Stabilization of Soft Tailings by Surcharge Loading for Re-Contouring of the Truenzig Tailings Pond of Wismut

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**Abstract**

Since 1991 the Wismut GmbH has been responsible for Truenzig tailings pond as one of the legacies of the uranium mining and milling left behind by the former Soviet-German Company (SDAG) Wismut. The stabilisation and remediation of the tailings ponds of the former uranium ore processing plants for the production of uranium concentrate (yellow cake) constitute one of the greatest challenges to the remediation effort in engineering as well as in ecological and financial terms. A central point of the remediation activities with tailings ponds is to control the re-contouring and covering of areas with the low consolidated fine tailings. The paper presents a case study of controlled tailings stabilization by surcharge loading for re-contouring of the tailings pond. Large embankment fills were placed stepwise on soft fine tailings on each partial pond to enhance the tailings consolidation along the future main trenches for runoff diversion on the final cover. The paper encloses the technical design, the monitoring system installed, the realization experiences made, measurements and modeling results from 2002 to 2010.

**The Wismut tailings pond legacies**

**Introduction**

Between 1945 and 1991 Germany was one of the world’s largest uranium producer. Especially in the eastern part, under control of and in cooperation with the former Soviet Union, the so called SDAG Wismut operated an important mining company. For the ore processing to uranium concentrate (yellow cake) two hydrometallurgical processing plants worked at the Seelingstaedt and Crossen sites (Figure 1).

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*Figure 1: Location of Wismut remediation sites*
Mill tailings at the Seelingstaedt site (State of Thuringia) were deposited into the Truenzig and Culmitzsch tailings ponds (TP). The facilities consist of two ponds for deposition of tailings either from the acid or alkaline processing. At the Crossen site (State of Saxony) mill tailings were deposited in the Daenkritz TP (small ponds) and at a later period in the Helmsdorf TP (single pond with carbonate tailings).

Table 1: Parameters of tailings ponds at Wismut GmbH

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Unit</th>
<th>Truenzig</th>
<th>Culmitzsch</th>
<th>Helmsdorf/Dänkritz</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tailings surface</td>
<td>ha</td>
<td>approx. 117</td>
<td>approx. 250</td>
<td>approx. 220</td>
</tr>
<tr>
<td>Total tailings volume</td>
<td>million m³</td>
<td>approx. 19</td>
<td>approx. 85</td>
<td>approx. 50</td>
</tr>
<tr>
<td>Tailings solids</td>
<td>million t</td>
<td>approx. 19</td>
<td>approx. 91</td>
<td>approx. 56</td>
</tr>
<tr>
<td>max. Tailings thickness</td>
<td>m</td>
<td>approx. 30</td>
<td>approx. 72</td>
<td>approx. 55</td>
</tr>
</tbody>
</table>

In 1991 the German Federal Ministry of Economics placed Wismut GmbH in charge of the remediation of sites and objects used by the former SDAG Wismut for uranium mining and processing operations. In addition to rehabilitation of the former uranium mines, the securing and long-term stabilization of the tailings ponds of the former ore processing plants constitute the greatest challenge to the Wismut remediation effort in engineering as well as in ecological and financial terms.

This paper provides a brief explanation introducing the principles underlying rehabilitation of tailings ponds and an outline of the case study of controlled tailings stabilization by surcharge loading for re-contouring of the Truenzig tailings pond.

The rehabilitation principle for the Truenzig tailings pond

In the nineties, extensive technical and economical analyses were done for a complete remediation of former Wismut legacies. Following these analyses of environmental benefit and costs, Wismut worked out a remedial concept that calls for dry in situ rehabilitation involving technical partial dewatering as the most appropriate option for the remediation of tailings ponds. This option was chosen because environmental impacts from the operations can be kept under control, the post-remediation risk is low, and the implementation can be carried out at comparatively lower costs over a defined period of time. The prospective remedial work was divided into the following main sequences:

- Freewater discharge and treatment
- Interim covering
- Contouring
- Final covering
- Landscaping
- Post-remedial monitoring and maintenance

The First main feature of the remediation option is the complete removal of pond water. These measures aimed at intercepting and treating pond water and seepage. Technical dewatering is also defined as the removal of pore water by technical drainage measures in order to ensure work safety during remediation operations and long-term stability of embankments and surface covers.
Second the placement of an interim cover layer is the initial step that will inhibit dust from dried tailings beaches. The interim cover also provides a platform for investigation and stabilization measures. As one of the most important functions the load of the interim cover accelerates consolidation processes within the tailings and reduces the period needed for remediation to complete.

After interim covering of exposed tailings (including soil-mechanical investigation results and detailed engineering designs) the tailings ponds will be contoured in order to construct a surface profile incorporating aspects of long-term stability.

The contoured surface will be capped by the final cover to reduce water infiltration and to give a basis for landscaping with vegetation as protection against erosion.

All sequences are accompanied by an extensive monitoring that continues in a post-remedial phase.

**Case study: Controlled tailings stabilization by surcharge loading for re-contouring the Truenzig tailings pond**

**Site history and conditions of Truenzig tailings pond**

In 1958 the construction of the Truenzig facility began on the site of the former uranium open-cast-mine Truenzig-Katzendorf (operated from 1949 to 1957) by building starter dams and embankments around the former mining area for the deposition of uranium mill tailings. The facility consists of two ponds for deposition of tailings either from the acid or alkaline processing. In its present state, the Truenzig facility is surrounded by embankments including the West dam, the North dam, the East dam and the Carbonate main dam as well as by heaps and natural slopes in the West and South.

During the operating life of the facility from 1960 to 1967, approx. 19 million m$^3$ of mill tailings were deposited at Truenzig TP, of which were 13 million m$^3$ of silicate mill tailings in pond A and 6 million m$^3$ of carbonate mill tailings in pond B. Discharge was initially from the crest of starter dams only. Over the years, the discharge area was extended in pond A as the dam was constructed at the entire northern front between the East dam and the West dam. During the operation of pond B, the discharge was from the crest of Carbonate main dam only. This explains the irregular vertical and horizontal layering of the tailings in the Truenzig TP. In the north of the facility, a relatively flat sloped tailings deposit consisting of sandy beach areas and the beginning of transition zones is overlaying the foundation. Tailings in the adjacent transition zone extending to the south are characterized by steeper slopes towards the basin centre. Tailings thickness increases towards the pond center to a maximum of 30 m in pond A and 20 m in pond B. After the end of the operations in 1967, the exposed sandy tailings beaches in pond A were mineral covered while the central fine tailings remained covered with water. Pond B was used for wastewater storage until 1990.

Remediation activities began in the early nineties with the staged removal of pond water and the placement of an interim 1 m thick cover to inhibit dust from dried tailings in pond A. The interim covering started in peripheral areas and finished in the center of pond A in 1995. In pond B the interim covering and pond water removal finished later in 2002.

Since 2001 the contouring of Truenzig TP is in realization with the dam flattening and plateau re-contouring to ensure a surface profile incorporating aspects of long-term stability.

In 2004 the final covering began on finished re-contouring areas.
Draft and development of the planned re-contouring option

The draft for the general re-contouring of the Truenzig tailings pond started with the examination of some different options for the contour design in pond A. As the result of the examinations a gentle valley with a substantially central east to west extending future main trench for runoff diversion was planned, where the surface water of pond A should be removed via an incision in the West dam. The preferred option was characterized by both a maximum incision in the West dam and a minimum amount of material needed for raising the surface along the main trench for runoff diversion. As best practice for raising the main trench area for runoff diversion a surcharge loading of contouring material was planned.

In advance of the planning a lot of geotechnical investigation measures and laboratory tests carried out to ensure the selection of the best option. On the basis of laboratory oedometer tests numerical analyses of the time-settlement process of the fine tailings in pond A were performed. Some test results of the void ratio–effective stress relationship of the tailings are presented with Figure 2. In addition the oedometer test results show, that the preparation of a stable surface for the main trench area, which consists of pure fine tailings with no sand deposits in it, will be impossible within the stipulated period without consolidation accelerating measures.

![Figure 2: Determination of input parameters for settlement prediction - compressibility](image)

Therefore it was planned to anticipate the predicted settlements by surcharge loading during the construction period combined with the installation of deep vertical drains, a horizontal drainage layer and associated drainage wells in the settlement sensitive pond area along the main trench. These measures shall ensure a continuous gradient of the main trench for runoff diversion at the end of the rehabilitation works.

On the basis of numerical calculations various configurations of vertical drains were evaluated as a safe option to achieve the needed acceleration of the time settlements. Resulting from these calculations it was decided to drive down vertical wick drains to depths from 5 to 25 m, considering, that the deepest vertical drains should be driven down to no more than 90% of total tailings thickness. The pond foundation should not be punctured to prevent pollutant discharges. The geotextile wick drains (width:
0.15 m, thickness: 0.01 m) were arranged in a triangular grid spacing of 3.0 m. With respect to the above mentioned oedometer data permeability and compressibility of the fine tailings were determined based on void ratios and water contents measured with depth. The individual drains shall act as sinks into which the tailings body will discharge via shorter drainage distances.

The embankment for surcharge loading was drafted with a length of approximately 750 m. The maximum thickness of the embankment was constructed on a 25 m wide strip and slopes of 1 : 5 on both sides. The width of the load deposit varies depending on the total height of the surcharge loading between 60 m and 135 m. The maximum thickness of the embankment is from 3.5 m to 11 m. The intended height of the loading contained the equivalent loading of contouring, final capping, required settlement compensatory measures and an additional temporary pre-loading.

**Practical preparation and realization of surcharge loading**

After technical planning and acceptance by the authorities in May 2002 the practical preparations for surcharge loading began with the construction of the horizontal drainage layer, stitching in the vertical wick drains and the pore water pressure sensors and installation of the settlement plates. Starting in January 2003 the embankment was built up stepwise along the future main trench. The construction phase ended in October 2005 followed by the idle phase with the embankment in place. During this phase the geotechnical evaluations were done as basis for the application for deconstruction of the overload. In the surcharge loading area we measured a complete decreasing of the excess pore water pressures. The deconstruction of overload masses along the main trench started after receipt of the acceptance by the authorities in October 2006. In November 2007 the deconstruction was completed.

The compensation loading distant from the trench proceeded until May 2009. The final capping including the installation of the main trench for runoff diversion on the final cover followed on the stabilized contour of pond A. These works will end in 2011.
Evaluation of the consolidation behavior

A comprehensive monitoring of the works by the geotechnical construction supervision was possible using instrumentation with pore water pressure sensors and settlement plates. The evaluation of the pore water pressure development related to the amounts of settlements was applied as the decision criterion for assessing the success of the construction work. Monitoring the settlements behavior and the pore water pressure development was carried out in the field based on the evaluation of 44 settlement points and 12 pore water pressure measurement points with 2 or 3 depth-dependent staggered sensors. To illustrate the measurement results, a common representation of the pore water pressure measurements with the amounts of settlements and the loading with time was prepared for each location. Figure 4 presents results for the measuring point 409P (sensors in a depth of 50 % and 80 % of total depth).
Figure 4: Development of pore water pressures and settlements due to loading

Results of pore water pressure and settlement measurements

The surcharge loading (started in January 2003) caused significant amounts of settlement, which were locally larger than the expected amounts. The surcharge loading also led to movements in horizontal direction. Smaller settlement portions observed at the same time in areas adjacent to the embankment might be explained by delayed consolidation-related vertical deformations. Right from the beginning of loading on fine tailings the pore water pressure increased as expected and alike the stiffness of the tailings. Since the completion of the final surcharge loading an almost linear increase of the amounts of settlement has been recorded. Since this time also a distinct bend and a subsequent decreasing course of the settlement curves can be perceived. A reliable criterion for evaluation and verification of consolidation progress was the decrease of excess pore water pressures with time. The approach to determine the equivalent permeability for the region of deep vertical wick drains in the numerical calculations could be confirmed in this case.

The main trench for runoff diversion from pond A is oriented East – West. An evaluation of the settlements in the main trench area is shown in Figure 4. Until the mid of 2006 the measured amounts of settlements were in accordance with amounts predicted with the construction planning. The amounts in the central area between the measuring points 421S and 427S were significantly larger than expected, while in the western area smaller amounts were measured. The surcharge loading caused vertical deformations. The spread of the tailings compressibility, however, was generally within the expected range of the settlement calculations.
In average, we measured an additional amount of settlements of approximately 10 % more than predicted. This result means only a small deviation from the calculations. The evaluation of the monitoring carried out in mid 2006 showed the following results:

- The excess pore water pressure values decayed by almost 90% in the main trench area. The largest values were measured near the surface and nearby the dewatering well.
- The time related pore water pressure decayed as planned or slightly faster, which could be due to the actually realized construction progress.

**Conclusions**

The partial deconstruction of the embankment for surcharge loading was approved by the authorities on the basis of the evaluation of the above monitoring results. During the layer-wise deconstruction of the embankment in pond A from 2006 to 2008 the excess pore water pressures completely decreased and settlement stability was achieved. All sequences were accompanied by an extensive monitoring of pore water pressures and settlements that continues for the final cover placement and the installation of the main trench for runoff diversion.

**References**

Wismut GmbH, 1999. Determining of soil mechanical parameters for settlement modeling of the tailings pond Truenzig A on the basis of the drill holes SA 29 to SA 43