

SKBF
KBS

TEKNISK
RAPPORT

79-17

**Water percolation effects on clay-poor
bentonite/quartz buffer material at
high hydraulic gradients**

R Pusch

Div. Soil Mechanics, University of Luleå, 1979-05-31

WATER PERCOLATION EFFECTS ON CLAY-POOR
BENTONITE/QUARTZ BUFFER MATERIAL AT
HIGH HYDRAULIC GRADIENTS

R Pusch

Div. Soil Mechanics, University of Luleå
1979-05-31

Denna rapport utgör redovisning av ett arbete som utförts på uppdrag av SKBF projekt KBS. Slutsatser och värderingar i rapporten är författarens och behöver inte nödvändigtvis sammanfalla med uppdragsgivarens.

I slutet av rapporten har bifogats en förteckning över av SKBF projekt KBS hittills publicerade tekniska rapporter i denna serie.

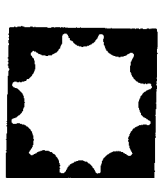
REPORT ON

**WATER PERCOLATION EFFECTS ON
CLAY-POOR BENTONITE/QUARTZ BUFFER
MATERIAL AT HIGH HYDRAULIC
GRADIENTS**

Luleå 1979-05-31

Div. Soil Mechanics, University of Luleå

R. PUSCH



WATER PERCOLATION EFFECTS ON CLAY-POOR
BENTONITE/QUARTZ BUFFER MATERIAL AT
HIGH HYDRAULIC GRADIENTS

Roland Pusch

University of Luleå 1979-06-07

WATER PERCOLATION EFFECTS ON CLAY-POOR BENTONITE/QUARTZ BUFFER MATERIAL AT HIGH HYDRAULIC GRADIENTS

By Roland Pusch

INTRODUCTION, SCOPE OF STUDY

In a previous study, reported in KBS 79-01, the eroding power of ground water entering a bentonite/quartz buffer mass was investigated. Such erosion may be produced at or immediately after the sealing of a repository of the KBS 1 concept type and similar rock plants. The hydraulic gradient may be high at those stages which could produce local redistribution of tiny clay particles or creating "piping" in the mass. Both effects should lead to undesired permeable passages which could deteriorate the barrier effects of the buffer mass. In this earlier study a buffer mass consisting of 20% (by weight) Na bentonite (MX-80 bentonite powder) and 80% silt/sand quartz material was investigated and it was found that piping with associated rapid water flow may take place. Very high hydraulic gradients were required to yield these effects, however, and the self-sealing ability was found to be very good.

The present study, which was performed in the same way as the previous one, concerned two buffer materials poor in clay. This was expected to make the buffer masses more sensitive to ground water erosion which called for repeated tests. The results from the study are presented in this report, reference being given in various respects to the earlier KBS 79-01 report.

DEFINITION OF PROBLEM

The main problem is the same as in the earlier KBS 79-01 study: Erosion by flowing water takes place when the flow rate approaches a critical value. Such

a condition may be reached when ground water from rock joints flows into the buffer mass. The process should be governed, in principle, by Darcy's law if the mass is completely or at least largely water saturated.

A critical state may also be reached when the fill has just been, or is being applied or compacted in a tunnel, shaft or any larger space. Thus, if the water pressure is built up rapidly in joints close to the rock/buffer mass interface, water may enter the buffer mass rapidly and cause local piping and washing effects.

Both cases can be considered by applying fairly high gradients as in the KBS 79-01 study.

EXPERIMENTAL INVESTIGATION

A test series was made in the laboratory to investigate the clay-transporting power of percolating water. Two buffer mass compositions were studied:

- I) 4% (by weight) Na bentonite + 96% quartz particles; initial water content about 0.5-1.0%
- II) 8% (by weight) Na bentonite + 92% quartz particles; initial water content about 1%.

Materials

MX-80 bentonite powder was used for the preparation of the "buffer substance" while its quartz component was obtained by mixing grains belonging to the silt and sand fractions according to VBB:s suggested grain size distribution curve (FAGERSTRÖM & LUNDAHL, KBS Technical Report no. 37 page 37). Figs. 1 and 2 illustrate the obtained grain size distributions.

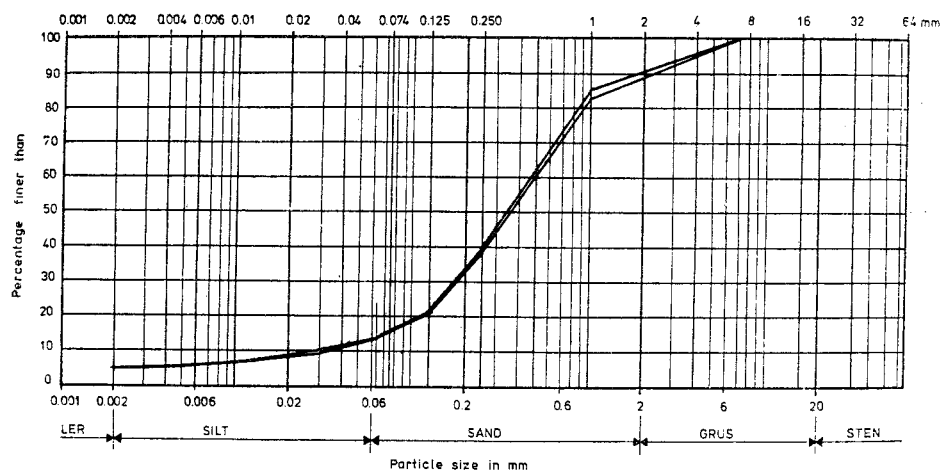


Fig. 1. Grain size distribution of "buffer substance" with 4% Na bentonite (clay fraction) and quartz material (Twin test)

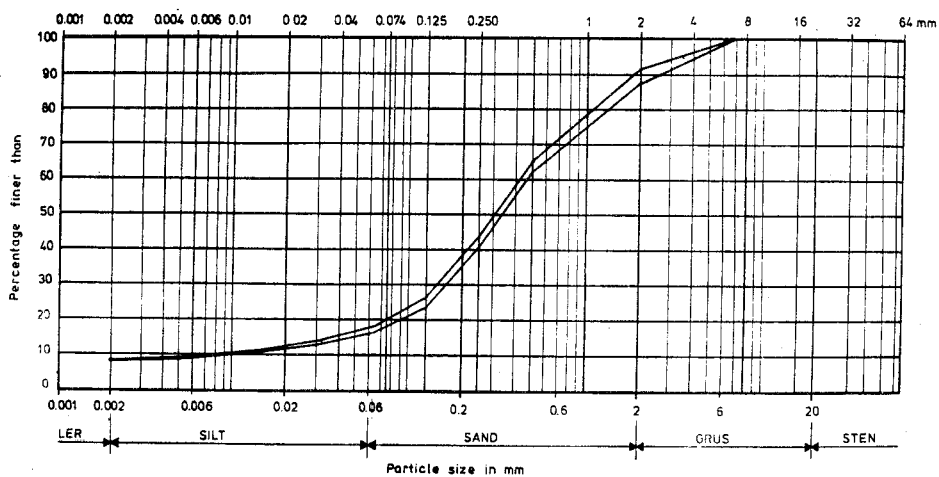


Fig. 2. Grain size distribution of "buffer substance" with 8% Na bentonite (clay fraction) and quartz material (Twin test).

The water used in the tests was the "Allard solution".

Test performance

The material was applied in columns consisting of steel cylinder sections (cf. Fig. 3 and detailed description in KBS 79-01). After having filled all the six sections of the two columns these were connected with a tube to which a vessel with "Allard solution" was attached. The water was put under pressure by compressed air, by which the desired hydraulic gradient could be obtained.

The application of the soil was made in thin layers which were compacted. After the completion of filling of each section, an additional one was attached and filled etc until the 0.3 m long pipe was completely filled.

After the application of the hydraulic gradient in the percolation phase, the percolated water from the columns was collected in flasks from which practically no water could evaporate. The amount of collected water was determined by weighing the flasks regularly, by which the permeability could be estimated. After the tests, the sections were disconnected and a large number of water content and clay content determinations were made to investigate how uniform the percolation had been and to find out whether there had been any clay particle redistribution.

As in the earlier study, it should be pointed out that the test conditions represent the very conservative case of an unlimited access of water from rock joints. In practice, the inflow of such water into the fill is governed by the flow capacity of the joints which can be very limited if ordinary rock sealing (injection) is made.

In the earlier study with 20% Na bentonite, the initial water content was about 20% while it was very much

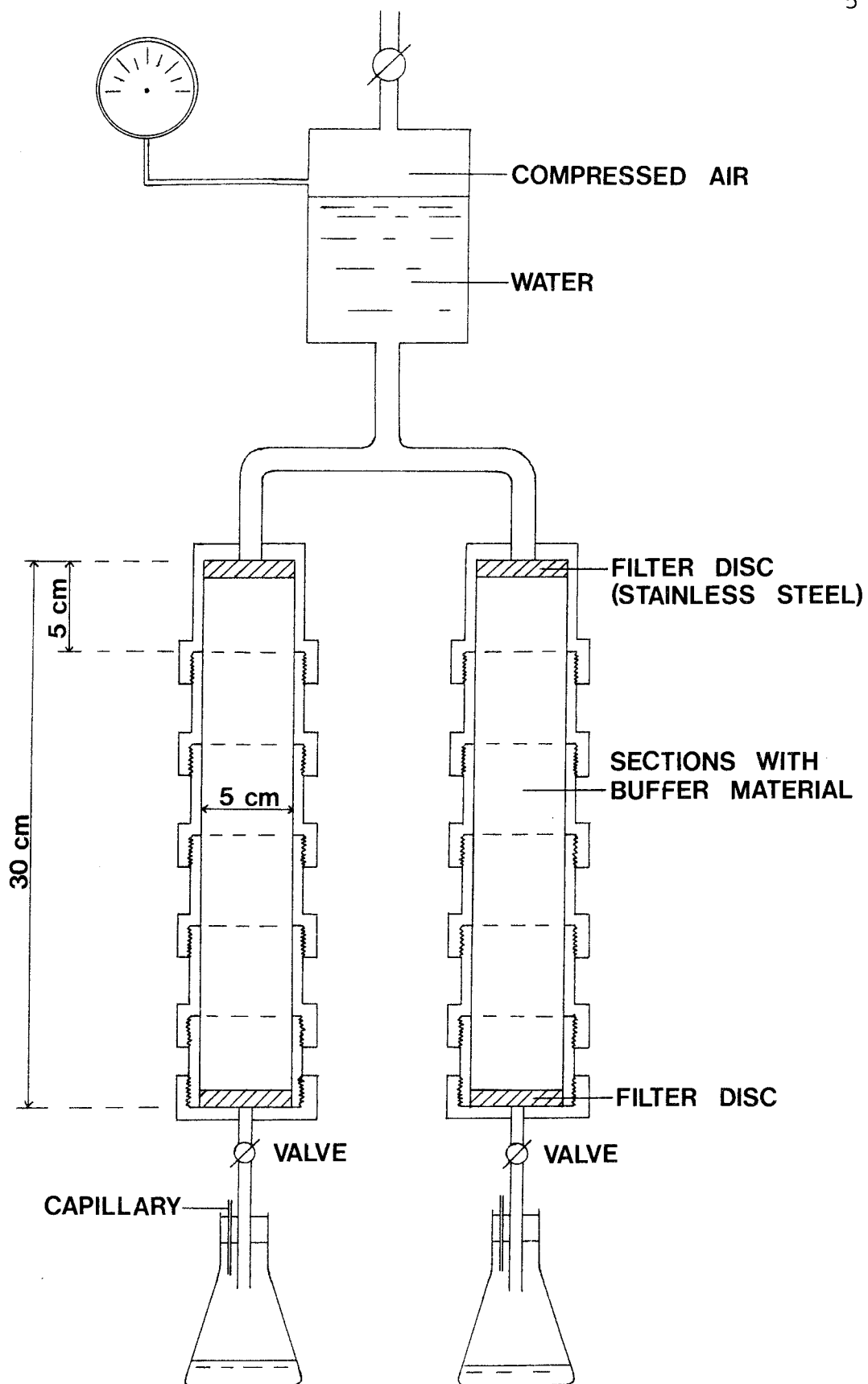


Fig. 3. Schematic view of test device

less in the present investigation. This may have required a longer time for reaching an equilibrium state of water saturation and also for obtaining a high degree of water saturation in the present study.

Test with 4% Na bentonite

The bulk density of the compacted mass was found to be 1.80 t/m^3 . 100 kPa water pressure was applied instantly as was specified by the original test program. Strong water percolation, probably associated with temporary piping, took place and since the test device did not have the required water flow capacity, the water pressure was reduced to 50 kPa ($i \approx 15$) for some hours. During that period the permeability dropped from about $8 \cdot 10^{-7} \text{ m/s}$ to about $4 \cdot 10^{-7} \text{ m/s}$. The water head was then increased to 100 kPa, i.e. $i \approx 30$, by which the permeability increased instantly to $1.2 \cdot 10^{-6} \text{ m/s}$ and then dropped to and stabilized at about $9 \cdot 10^{-7} \text{ m/s}$. Successive pressure increments to 150 kPa ($i \approx 50$), 200 kPa ($i \approx 70$), 250 kPa ($i \approx 85$), and 300 kPa ($i \approx 100$) gave a linearly increased permeability, the maximum value being about $7 \cdot 10^{-6} \text{ m/s}$ immediately after the application of the 300 kPa pressure. This pressure was then kept constant for about one week at the end of which the permeability stabilized at $3 \cdot 10^{-6} \text{ m/s}$. The pressure was then reduced to 150 kPa which yielded a constant permeability of 10^{-6} m/s after about one week. A subsequent pressure reduction to 75 kPa gave a further, instant permeability drop to $5 \cdot 10^{-7} \text{ m/s}$.

The water content after the test is given by the "I"-column in Fig. 4. It is obvious that the water distribution is homogeneous throughout the column. 18-19% water content corresponds to 97-99% degree of water saturation, which is remarkably high. Fig. 5 shows that the clay content, determined by performing 15 sedimentation analyses, was not changed during the

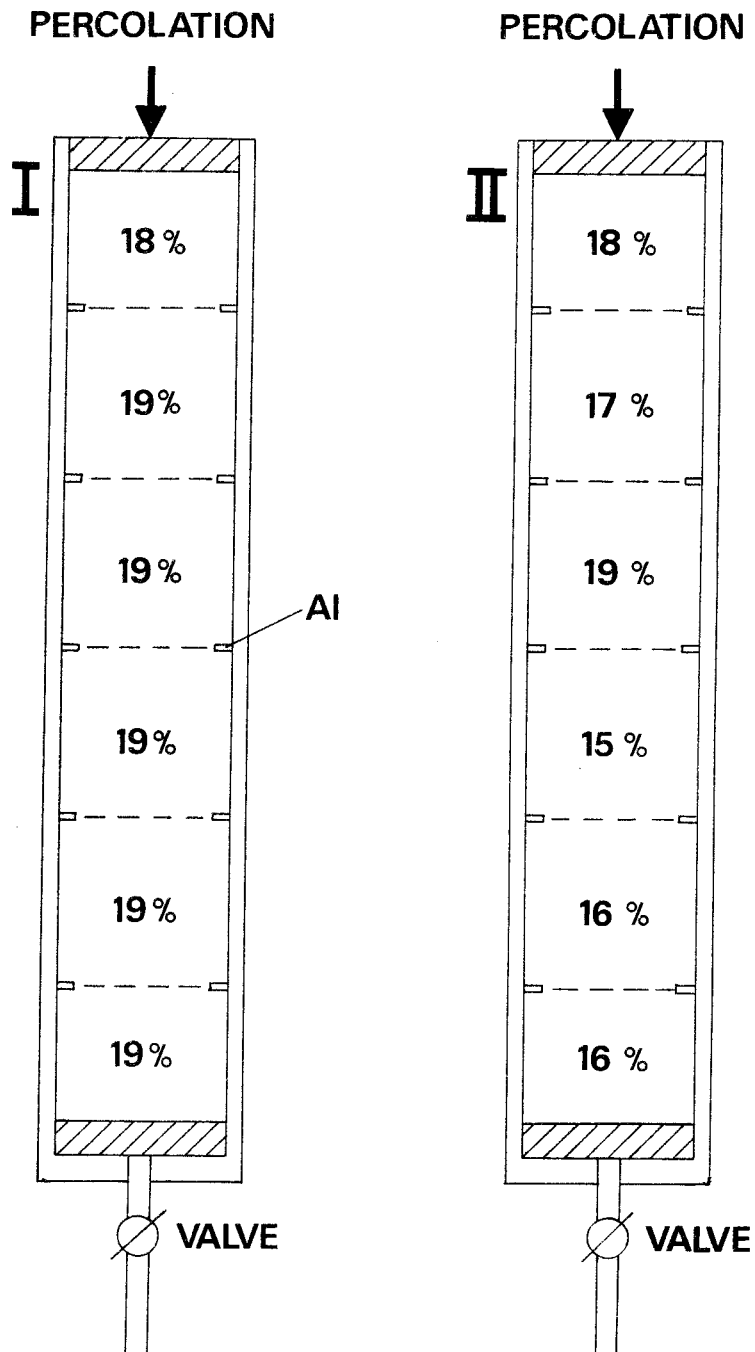


Fig. 4. Water content distribution in 4% Na bentonite (I) and 8% Na bentonite (II) test, respectively

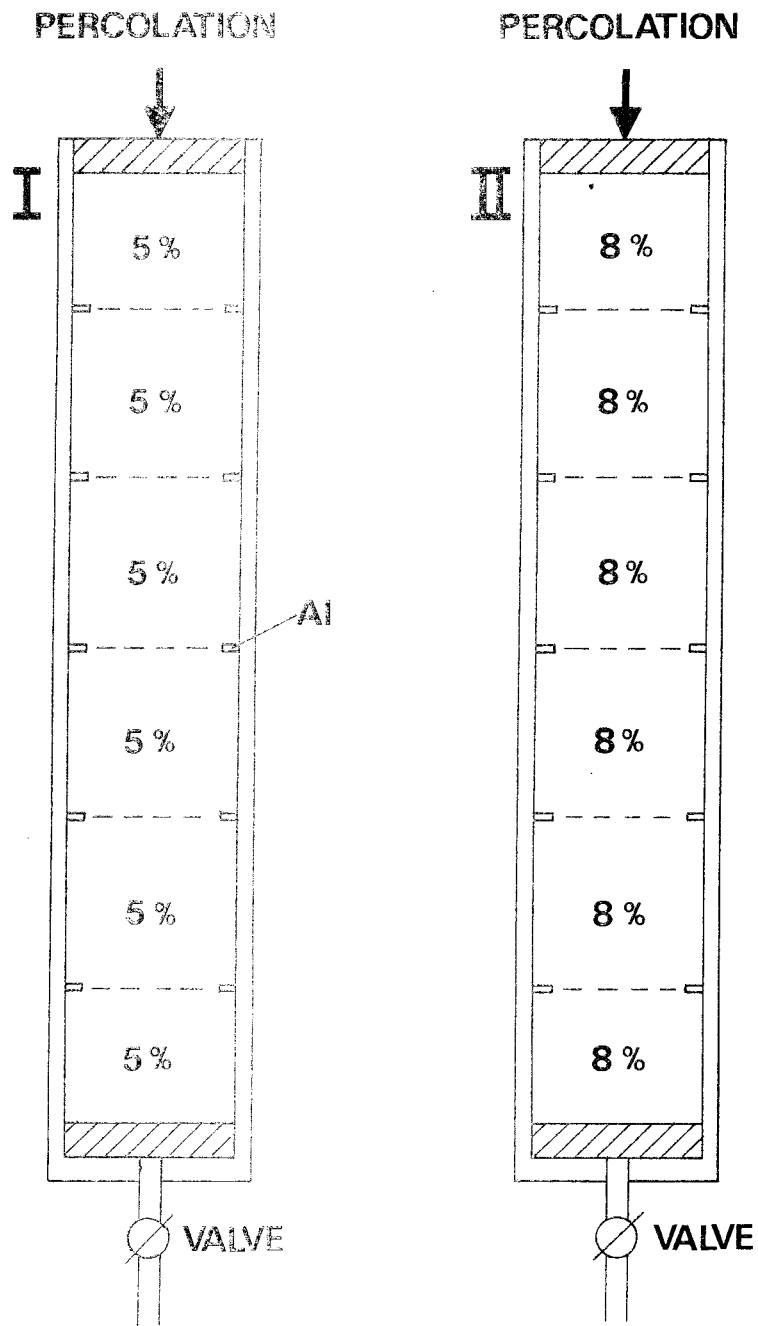


Fig. 5. Clay content distribution in 4% Na bentonite (I) and 8% Na bentonite (II) test, respectively

percolation.

Test with 8% Na bentonite

The bulk density of the compacted mass was found to be 1.80 t/m³.

Since the same pressure device was used for the 4% Na bentonite as well as for the 8% Na bentonite, both tests being run parallel, the same program was applied for both materials.

The instantly applied 100 kPa water pressure did not yield any water percolation through the bentonite-richer mass. Nor did the subsequent 50 kPa water pressure. When the pressure was raised again to 100 kPa ($i \approx 30$), water started entering the flask for collection of water, the estimated permeability after stabilization being of the order of 10^{-7} m/s. Successive pressure increments to 150 kPa ($i \approx 50$), 200 kPa ($i \approx 70$), 250 kPa ($i \approx 85$), and 300 kPa ($i \approx 100$) gave an approximately linear increase of the permeability. The maximum value, $3 \cdot 10^{-7}$ m/s appeared immediately after the application of the 300 kPa pressure. At the end of the one week period during which this pressure was kept constant, the permeability stabilized at about $1.5 \cdot 10^{-7}$ m/s. The subsequent pressure reduction to 150 kPa yielded a constant permeability of about $4 \cdot 10^{-8}$ m/s after about a week. A further pressure reduction to 75 kPa reduced the permeability to about $1.5 \cdot 10^{-8}$ m/s.

The water content after the test, given by the "II"-column in Fig. 4 was found to be of the same order of magnitude as in the previous test, which it should in fact be since the bulk densities were identical and the degree of water saturation was very high in the 4% Na bentonite test. However, the water content was somewhat lower in the bottom part of the 8% Na bentonite

column which indicates, firstly, that more air is enclosed in the pores in this part. Secondly, it means that the successive changes in permeability are not entirely produced by pressure changes but also by the continuation of the saturation processes.

As in the 4% Na bentonite test, the 8% Na bentonite test showed no clay particle redistribution (Fig. 5). 15 sedimentation analyses were performed in this test also.

CONCLUSIONS

The main conclusions are:

1. The average permeability at high hydraulic gradients ($i \approx 100$) is high for the 4% Na bentonite and the 8% Na bentonite buffer masses ($3 \cdot 10^{-6}$ m/s and $1.5 \cdot 10^{-7}$ m/s) compared with the previously studied 20% Na bentonite buffer mass ($< 10^{-9}$ m/s).
2. Local piping is easily produced when the clay content is low. During real conditions, e.g. when the development of higher gradients will be slower and where the flow will be restricted due to the limited capacity of existing rock joints, this will probably not cause difficulties. The observed piping did not produce any observable clay-particle redistribution and no permanent, highly permeable passages were formed.
3. The test results indicate that the permeability is pressure-sensitive and, thus, that Darcy's law is not valid. The successive water uptake leading to an increased but not complete degree of saturation, and associated mechanisms (capillarity effects, air bubble

formation etc) may, however, have contributed to this anomaly. Thus, the safest assumption is that Darcy's law is valid, which in turn means that the investigated clay-poor materials are very much less effective as sealing substances than the previously studied 20% Na bentonite mass.

4. Considering the fact that a permeability of the order of 10^{-6} - 10^{-7} m/s can easily be obtained by using well compacted ordinary till or till-like material with some additional fines, the use of 4-8% Na bentonite additives is not especially effective. The reason for this is the fairly high porosity (about 30%) which requires considerably higher amounts of Na bentonite to improve the sealing properties of the mixture. For this purpose, the Na bentonite content should be at least 10-15%, this conclusion being supported by earlier investigations.

REFERENCES

- | | |
|---------------------------------------|---|
| FAGERSTRÖM, H. &
LUNDAHL, B., 1977 | Hantering av buffertmaterial
av bentonit och kvarts. KBS
Technical Report no. 37. |
| PUSCH, R., 1979 | Clay particle redistribution
and piping phenomena in ben-
tonite/quartz buffer material
due to high hydraulic gradients.
SKBF/KBS Report 79-01. |

FÖRTECKNING ÖVER SKBF PROJEKT KBS TEKNISKA RAPPORTER

- 79-01 Clay particle redistribution and piping phenomena in bentonite/
quartz buffer material due to high hydraulic gradients
Roland Pusch
University of Luleå 1979-01-10
- 79-02 Försöksområdet vid Finnsjön
Beskrivning till berggrunds- och jordartskartor
Karl-Erik Almén
Lennart Ekman
Andrzej Olkiewicz
Sveriges Geologiska Undersökning november 1978
- 79-03 Bergmekanisk bedömning av temperaturlastning vid slutförvaring
av radioaktivt avfall i berg
Ove Stephansson
Bengt Leijon
Högskolan i Luleå 1979-01-10
- 79-04 Temperatur- och spänningsberäkning för slutförvar
Taivo Tarandi
VBB Vattenbyggnadsbyrån, Stockholm februari 1979
- 79-05 Kompletterande berggrundsundersökningar inom Finnsjö- och
Karlshamnsområdena
Andrzej Olkiewicz
Sören Scherman
Karl-Axel Kornfält
Sveriges Geologiska Undersökning 1979-02-02
- 79-06 Kompletterande permeabilitetsmätningar i Karlshamnsområdet
Gunnar Gidlund
Kent Hansson
Ulf Thoregren
Sveriges Geologiska Undersökning februari 1979
- 79-07 Kemi hos berggrundsvatten i Blekinge
Gunnar Jacks
Institutionen för Kulturteknik, KTH, februari 1979
- 79-08 Beräkningar av grundvattenrörelser inom Sternöområdet i Blekinge
John Stokes
Institutionen för Kulturteknik, KTH, februari 1979

- 79-09 Utvärdering av de hydrogeologiska och berggrundsgeologiska
förhållandena på Sternö
Kaj Ahlbom
Leif Carlsson
Gunnar Gidlund
C-E Klockars
Sören Scherman
Ulf Thoregren
Sveriges Geologiska Undersökning, Berggrundsbyrån,
februari 1979
- 79-10 Modellberäkningar av grundvattenförhållandena på Sternö
Carl-Lennart Axelsson
Leif Carlsson
Sveriges Geologiska Undersökning september 1979
- 79-11 Tolkning av permeabilitet i en befintlig berganläggning
Ulf Lindblom
Alf Norlén
Jesús Granero
Kent Adolfsson
Hagconsult AB februari 1979
- 79-12 Geofysisk borrhålsmätning i 2 st borrhål på Sternö
Kurt-Åke Magnusson
Oscar Duran
Sveriges Geologiska Undersökning februari 1979
- 79-13 Bildning av fritt väte vid radiolys i lerbädd
Trygve Eriksen
Johan Lind
Institutet för Kärnkemi KTH 1979-03-28
- 79-14 Korrosionsprovning av olegerat titan i simulerade
deponeringsmiljöer för upparbetat kärnbränsleavfall.
Slutrapport.
Sture Henrikson
Marian de Pourbaix
Studsvik Energiteknik AB 1979-05-07
- 79-15 Kostnader för hantering och slutförvaring av högaktivt avfall
och använt kärnbränsle
Arne W Finné
Åke Larson Byggare, april 1979
- 79-16 Beräkning av permeabilitet i stor skala vid bergrum i Karlshamns
hamn
Ulf Lindblom
J J Granero
Hagconsult AB Göteborg, 23 augusti 1979
- 79-17 Water percolation effects on clay-poor bentonite/quartz buffer
material at high hydraulic gradients
R Pusch
Div. Soil Mechanics, University of Luleå, 1979-05-31