

## Ultrasonic testing of a sealing construction made of salt concrete in an underground disposal facility for radioactive waste

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### Abstract

For the closure of radioactive waste disposal facilities engineered barriers- so called “drift seals” are used. The purpose of these barriers is to constrain the possible infiltration of brine and to prevent the migration of radionuclides into the biosphere. In a rock salt mine a large scale in-situ experiment of a sealing construction made of salt concrete was set up to prove the technical feasibility and operability of such barriers.

In order to investigate the integrity of this structure, non-destructive ultrasonic measurements were carried out. Therefore two different methods were applied at the front side of the test-barrier:

1 Reflection measurements from boreholes

2 Ultrasonic imaging by means of scanning ultrasonic echo methods

This extended abstract is a short version of an article to be published in a special edition of ASCE Journal that will briefly describe the sealing construction, the application of the non-destructive ultrasonic measurement methods and their adaptation to the onsite conditions -as well as parts of the obtained results. From this a concept for the systematic investigation of possible contribution of ultrasonic methods for quality assurance of sealing structures may be deduced.

**Keywords:** Ultrasonic reflection measurement, dry contact transducers in boreholes, interface salt-concrete / rock salt, ultrasonic imaging of internal reflectors

## 1. Introduction

In order to safely seal radioactive waste disposals in rock salt for long time periods, sealing structures e.g. made of salt concrete are used. In the radioactive waste disposal facility ERAM in Morsleben the functional capabilities of such sealing structures are demonstrated and investigated by in-situ experiments [1]. In this paper first results of initial ultrasonic experiments which could serve as quality assurance of such structures are summarized.

For nondestructive investigations of sealing constructions made from salt concrete by means of ultrasonic methods it is absolutely necessary to work with dry contacts transducers, as they are in use for normal concrete since about 2002 [2], recently available also from other sources [3]. The main task of this first measuring campaign was to find out if the already existing ultrasonic measuring methods are principally suited for solving special questions of such sealing constructions. These methods are

- Reflection measurement from boreholes as first step to develop through transmission measurement between boreholes (analog to borehole tomography applied in geophysics)
- Ultrasonic echo imaging experiments on site by means of SAFT reconstruction (Synthetic Aperture Focusing Technique) in including phase analysis in continuation of initial experiments at test specimens [4]



Figure 1. Front side of the sealing construction during experiments

## 2. Measuring and evaluation methods

### 2.1 Reflection measurement from bore holes

In order to avoid liquid coupling agent dry coupling is applied for ultrasonic measurement from horizontally orientated bore holes. This is feasible by dry coupling sensor types, (typically applied for ultrasonic echo measurement). In this case an in-house built sensor probe consisting of 6 transmitting and 6 receiving 50 kHz shear wave transducers was used as shown in figure 2. They are used just like a typical ultrasonic echo sensor probe. Sufficient coupling is assured inside the borehole by the hydraulic pressure system shown in figure 2 (red sled). Stepwise data collection (typically 25 mm) is demonstrated in figure 3.



Figure 2. Ultrasonic probe for bore holes  
6 transmitting and 6 receiving point contact transducer



Figure 3. Borehole probe applied at the sealing construction

### 2.2 Ultrasonic imaging by means of scanning ultrasonic measurements

The measurements were conducted similarly to ordinary reinforced concrete structures. From reconstruction calculation of data sets measured with ultrasonic shear wave pulses the inner structure of the salt concrete can be imaged. We applied an existing measuring system which is usually used for reinforced concrete. Reflectors in up to 1.50 m depth can typically be detected with a spatial resolution of 30 mm.

In figure 1 in the center the metallic rectangle represents a building scanner which was applied for automated scanning measurement by means of ultrasonic echo (measuring field typically 1.5 m<sup>2</sup> per position). Data was collected at three areas of the sealing construction. Data migrated using the SAFT-Algorithm [2] indicate the location of reflectors; additionally a

phase analysis allows differentiating between reflectors with positive or negative acoustic impedance [2]. From that air inclusions may be localized.

### 3. Results (Examples)

In order to demonstrate the suitability of the described methods for the application at sealing construction two results of the measuring campaign at ERAM are summarized in the following.

#### 3.1 Reflection measurement from bore holes

In figure 4 the result from a borehole probe as in figure 3 is presented as an example. We visualized the reflected amplitudes along the bore hole. The sounding direction was pointing to the interface between the salt-concrete sealing construction and the surrounding rock-salt. At this interface significant reflections are observable (shown at the left side in figure 3). From the known distance the shear wave velocity was calibrated to 1914 m/s, which corresponds to calibrating at other areas.

The examples of ultrasonic intensity versus distance at the 3 indicated locations demonstrate that the intensity is rather high until a depth of about 0.7 m. This, and the intensity variation may be interpreted as the two abutments for injection, which are placed in this depth area. The reflection intensity in the depth larger 0.6 m corresponds to the attended low reflection coefficient between salt concrete and rock salt. The broadening of the reflecting area has to be further investigated.

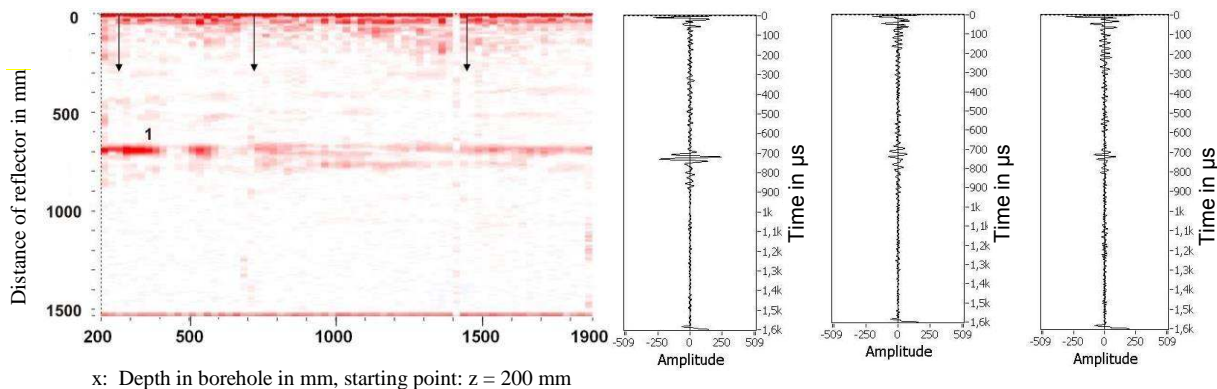


Figure 4. Borehole probe in RA516, sounding into direction of interface,  $c_s = 1914$  m/s  
from left to right: Reflector distance vs. depth of ultrasonic probe center (B-Scan),  
Intensity vs. time (A-scans) for 3 indicated depths at 300 mm, 700 mm, 1400 mm, indicated by arrows

#### 3.2 Ultrasonic imaging

The example presented here corresponds to the scanner location as demonstrated in figure 1. The main purpose of measuring at this site was to identify the nearest built-in construction part to the surface. From the given information of the construction plan and the capability of the measuring system (maximal depth because of limited time axe) it was assumed that this should be a possible task.

First results indicate reflectors not being represented in the construction plan. As an example two planar reflectors are shown in Figure 5 below. It can be observed that they are included in a depth of 300 mm (Figure 5 left). From their phase value around  $0^\circ$  (weighted average  $-7^\circ$ ) one might conclude an small air inclusion parallel to the measuring surface.

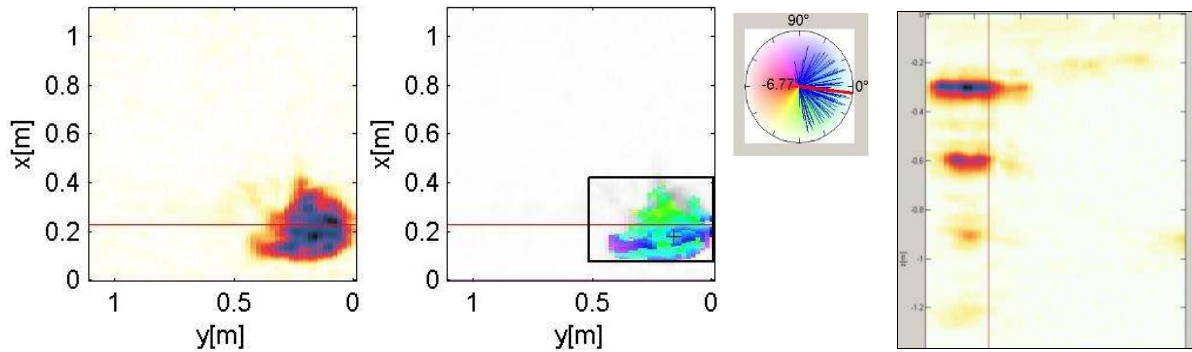


Figure 5. Example of ultrasonic imaging result from scanner location as shown in figure 1. right: B-scan from SAFT reconstruction showing plan reflector at  $z = 300$  mm together with 3 multiples, left (two depth sections (C-scan): Magnitude and Phase with color bar and weighted average phase value (7)

The original task to identify deeper reflectors requires further data analysis and will be presented in following publications.

#### 4. Conclusions

We applied ultrasonic nondestructive testing methods for the first time at a sealing construction made from salt concrete.

Reflection measurements were carried out from existing boreholes. Logging equipment made from point contact transducers was constructed in order to fit the borehole geometry. A sufficient surface contact was assured by an air pressure clamping construction. This first application of such a system demonstrates an encouraging principle for proving the integrity of the salt concrete between boreholes over large distances.

We carried out automated ultrasonic echo measurements with imaging by means of reconstruction calculation. Several reflectors caused by auxiliary structures could be successfully imaged, some of the reflectors are planned to be verified. Known, relatively small reflectors in the depth around 1.80 m were imaged suggestively, but the system applied was at its limit of measuring the echo run time.

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