 6 mm | Inner diameter | 8 mm |
| Height | 3 m | Length | 40 mm | Outer diameter | 16 mm |
| | | Amount | 40 pieces | | |

Nailing is a simple and fast way to fasten the geotextile. The fastening took about an hour, including the drilling and fastening itself. The geotextile was stretching so it took the shape of rock surface nicely. The attachment of the geotextile to rock wall was durable and it didn't break even when it was pulled off, as can be seen in Figure 5-1.

In the top part of the geotextile covered area, the rock surface was rougher than at the lower part. That's why more nails were used at the top part of the geotextile compared to the lower part. In this way the geotextile followed the rock surface better. In total about 40 nails were used. The attached geotextile is shown in Figure 5-2.

Ten months after the first fastening test, significant corrosion was detectable in the nails and washers. If corrosion continues linearly the nails could be destroyed in less than three years. Depending on the operational time-schedule in the deposition tunnel, this may cause problems.

#### *Nailing of glass fibre geotextile (type II)*

With the glass fibre geotextile the objective was to use fewer nails than with plastic type geotextile. Into the left edge the nails were put in about 30 cm intervals and to the right edge about 50 cm intervals. Fastening of the glass fibre geotextile can be seen in Figure 5-3 and 5-4. The weakness ofthe fabric caused some challenges when the washer didn't hold the fabric when pulled. If the hole was drilled trough the fabric, the hole was too big for the washer.

For the future usage the washer should be larger, otherwise the fastening is not likely to withstand the pellet installation. Another possibility is to add some metallic wire into the front edge of the fabric, as strengthening. The amount of wire would likely be under 20 g/m fabric.

### 5.3.2 Gluing

The second fastening test consisted of two different scale tests and included two different glues (see Appendix 3 and 4):

- A one component MS-polymer glue (Kiiltofix masa)**.**
- A 2-component epoxy glue (Araldite rapid).

#### *The first gluing attempt*

The first test section was about 1×1 meter. The surface of the rock was wet, very rough and dusty. MS-polymer glue was extruded in a 5 mm thick line, at the edges of the geotextile in an about 5 cm wide area. Figure 5-4 shows the extruding of glue onto the geotextile. About 200 ml of the glue was used in the first fastening test.

The geotextile was pressed against the rock surface by hands for one minute. It didn't stick to the rock wall, because the glue couldn't get a good contact to the rock surface.

***Figure 5-1.*** *Testing the attachment by pulling the geotextile.*

***Figure 5-2.** The attached geotextile.*

*Figure 5-3. On the left, the fastening process and on the right the glass fibre fabric installed on the rock wall.*

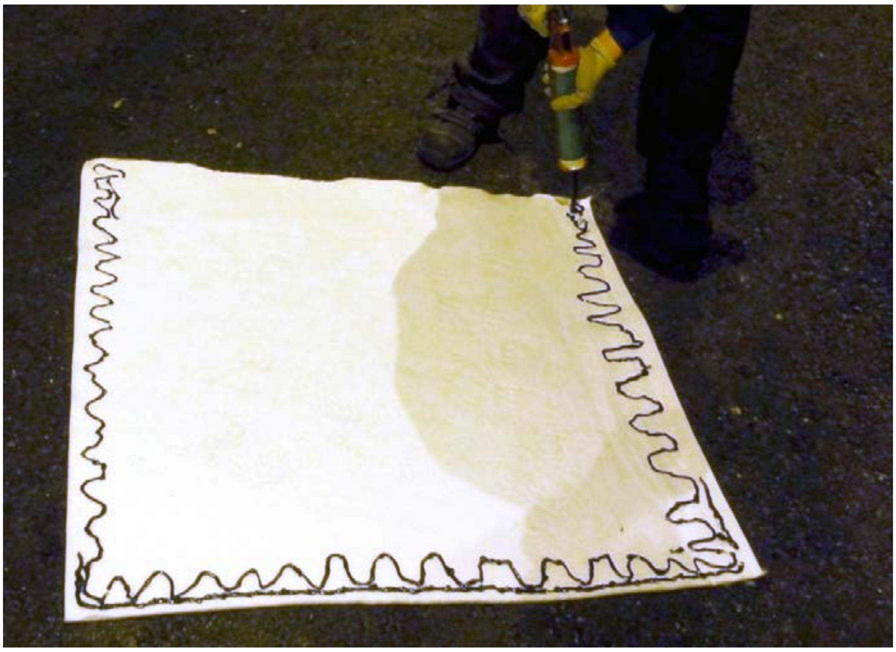


*Figure 5-4. Extruding MS-polymer glue.*

### The second gluing attempt

Two smaller sections, 20–25×20–25 cm, of geotextile were tested. This time the fastening place was moved to smoother surface and now both glues were tested side by side. Greater amount of glues were used in the second test than first gluing, about 50 ml MS-polymer glue and about 30 ml epoxy glue. The glue was spread only to a few points, in order to increase the contact surface between the geotextile and the rock surface.

Both geotextile sections were pressed against the rock surface by hands for one minute and both geotextile sections stayed on the wall. One of the small fastened geotextile sections can be seen in Figure 5-5.

***Figure 5-5.** The small geotextile sections on the wall.*

### 5.3.3 Cement paste

The cement used to fasten the glass fibre fabric (type II) was Plussementti manufactured by Finnsementti Oy, a datasheet is provided in Appendix 5. The cement was mixed manually with a trowel. The amount of water was kept as low as possible, in order to create a toothpaste like consistency. The glass fibre fabric used in the test was approximately 1×1 m.

The cement was applied to the glass fibre fabric with a trowel. Due to the spreading method the amount of the cement was approximately 2 kg. The width of the area where the cement was spread was about 20 cm, see Figure 5-6. When the fabric was ready, it was pushed against the wet and dusty rock surface. Based on the hardening times of the cement, the fastening can be assumed to have some affect after 5 h.

One additionally fabric was fastened with cement. The second fabric was about 1×0.4 m. The cement was spread only to the centre of the fabric, and a little bit thicker layer was used. The amount of cement was approximately similar as in the first fabric (2 kg/m$^2$). The purpose was to have on test fabric what could be pulled out later.

The second fabric was partially pulled out after four days of hardening. At that time the adherence between the fabric and the rock surface was harder than the fabric, resulting to the tearing of the fabric, as can be seen in Figure 5-7. Although in some point the cement was sticking into the rock surface, and got loose from the fabric.

***Figure 5-6.** The glass fibre fabric with cement ready to be installed onto the rock surface.*

***Figure 5-7.** The attachment was stronger than the glass fibre fabric.*

## 5.4 Discussion

- The express nails seemed to be the best alternative in order to fasten the geotextile onto rock wall. The drilling needed for the fastening is minimal and very shallow, and shouldn't cause any major occupational hazards.
- Due to the difficulties observed in the nailing process with the glass fibre fabric, the diameter of the washer should be significantly extended.
- If the steel in the express nails can't be accepted due to long term safety aspects it could be changed to some other metal such as copper or titanium. In that case the nails must be specially manufactured for this purpose.
- Steel is also prone to corrode in the deposition tunnel conditions. Corrosion might destroy the nail in less than three years, based on the observations made during the fastening tests.
- The geotextile should be pre-perforated to avoid jamming of the drill (in the case of plastic geotextile), and to facilitate the installation procedure.
- The gluing would require a cleaning of the rock surface, and possibly even drying, and is therefore not a practical method. The glues tested were also potentially hazardous from a long term safety point of view, and could therefore not be used in repository conditions.
- The cement gluing might be a possibility, but it would cause difficulties to the deposition time schedule due to the hardening time. Also the amount of cement used in the fastening test was quite high, lowering the effective area available for the water distribution.
- Based on the fastening tests the express nails are the most promising method for further development. Since none of the tested fastening methods can be accepted at the current state from a long term safety point of view, express nails are most likely to lead to acceptable result with the least amount of effort.

# 6 Summary and conclusions

As shown in the laboratory scale tests, there were no major differences between the three tested fabrics regarding water distribution properties, even if one of them not was designed to function as drainage. Based on the laboratory scale tests the material has only small significance on the function of the fabric in a bentonite pellet-fabric system. If so desired, it might be possible to find a better glass fibre fabric more suitable for this application.

The results from the ½-scale steel tunnel test showed increasing water storing capacity of the pellet filling when using geotextile as a distributor. The scale of the benefits is uncertain, since the test setup didn't remain identical throughout the tests. The use of geotextile seems at least to increase the water storing capacity of a pellet filling with 30%. The exact amount of increase of the water storing capacity would demand additional testing, and studying the effect of sieved pellets on the water storage capacity.

Based on the results from the ½-scale steel tunnel tests, the geotextile delays piping and increases the water storing capacity at least up to the tested 0.5 l/min inflow rate. In a full scale deposition tunnel (SKB or Posiva type) the inflow could be as high as 1 l/min in a 6 m long tunnel section. Since the inflow limit is a function of the backfilling rate, the exact inflow rate limit cannot be exactly quantified based on the performed tests. At point inflow rates higher than 1 l/min and tunnel section, other water handling methods probably will be required. These methods were, however, not studied in this project.

Since the steel tunnel has a limited length it was only possible to test if water could be led to the other side of the tunnel. In full scale it will also be possible to lead water backwards in the tunnel. The tested width of the geotextile was also adapted to the size of the steel tunnel. This can be further optimized in a full scale deposition tunnel.

A wetted wall of pellet was ending all three tests. This may also have increased the pellet fillings possibility to store water. When the flowing water reaches the wetted wall it will probably turn and flow against drier parts of the filling instead of through the tight wall. The technique with building a tight wall of wetted pellets can be used also in full scale and should be further investigated.

It is important to mention that although it is possible to have a general view of how water is transported in a pellet filling, the behavior is somewhat irregular and not always repeatable (Sandén and Börgesson 2014). The number of tests performed is still small and it will be necessary to do several new tests in large scale in order to get more data regarding the variation in water storage capacity.

The express nails seemed to be the most promising method for fastening of the fabric onto the rock wall. The method requires only minimal preparation of the rock surface and the nails can be applied fast without any disturbance to other works on-going in the tunnels.

The glass fibre geotextile is more fragile, and requires bigger washers than used in the tests. The washers used in the test couldn't prevent the fabric from getting loose during the installation of the pellets. A possibility could be to add some metallic wire into the fabric in order to increase durability of the attachment.

The cement might be a possibility for the fastening, but there are still many open subjects concerning the long term safety perspective. The amount of cement required for the fastening might also be too great to be convenient.

Based on the fastening test done, the express nails with larger washers are recommended as fastening method.

# References

SKB's (Svensk Kärnbränslehantering AB) publications can be found at www.skb.se/publications.


**Andersson L, Sandén T, 2012.** Optimization of backfill pellet properties. ÅSKAR DP2. Laboratory tests. SKB R-12-18, Svensk Kärnbräsnlehantering AB.

**Dixon D, Anttila S, Viitanen M, Keto P, 2008a.** Tests to determine water uptake behaviour of tunnel backfill. SKB R-08-134, Svensk Kärnbräsnlehantering AB.

**Dixon D, Lundin C, Örtendahl E, Hedin M, Ramqvist G, 2008b.** Deep repository – engineered barrier systems. Half scale tests to examine water uptake by bentonite pellets in a block–pellet backfill system. SKB R-08-132, Svensk Kärnbräsnlehantering AB.

**Sandén T, Börgesson L, 2014.** System design of backfill. Methods for water handling. SKB R-14-09, Svensk Kärnbräsnlehantering AB.

**Sandén T, Börgesson L, Dueck A, Goudarzi R, Lönnqvist M, 2008.** Deep repository – Engineered barrier system. Erosion and sealing processes in tunnel backfill materials investigated in laboratory. Baclo project-phase 3. SKB R-08-135, Svensk Kärnbräsnlehantering AB.

**Huang H-Y, Gao X, 2004.** Geotextiles. University of Tennessee. Available at http://web.utk.edu/~mse/Textiles/Geotextiles.htm [6 May 2013].

# Appendix 1

## Product data sheet, Fibertex F-1000M

CONSTRUCTION

4465 01032012

Product data sheet

# Fibertex F-1000M White

**Geotextile for application standards**

| | | | | |
|---|---|---|---|---|
| √ Construction of roads and other trafficked areas EN 13249 | √ Construction of railways EN 13250 | √ Earthworks, foundations and retaining structures EN 13251 | √ Drainage systems EN 13252 | √ Erosion control systems EN 13253 |
| √ Construction of reservoirs and dams EN 13254 | √ Construction of canals EN 13255 | √ Tunnels and underground structures EN 13256 | √ Solid waste disposals EN 13257 | √ Liquid waste containment projects EN 13265 |

**Functions / Intended uses** F + S + D + P

**Characteristics**

| Characteristic | Test methods | Units | Nominal value | Tolerance |
|---|---|---|---|---|
| Tensile strength MD | EN ISO 10319 | kN/m | 34,0 | -4,4 |
| Tensile strength CD | EN ISO 10319 | kN/m | 75,0 | -9,8 |
| Elongation MD | EN ISO 10319 | % | 110 | -22 +25 |
| Elongation CD | EN ISO 10319 | % | 60 | -12 +14 |
| Dynamic perforation resistance | EN ISO 13433 | mm | 0 | +2,0 |
| Static puncture (CBR-test) | EN ISO 12236 | N | 10000 | -1000 |
| Opening size | EN ISO 12956 | µm | 70 | ±21 |
| Water permeability at 50 mm WH | EN ISO 11058 | m/sec | 0,02 | -0,01 |
| Water flow capacity at 20 kPa Hydraulic gradient: 1,0 Surface: rigid / soft | EN ISO 12958 | $10^{-6}$ m²/s | 10 | -3,0 |
| Protection efficiency at 300 kPa | EN 13719 | % | 0,8 | +0,2 |
| Pyramid puncture resistance | EN 14574 | N | 1200 | -360 |

**Durability**

To be covered within 2 weeks after installation

More than 25 years of service life can be obtained provided that the geotextile is used in natural soils with pH between 2 and 13 at a soil temperature < 25°C

| Characteristics not mandatory | Test methods | Units | Nominal value | Tolerance |
|---|---|---|---|---|
| Weight | EN ISO 9864 | g/m² | 1000 | ± 100 |
| Thickness at 2 kPa | EN ISO 9863-1 | mm | 7,0 | ± 1,4 |

Material : 100% PP

CE

0799-CPD-016

2002 / 2012

Fibertex Nonwovens A/S Svendborgvej 16 DK-9220 Aalborg Ø Denmark Tel +45 96 35 35 35 Fax +45 98 15 85 55 www.fibertex.com

Fibertex NONWOVENS

## Product data sheet, Needle mat AF 800-6

Joint - Stock Company
"VALMIERAS STIKLA ŠĶIEDRA"

# Technical Data Sheet

**F 15**
**Version No. 3**

| Characteristic | NEEDLED MAT<br>AF 800 – 6 | Test method |
|---|---|---|
| Weight, $g/m^2$ 1)<br>Nominal value<br>Tolerance, % | 800<br>+/- 10 | ISO 3374 |
| Thickness, mm 2)<br>Mean value<br>Single values | 6 +/- 1<br>4 – 8 | DIN EN ISO 5084 |
| Type of glass | 100 % E – Glass | DIN 1259 |
| Binding | Non | |
| Temperature resistance | $600^0$ C | |
| Combustibility | Non-combustible | DIN 4102 |
| Width nom., cm 3)<br>Tolerance, cm | 100<br>+/- 1 | DIN EN 1773 |
| Roll length, m 3) | 50 | |

1) The tolerance is determined for the test samples 316 x 316 mm
2) Measuring device with 25 $cm^2$ measuring area; pressure – 10 $g/cm^2$
3) Width up to 200 cm and other roll lengths are available upon request

## Packing, Storage, Transporting

**Packing:**
- felt wound on the core with inside diameter 76 mm or without core,
- each roll wrapped in the plastic.

**Transporting** - Covered means of conveyance.

**Storage** - Clean and dry storage, goods have to been stored in the producer's packing.

14.04.2004

## Product data sheet, MS-polymer glue, Kiiltofix Masa

KIILTO®

EMISSION CLASS FOR BUILDING MATERIAL M1

NSF

# KIILTOFIX MASA

**AREA OF APPLICATION** One component KiiltoFix Masa bonding sealant is based on a new silyl polymer technology. It is suitable for bonding and sealing outdoors and indoors. Suitable for bonding different steel bodies (cars, ships, caravans) that need fast curing, lining work, installation of building boards and movement joints that are subjected to hard mechanical wear. KiiltoFix Masa bonding sealant can be used in places where food is handled.

**SUBSTRATE** The substrate must be dry and free of dust, grease and oil. The product has good adhesion to various stones, concrete, most metals, wood, glass and glazed surfaces as well as epoxy and polyester surfaces. If using plastic, test adhesion before the actual use.

**PROPERTIES**

* NSF-approved product for occasional contact with food
* complies with M1-emission classification standards
* elastic
* fast curing
* excellent adhesion to various materials
* free of solvents
* free of isocyanates and phtalates
* easy to apply even at low temperatures
* overpaintable with most waterbased paints (test before use)
* excellent weather resistance
* good resistance against UV light
* good chemical resistance (diluted solutions)
* sea water resistant
* not for glazing purposes

**TECHNICAL DATA**

| | |
|---|---|
| Type | MS polymer |
| State | paste with high viscosity |
| Curing | moisture curable |
| Skin formation time | approx.. 15 min (23 °C, RH 50%) |
| Shrinkage | approx.. 2% |
| Density | approx.. 1.5 kg/l |
| Application temperature | + 1 … + 40°C |
| Temperature resistance | - 40 … + 90°C |
| Tensile strength (DIN 53504 ) | 2 $N/mm^2$ |
| Elongation at break(DIN 53504) | 400 % |
| Shore A hardness | 40 |
| Max allowed distortion | 10% |

* the values shown above are for guidance only and thus can not be considered a material specification (especially tack free -time and curing depend strongly on prevailing conditions such as temperature and humidity)

**CONSUMPTION** 5 x 5 mm joint approx. 12 m/cartridge

KIILTO OY • P.O. Box 250, 33101 Tampere • Tel. +358 (0)207 710 100 • Fax +358(0)207 710 101 • www.kiilto.com

| | |
|---|---|
| **APPLICATION METHODS** | With a sealant application gun. Cut the nozzle to the desired joint width (1-10 mm). |
| **SKIN FORMATION TIME** | approx. 15 min (23°C, RH 50%) |
| **CURING RATE** | 3 mm/24 h<br>10 mm/7 days (23 °C, RH 50%) |
| **RECOMMENDED WORKING CONDITIONS** | Application temperature should be + 1…+ 40 ºC. Curing time and vulcanisation depend strongly on working conditions such as room temperature, air humidity, material and dryness of the surfaces as well as the sealant amount. Our recommendations can therefore only be used as a guidance. |

**INSTRUCTIONS FOR USE**

Cut the cone on the cartridge top. Screw the nozzle to the front end thread and cut it to match the desired joint width. Spread the product either with a manual or pneumatic sealant application gun. If needed smoothen/shape the seal with a moistened knife. If sealant is used for gluing purposes, apply in stripes and event out with a knife, if necessary. The surfaces to be glued or sealed need to be clean and dry before the work.

Fresh stains can be removed with xylene or acetone. Cured stains can be removed only mechanically.

| | |
|---|---|
| **PACKAGING AND COLOR** | 290 ml cartridge<br>colours: white, grey, brown, black and beige |
| **SAFETY AT WORK AND ENVIRONMENTAL SAFETY** | Keep out of the reach of children.<br>Uncured product must not be poured down the drain. Small amounts of uncured product can be disposed after letting it cure with air humidity.<br>Cured product is disposable with community waste. |
| **STORAGE** | 18 months in an unopened in a dry and cool (+ 10 °C…+ 25 °C) place package. |
| **NOTE** | The recommendations above are based on our own research and our best knowledge. The local working conditions and methods may vary and are beyond our control. Therefore we cannot be held responsible for the actual work on the site.<br><br>Check the validity of the printed technical data sheet from our Technical Service, tel. +358 (0)207 710 100 or www.kiilto.com |

updated 5/2012

# Appendix 4

## Product data sheet, Araldite Rapid

HUNTSMAN

Enriching lives through innovation

**Advanced Materials**

# Araldite® Rapid

**DIY Adhesives**

**TECHNICAL DATA SHEET**

## Araldite® Rapid
## Two component epoxy paste adhesive

**Other commercial names**

- **Araldite® Rapide**
- **Araldite® Rapido**

**Key properties**

- **Fast curing**
- **General purpose**
- **Low shrinkage**
- **Bonds a wide variety of materials**
- **Tough and resilient**

**Description**

Araldite® Rapid is a quick cure, multipurpose, two component, room temperature curing adhesive of high strength and toughness. It is suitable for bonding a wide variety of metals, ceramics, glass, rubbers, rigid plastics, and most other materials in common use. It is a versatile adhesive for the craftsman.

**Product data**

| Property | Araldite® Rapid Resin | Araldite® Rapid Hardener | Araldite® Rapid mixed |
|---|---|---|---|
| Colour (visual) | opaque | pale yellow | pale yellow |
| Specific gravity | 1.16-1.18 | 1.15-1.18 | ca 1.18 |
| Viscosity at 25°C (Pas) | 25-45 | 20-40 | typically 25-35 |
| Pot Life (100 gm at 25°C) | - | - | 5 - 8 minutes |

**Processing**

**Pretreatment**

The strength and durability of a bonded joint are dependant on proper treatment of the surfaces to be bonded.
At the very least, joint surfaces should be cleaned with a good degreasing agent such as acetone, iso-propanol(for plastics) or proprietary degreasing agent in order to remove all traces of oil, grease and dirt.
Low grade alcohol, gasoline (petrol) or paint thinners should never be used.
The strongest and most durable joints are obtained by either mechanically abrading or chemically etching ("pickling") the degreased surfaces. Abrading should be followed by a second degreasing treatment

| Mix ratio | Parts by weight | Parts by volume |
|---|---|---|
| Araldite® Rapid Resin | 100 | 100 |
| Araldite® Rapid Hardener | 100 | 100 |

The resin and hardener should be blended until they form a homogeneous mix.

**Application of adhesive**

The resin/hardener mix is applied directly or with a spatula to the pretreated and dry joint surfaces.

A layer of adhesive 0.05 to 0.10 mm thick will normally impart the greatest lap shear strength to the joint. Huntsman stresses that proper adhesive joint design is also critical for a durable bond. The joint components should be assembled and secured in a fix position as soon as the adhesive has been applied.

**Equipment maintenance**

All tools should be cleaned with hot water and soap before adhesives residues have had time to cure. The removal of cured residues is a difficult and time-consuming operation.

If solvents such as acetone are used for cleaning, operatives should take the appropriate precautions and, in addition, avoid skin and eye contact.

**Times to minimum shear strength**

| Temperature | °C | 10 | 15 | 23 | 40 | 60 | 100 |
|---|---|---|---|---|---|---|---|
| Cure time to reach | hours | - | - | - | - | - | - |
| LSS > 1MPa | minutes | 35 | 20 | 20 | 5 | 2 | <1 |
| Cure time to reach | hours | 2 | - | - | - | - | - |
| LSS > 10MPa | minutes | - | 70 | 60 | 25 | 10 | 2 |

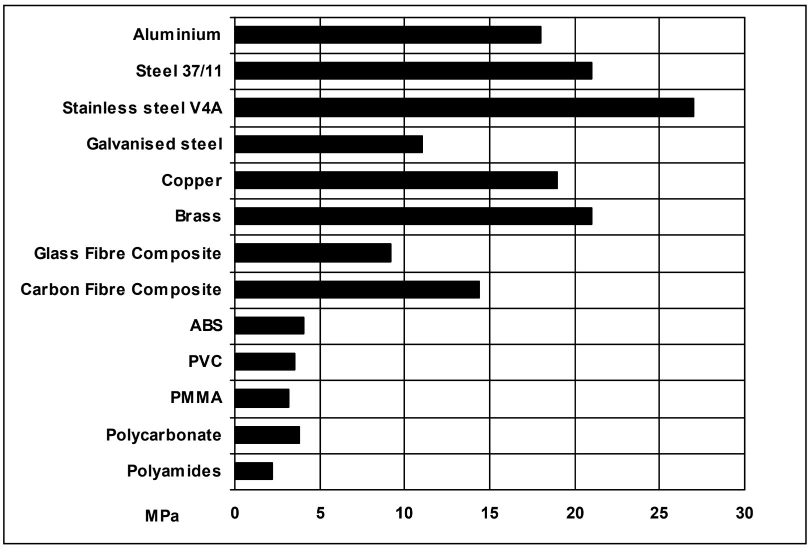
LSS = Lap shear strength.

## Typical cured properties

**Average lap shear strengths of typical joints (ISO 4587)**

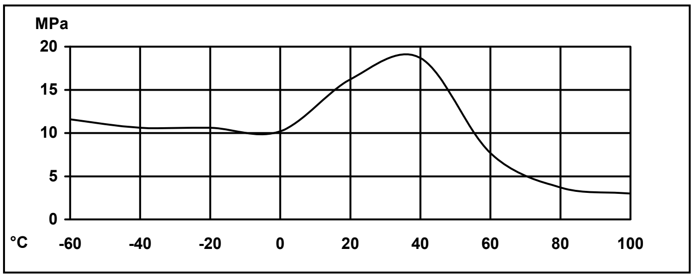
Cured for 16 hours at 40°C and tested at 23°C.

Pre-treatment: plastics abraded, metals sandblasted.



**Lap shear strength versus temperature (ISO 4587) (typical average values)**

Carried out on aluminium, cure= 7 days /23°C




## Storage

Araldite® Rapid may be stored for up to 3 years at room temperature provided the components are stored in sealed containers.

## Handling precautions

**Caution**

Our products are generally quite harmless to handle provided that certain precautions normally taken when handling chemicals are observed. The uncured materials must not, for instance, be allowed to come into contact with foodstuffs or food utensils, and measures should be taken to prevent the uncured materials from coming in contact with the skin, since people with particularly sensitive skin may be affected. The wearing of impervious rubber or plastic gloves will normally be necessary; likewise the use of eye protection. The skin should be thoroughly cleansed at the end of each working period by washing with soap and warm water. The use of solvents is to be avoided. Disposable paper - not cloth towels - should be used to dry the skin. Adequate ventilation of the working area is recommended. These precautions are described in greater detail in the Material Safety Data sheets for the individual products and should be referred to for fuller information.

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## Appendix 5

## Technical data sheet, Finnsementti, Plussementti CEM II/B-M

FINNSEMENTTI

# TECHNICAL DATA SHEET

**PLUSSEMENTTI CEM II/B-M (S-LL) 42,5 N**

The cement has the CE mark and complies with the standard EN 197-1: 2011.
EC-certificate of conformity:
Certificate no. 0416-CPD-5483 for Plussementti, Parainen
0416-CPD-5482 for Plussementti, Lappeenranta

**Typical properties of cement and clinker**:

| Property of cement | Typical values | Requirement EN 197-1 |
|---|---|---|
| 1d strength | 10…14 MPa | none |
| 2d strength | 21…26 MPa | ≥ 10 MPa |
| 7d strength | 34…39 MPa | none |
| 28d strength | 46…52 MPa | ≥ 42,5 MPa and ≤ 62,5 MPa |
| Initial setting time | 150…210 min | ≥ 60 min |
| Expansion | 0…1,5 mm | ≤ 10 mm |
| Fineness (Blaine) | 420…470 m2/kg | none |
| Loss of ignition | - | none |
| Insoluble residue | - | none |
| Sulfate content $SO_3$ | 3,0…3,3 % | ≤ 3,5 % |
| Chloride $Cl^-$ | ≤ 0,08 % | ≤ 0,10 % |
| $Cr^{6+}$ | 0…2 mg/kg | ≤ 2 mg/kg |

| Chemical properties of clinker | % |
|---|---|
| CaO | 63…65 |
| $SiO_2$ | 20…22 |
| $Al_2O_3$ | 4,0…5,4 |
| $Fe_2O_3$ | 2,8…3,3 |
| MgO | 2,5…3,2 |

| Other main constituents | | Requirement EN 197-1 |
|---|---|---|
| Limestone | 6…15 % | |
| Blast furnace slag | 15…25 % | |
| Sum of other main constituents | ≤ 35 % | ≥ 21 % and ≤ 35 % |

7/2013