NEW AND ALTERNATIVE BARRIER SYSTEMS – INVENTION, APPROVAL, REALIZATION AND QUALITY ASSURANCE STANDARDS DURING CONSTRUCTION

A. WITZSCHE AND J. WEIß *

** CDM Smith Consult GmbH, Neue Bergstraße 13, 64665 Alsbach, Germany*

SUMMARY: A number of stonepits are to be backfilled after their excavation, and the initial state is to be restored. Usually there is not sufficient ground material available for the backfilling, so that these quarries are often used for landfills, even though pit landfills should be avoided. However, there are sufficient technical possibilities that would allow a quarry to meet the requirements for a landfill site under the Landfill Ordinance. The mono-landfill for foundry sands in the basalt-quarry in Nieder-Ofleiden, is in terms of external monitoring, a good example of how a vertical sealing system can be constructed to ensure the protection of groundwater. For these vertical sealings, special requirements must be developed as they cannot be derived from the normal technical standards.

1. INTRODUCTION

The necessary security measures of the various classes of landfills are regulated by the German Landfill Ordinance known as the "Deponieverordnung" from 2009 with amendments from 2013. However, there are special problems in the securing of landfills situated in a stonepit that cannot be solved using the traditional measures. For these problems, specialized solutions are to be developed by the engineers. Of course, when developing a specialized solution, the quality in the production as well as the long-term durability of the materials should be equal to that of standard solutions.

According to the Landfill Ordinance "Deponieverordnung", when choosing new sites for landfills, pit landfills are to be avoided. Nevertheless, the realization of a landfill is sometimes necessary due to the fact that there is not enough material for backfilling available within a reasonable amount of time for the refilling of an excavation pit. Particularly in the case of excavated quarries, backfilling must occur along relatively steep and sometimes almost vertical quarry walls. These limitations must then be meet with sealing system in order to ensure adequate protection of the environment against potential leaks of pollutants via the water path out of the landfill.

Using the example of class I landfill in Central Hesse, the process of a vertical wall sealing is shown as well as the monitoring of the production and testing of the quality of the sealing.

Proceedings Sardinia 2015, Fifteenth International Waste Management and Landfill Symposium
S. Margherita di Pula, Cagliari, Italy; 5 – 9 October 2015

2. LOCATION AND BOUNDARY CONDITIONS OF THE LANDFILL

The mono-landfill, Nieder-Ofleiden, is located in Central Hesse directly near the city of Homberg/Ohm. In Europe's largest basalt quarry from the Mitteldeutsche Hartenstein-Industrie GmbH (MHI), in which the basalt mining is still actively running, the HIM GmbH operates a mono-landfill for the depositing of foundry sands since the 1980s. Planning for the different landfill sections has been carried out since the early 2000s by BFM GmbH in Wiesbaden and the external monitoring and the coordination with regulatory authorities have been carried out since the mid-1990s by CDM Smith Consult GmbH.

In the landfill, no hazardous waste (Class I) can be stored according to the new classification guidelines. The deposited materials have, since the beginning of landfill, been foundry sands that accumulate from production residues of a nearby iron foundry.

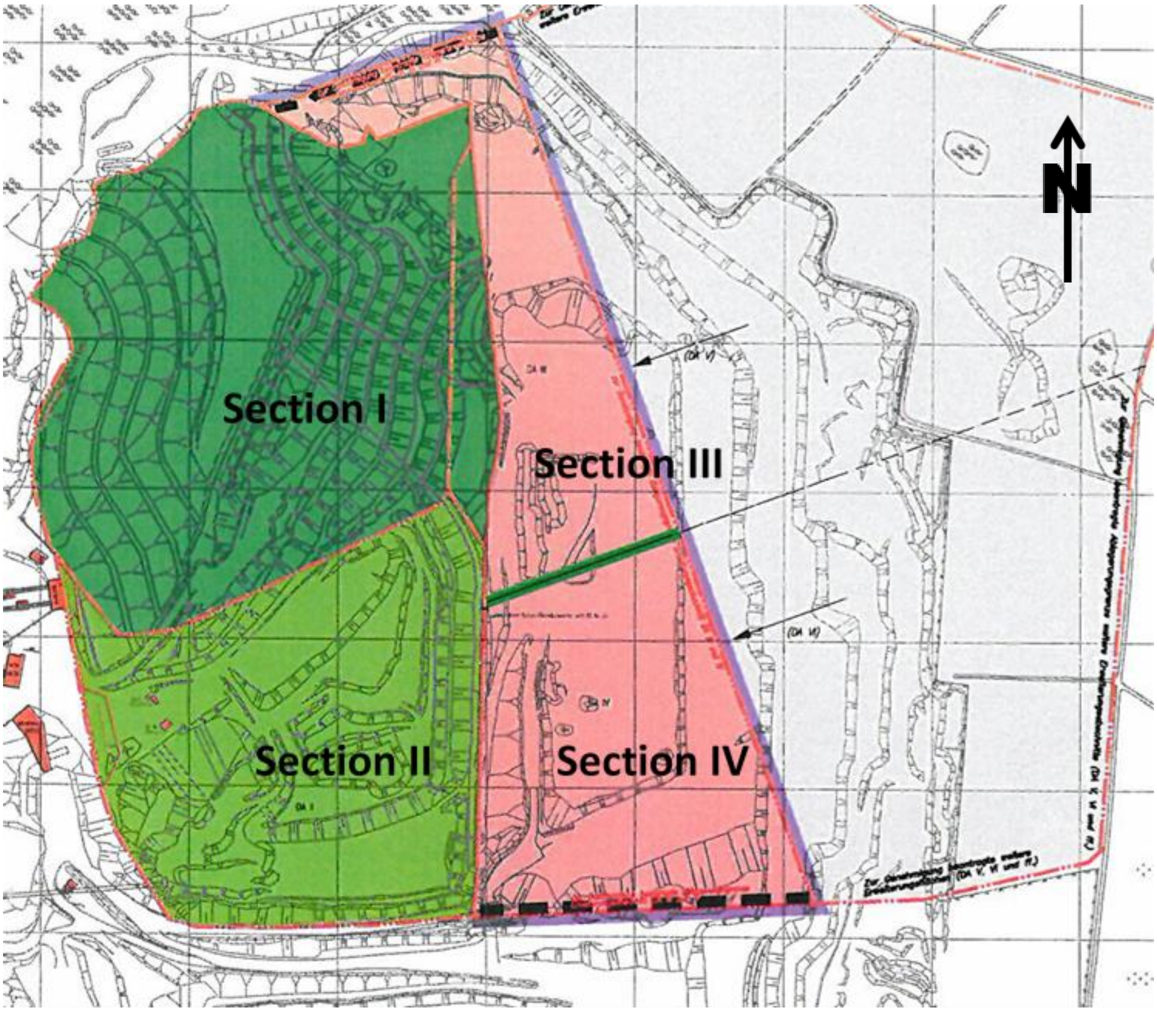

Figure 1. Map of landfill sections of the landfill Nieder-Ofleiden

Initially, these sands were deposited in accordance with the former legal provisions on the leveled base surface of the quarry without underground sealing measures. At the beginning of the 1990s, the approval authorities called for an intermediate seal for the older areas and a bottom liner for the remaining base surfaces to be installed according to applicable regulations, in order to continue operation of the landfill.

Figure 1 shows the actual realized landfill sections. The green areas indicate sections that are already filled or are currently being filled (section 2). The red areas were undergoing sealing measures in 2014. The works were completed in October 2014. Since then these areas are being filled.

During the construction of the base sealing in landfill section II, a drainage tunnel was excavated in the southeast of the site through which the entire water obtained both from the already built and backfilled sections as well as other sections can be discharged. The gallery is accessible and leads the accumulating groundwater under the man-made geological barrier in an open channel. The leachate from the individual landfill sections is discharged through closed pipelines (Figure 2).

In the newer eastern part of section 1 a mineral bottom liner already exists. The filling of the landfill section was carried out exclusively in slopes, which were constructed towards the inside of the pit. With the expansion of the landfill to section 2, the area was met with a steep rock face in the quarry (Figure 2), which has not been mined due to the insufficient quality of the rock.

The wall has an inclination of approx. 70 ° and a height of approx. 40 m. In order to not lose valuable landfill space and to achieve a complete filling of the pit, it is necessary to store the deposited material up to the rock wall.

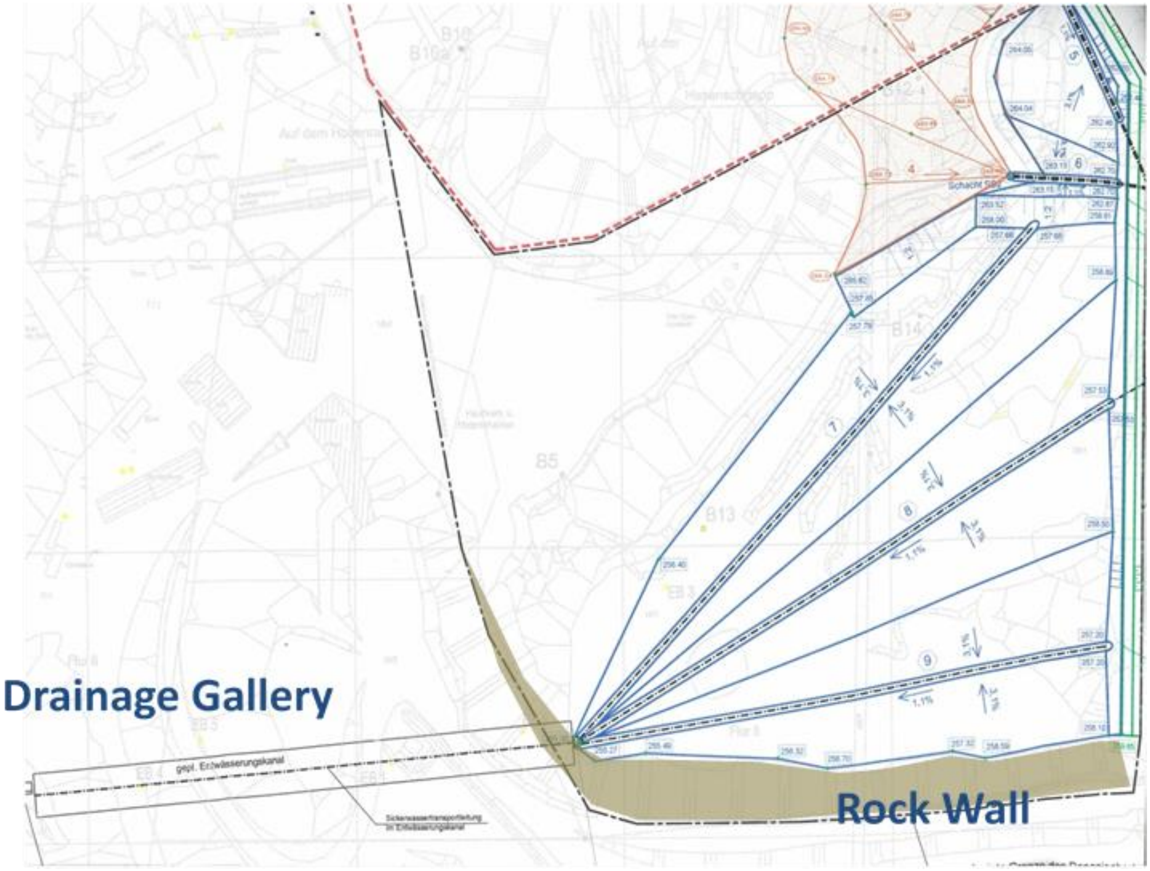

Figure 2. Drainage Gallery and Rock Wall in Section II

In the authorization granted in 1995 for the vertical sealing on the wall, the construction of a 1 m thick clay sealing should be installed behind gravel gabions which had to be planned and approved. However, the construction of this sealing proved to be almost impossible and would also cost precious landfill space. Furthermore, the incurred costs for a 40 meter high sealing of the wall would be extremely high.

Figure 3. Rock Wall in the South of the Landfill

A more practical and economical solution for the vertical rock face sealing consisting of a combination of air-placed concrete with a sealing layer of bitumen. This bitumen product as is also used to seal houses from groundwater, was planned and realized.

The procedures for the individual steps for the implementation of this sealing system were compiled in a Quality Assurance Plan (QAP). This plan contained all the requirements for applying the sealing system and the necessary control steps. It was developed by the planning office and the external monitor of the building owner and agreed upon by the regulatory authority. The suitability of the individual elements of the sealing system was reviewed and approved in coordination with the authorities. In the Quality Assurance Plan (QAP), the origin of the materials, on-site storage, and the installation were predefined. Furthermore, the number and type of inspections and documentation of the individual sealing elements were also defined in the QAP. There are two different authorities to ensure the quality in installed systems. On the one hand the self monitoring of the manufacturer and the construction company; and on the other hand the external monitoring of the building owner and the authorising agency.

For the 40-meter-high rock wall, a gradual approach in phases from heights of approx. 6 - 8 meters were chosen. The procedure is shown schematically in Figure 4 for the first two sections.

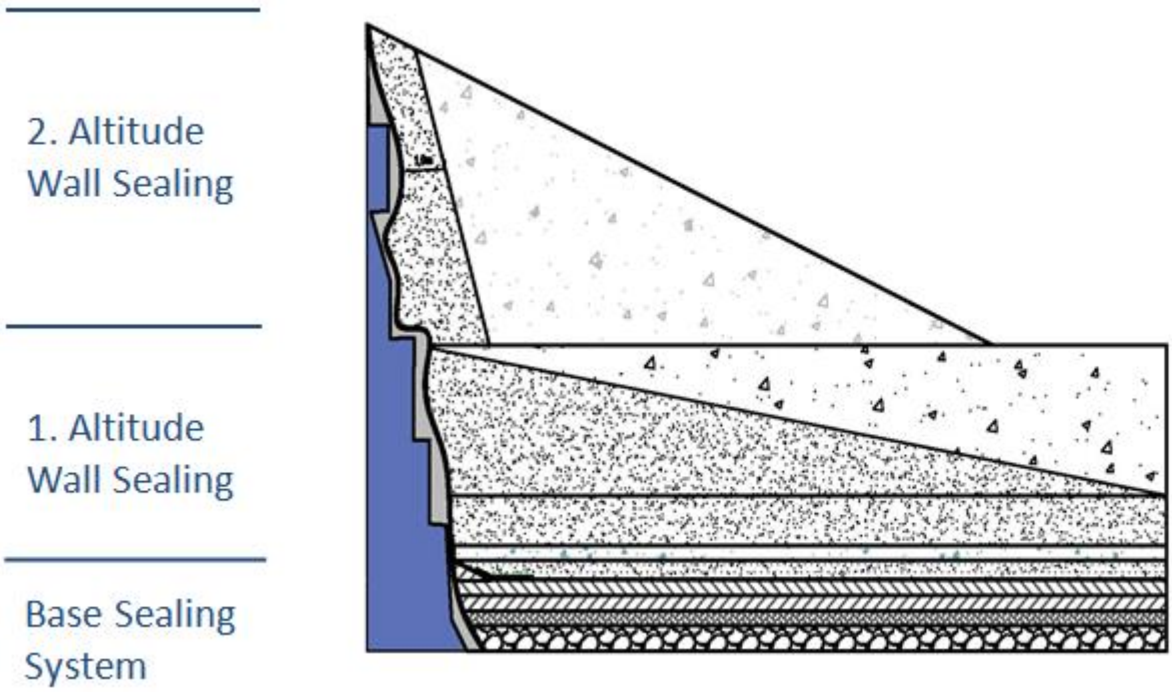

Figure 4. Schematic drawing of the wall sealing - Workflow

The veritcal sealing system is comprised of the following components (see Figure 5). They will be described in chapter 4.

- Basalt wall (cleaned of any lose material)
- Air-placed concrete shell (grain 0/8 mm) – base layer to fillet
- Air-placed concrete shell (grain 0/4 mm) – surface layer
- special bitumen coating - sealing liner (minimum 4 mm thick)
- fine foundry sand – coating layer

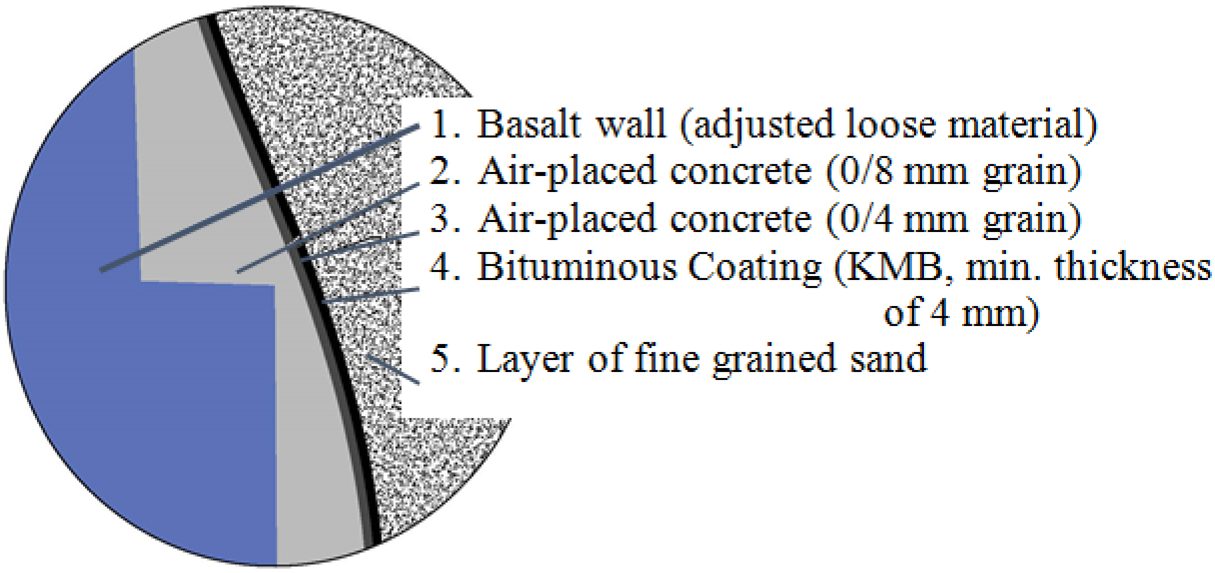

Figure 5. Construction of the Rock Wall Sealing

3. SEALING ELEMENTS AND QUALITY SPECIFICATIONS

3.1 Rock Wall

The almost vertical rock wall in the south of the site was created during the blasting operations conducted by basalt mining. The mining left behind loose basalt stones on the surface of the wall. Years of freezing and thawing and other weather influences have also led to the further loosening of the rocks on the wall. In order to obtain a stable sub-surface for the sealing system, an examination of the basalt surface needed to be carried out. The aim of this investigation was to identify loose material that needed to be removed.

In order to remove the loose rocks, the construction supervisor and the external monitors used a mobile crane in order to examine the wall.

Figure 6. Inspections Along the Rock Wall

The loose rocks were documented for removal. Loose rocks, which could not be cleared out because of their size and location in the wall were fixated into position with air-placed concrete. Also open cavities were closed using air-placed concrete. The inspection of the wall was then carried out visually. In addition, the results of the secured wall were documented.

3.2 Air-placed concrete Base Layer (Grain Size 0/8 mm)

As the base layer of the sealing system, a qualified air-placed concrete layer was applied to the basalt wall. The main function of this layer was not only to fill the cavities but also to smoothen irregularities in the rock wall. This layer needs to bond intensely with the wall as it will form a solid basis for the entire sealing system.

Precise geometrical requirements were defined regarding the production quality of this base. The radius to be met to smoothen the wall had been defined for vertical and horizontal bulges. Vertically, this radius should be ≥ 2 m and horizontally ≥ 0.15 m. The air-placed concrete used corresponded to a C25/30 in compliance with DIN EN 206-1, DIN 1045-2.

The minimum thickness on top of the basalt surface was required to be ≥ 4 cm. This was necessary to guarantee that the applied layer would be stable enough.

This stability was checked by means of pressure tests on the wall. The consistent quality of the supplied air-placed concrete was periodically tested immediately after the delivery on the basis of the delivery slips and with test cubes. After 7 days, the samples had to have at least 50 % of its required final strength.

3.3 Air-placed concrete of the Surface Layer (Grain Size 0/4 mm)

The requirements for the top layer of the air-placed concrete basically corresponded to those of the base layer. Beyond that, this layer had to provide sufficient smoothness to be able to apply the sealing layer on top of it. The unevenness on the surface of this layer was defined as ≤ 2mm in the quality assurance plan. This layer was applied to the base layer relatively thinly (≥ 1cm).

In this case, the consistent quality of the supplied concrete was also tested periodically. The initial strength after 7 days also had to reach 50% of the final strength.

3.4 Polymer-Modified Bitumen Coating – Sealing liner

Before the polymer-modified heavy-weight bitumen coating can be applied to the air-placed concrete, it needs to be cleaned to remove loose fine particles. This is done with the help of compressed air. The bitumen coating represents the actual sealing as it covers the air-placed concrete with a flexible sealing layer. This sealing layer must meet the requirements of DIN 18 195 T 6, sealing against percolating water. These requirements need to be proven in the data sheets of the supplied material. The planner selected a product which is a sprayable, flexible two-component bituminous sealant, which is supplied to the construction site proportionately and mixed on-site.

The material was applied in two spraying operations of a minimum thickness of 2mm, which had to be met after drying. The thickness was tested regularly according to the requirements of the quality assurance plan before and after the drying process (pin test in moist state) and the results were documented.

In addition to the thickness of the applied bitumen coating two more parameters need to be tested: the density of the material and the drying time.

The density was determined in samples which were regularly taken from the spraying process. It amounted relatively consistently to 1.0kg/dm³. Drying time has to be approximately 3 days (72 hours) corresponding to the manufactures information. This was in line with the requirements of the material manufacturer. Due to the specific boundary conditions of the quarry wall, which was mainly situated in the shade, the stage of drying reached was checked on a regular basis. A sufficient degree of drying of the bitumen coating is absolutely necessary before applying the protective layer.

3.5 Protective Layer Consisting of Fine-Grained Foundry Sand

To protect the bitumen coating from mechanical damage during the application of the foundry sand fine-grained foundry sand was applied to the rock wall immediately after drying. These are fined sands without any contraries which is an industrial waste of the foundry operation. The material had to have a grain size of 0/1mm.

This protective layer on top of the bitumen coating was applied layer by layer. It was applied with an excavator, which located the material at the sealed rock wall. To guarantee that the normal foundry sand would be far enough from the wall, a 1 meter thick layer of fine-grained foundry sand was located before the wall and stabilized with another 2 meter thick layer of normal foundry sand so that the total width amounted to at least 3 meters with special attention paid to the installed protective layer (cf. Illustration 4, second altitude).

Thanks to this construction method, the protective layer could be applied along the entire height of the individual sections of the sealed rock wall in a relatively short time, although the quantity of fine sand meeting the requirements of the protective layer was limited. When the actual foundry sand was located it did not get in contact with the vertical sealing layer. As an additional consequence, the sealing layer was also protected against falling rocks from the operation of the quarry shortly after the installation.

3.6 Construction Technique – Test Fields and Implementation

During the entire construction period, the quality assurance plan was adjusted to the findings of the construction work. It contains the boundary quality conditions for all building materials, the sampling and test intervals of our own and third-party monitoring and the requirements for the documentation of the tests. In the quality assurance plan, a test field for the formation of the vertical wall sealing was demanded, in which the contractor had to test the planned method in the practical construction conditions on large scale. Special importance was attached to the test fields located in the encountered boundary conditions of having to provide non-standard sealing of a vertical rock wall. A suitable spraying technique both for the air-placed concrete and the polymer-modified bitumen coating had to be found to reach a consistent quality of the work done.

Great importance was also attached to health and safety measures during the construction work as people had to work at the bottom of a 40 meter high rock wall, and it could never fully be ruled out that there would be no rocks falling from the upper part of the rock wall. Therefore, the building sections, in which people were working, were secured by a steel net fixed to a mobile crane. Falling rocks were retained by the net and thus a maximum degree of safety was achieved for the people working right on the wall (see Figure 3). As a consequence, people were only able to work in a small strip beneath the net.

4. BECOMING A PART OF THE REGULATIONS AND CONCLUSIONS

The described barrier system for vertical walls is actually a prototype. It is still far away from becoming a part of the German landfill regulations known as “Deponieverordnung”. However, the first steps towards this have already been taken.

The LAGA adhoc committee is working on this. First the definition of some basics had to be identified. For example, the definition of slopes and walls. The german “Deponieverordnung” contains barrier systems for slopes only. Till now walls have not been regulated. Because of this there is no need for a technical or geological barrier. Not only the non-regulation is a legitimation to omit the technical or geological barrier. There is a physical basis as well. In case of a vertical wall the sealing liner only has to prevent against percolating water. The design criteria for the landfill base and especially the drainage system have to assure that no circumstances are present which would allow a permanent filling of leakage water. Another important design detail is the connection between wall sealing and base sealing system.

Lastly a higher groundwater level from behind the wall sealing is not allowed. Otherwise technical solutions have to be installed. These are some of the important design criteria to be solved and have to gathered in a German regulation for sealing systems designed for vertical walls.

The vertical rock wall sealing in the basalt quarry in Nieder-Ofleiden to create landfill space for a mono-landfill of landfill class I for foundry sands was completed to a level above the fourth altitude. During this project, a great deal of experience was gained in regards to implementing such sealings, and it can be stated that safe sealing can be produced as long as comprehensive tests are conducted and constantly adjusted to an extraordinary sealing system for such rock walls.

ACKNOWLEDGEMENTS

The authors wish to thank Mrs. B. Schmitt-Biegel (HIM GmbH) and Mr. H. Krähling (OPG Offenbach) for putting the acquired data at disposal for publication.

REFERENCES

Bundesgesetzblatt: (2009). Verordnung über Deponien und Langzeitlager (Deponieverordnung – DepV), Ausfertigungsdatum 27.04.2009 – geändert 02.05.2013

BFM (2008) - Baugrundinstitut Franke-Meißner und Partner GmbH, Deponie Nieder-Ofleiden, Herstellung einer Basis-, Zwischen- und Felswandabdichtung im Deponieabschnitt II, Bereich DA II.2, 10.03.2008

BFM (2013) - Baugrundinstitut Franke-Meißner und Partner GmbH, Deponie Nieder-Ofleiden, Deponieerweiterungsabschnitte DA III und DA IV.1, 28.02.2013

Weiss, Witzsche (2011) New and alternative barrier systems – Quality Assurance during construction and efficiency control in the aftercare period (Germany) .In Sardinia 2011, B11: Landfill barrier systems, CISA Publisher, Cagliari, pp. 213-214 and CD.

Weiss (2014) Alternatives Barrieresystem für eine vertikale Wand einer DK I Deponie (Germany). 10. Leipziger Deponiefachtagung