# Fluidic functional verification for closing structures and fluid supported sealing of the contact zone

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## INTRODUCTION

In Germany highly radioactive substances have to be stored in salt-, clay- and/or granite formations. The STROEFUN-project (STROEFUN is the German acronym for the title) focuses on the contact area between the potential host rock halite and the required geotechnical barrier as a necessary security device for the storage of radioactive waste.

The geotechnical barrier has to shield the emplacement area against the rest of the mine in case of fluid ingress, so that it is difficult for the fluid to reach the stored waste. The integral permeability between the building material and the rock contour is a central component for proving the required sealing.[1] The project was funded by the Federal Ministry for Economics and Energy.

## CONSTRUCTION AND CONCEPT

In this project the geotechnical barrier is a dam structure, at the Teutschenthal mine in Germany at a depth of 680 metres. The dam consists of the so-called sorel concrete A1. This concrete type is the most likely one to be used due to the long-term stability against a possible inflow of a $MgCl_2$-enriched brine.[2] It is based on a mixture of salt, brine and magnesia. To increase the stability of the mixture, a small quantity of anhydrate was added.

A half-dam was constructed to allow scientists an easy access for their investigations. The project's aim was to determine the sealing effect of the closure structure using a newly developed measurement system. Furthermore, an injection pipe could be installed to reduce the permeability in a specific area.

The concept consists of so-called control chambers, which are integrated into the structure along the rock contour. In this chamber system air pressure is applied to the contact zone. This stimulates a controlled flow process, in which the range and effects are monitored by the measuring system. Figure 1 gives an overview of the installed injection pipes and the control chambers.

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[1] Weber, Jonas (2018): Untersuchung von Materialien zur Abdichtung des Kontaktbereichs zwischen Streckenverschlussbauwerken aus hydraulisch abbindenden Baustoffen und dem Salzgebirge. 1. Auflage. Clausthal-Zellerfeld: Papierflieger Verlag (Wissenschaftliche Reihe, 30)

[2] Becker, D-A; Buhmann, D.; Mönig, J.; Noseck, U.; Rübel, A.; Spießl, S. (2009): Endlager Morsleben. Sicherheitsanalyse für das verfüllte und verschlossene Endlager mit dem Programm PROSA. AF-Colenco AG.

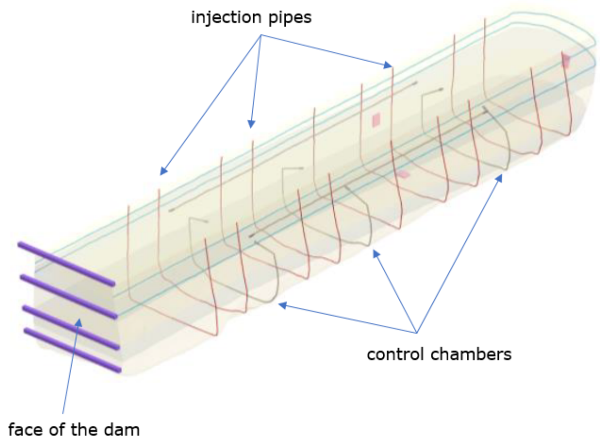


*Figure 1. Overview of the installed measurement, test and injection infrastructure (source: own illustration).*

If the permeability is too high, it is possible to inject a low viscosity sealing material into the contact area via injection pipes. Subsequently, the integral permeability at the contour can be measured again. The obtained data are used to evaluate the permeability between the host rock and the dam.

One advantage of this new measurement system is that no drill cores must be extracted. Drill cores just represent a specific local spot and do not give a reliable overview of the system. Furthermore, damaging the system due to core extraction is prevented.

For the reduction of the permeability two different injection agents were prepared. One is a particle-based injection agent which consists of a mixture of magnesia oxide, anhydrite and magnesium chloride solution. The other one is the epoxy Epojet LV from Mapei.

**Permeability tests and injections**

After six months the integral permeability was tested. In the first section, between the first and the second control chamber, the permeability was $8{,}0 \cdot 10^{-15}$ m². In the second section, between the second and the third control chamber, the value of the integral permeability was $3{,}0 \cdot 10^{-15}$ m². These permeabilities are so high that injections seem to be necessary.

Seven months after the dam construction the first injection had taken place by injecting 1800 $cm^3$ of the particle-based liquid agent at a pressure of $18 \cdot 10^5$ $N/m^2$ in the last injection pipe. Afterwards the pipe was cleaned and one week later 7000 $cm^3$ epoxy were injected into the same pipe at a pressure of $40 \cdot 10^5$ $N/m^2$. At the same time 2300 $cm^3$ at a pressure of $15 \cdot 10^5$ $N/m^2$ were injected in the upper vertical pipe. These injections were realised to obtain first experiences with injections and the injection agents.

Directly after the injections the integral permeability between the control chambers were tested, but no changes in permeability have been noticed, which was expected due to the distance to the control chambers.

Nine months after the dam construction another injection was planned, but it was not possible to inject the particle-based agent into one of the first four injection pipes at a pressure of $70 \cdot 10^5$ $N/m^2$. A further increase in the injection pressure could lead to fracking, which could damage the whole structure, so no further research could be done on that dam.

While cleaning these pipes with $MgCl_2$-solution a test was run to inject this liquid and 75 $cm^3$ into pipe 3 at a pressure of $60 \cdot 10^5$ $N/m^2$ and 50 $cm^3$ were inserted into pipe 1 at $50 \cdot 10^5$ $N/m^2$.

With the last permeability measurement between the first and second control chamber a value of $7{,}0 \cdot 10^{-15}$ m² was generated and between the second and third chamber $9{,}0 \cdot 10^{-16}$ m².

**RESULTS UND INTERPRETATION**

The goal of this project was to develop a system which could measure the integral permeability in the contact area. This system has been tested successfully. It seems that integral permeability over time decreases due to the convergence of the host rock.

In addition, drill hole samples of the contact area have been taken, and they seem to prove the results of the test chambers, and are now being examined for their permeability.

Another goal was to prove a decrease in the permeability due to the injections. This has not been proven yet.

The failed injections at the first four injection pipes lead to the conclusion that the convergence of the surrounding rock has an important sealing aspect due to the compression of the injection pipes. Also, a possible injection with the $MgCl_2$-solution while the grout could not be injected, demonstrates that injections with non-particle-based injection agents can be used for a longer time, while particle-based injection agents cannot.


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Did his bachelor's and master's degree at the Clausthal University of Technology in the field of mining. In 2017, he started as a research assistant at the Chair of Underground Mining at the same university. His professional focus is on salt and contributes to safe storage of highly radioactive materials in Germany.