THE APPLICATION OF GEOSYNTHETICS IN THE REHABILITATION OF TAILINGS PONDS AT WISMUT GMBH

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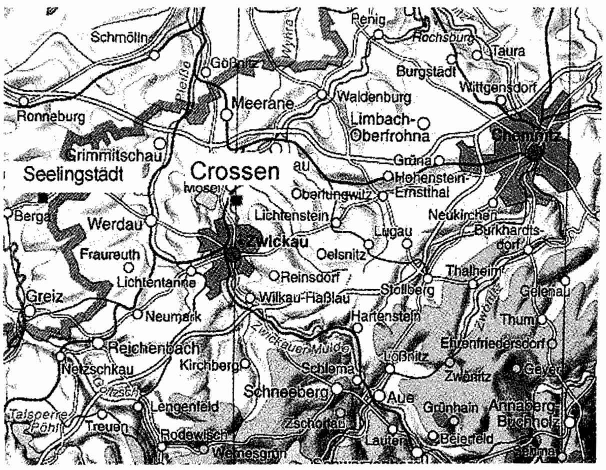
INTRODUCTION

In 1991 the German Federal Ministry of Economics placed WISMUT GmbH headquartered in Chemnitz (South East Germany) in charge of the rehabilitation of sites and objects used by the former SDAG WISMUT for uranium mining and processing operations.

In addition to remediation of underground and open-cast mines, the stabilisation and remediation of the tailings management facilities (TMF) of the former Seelingstädt and Crossen ore processing plants (Figures 1 and 2) constitute the greatest challenge to the WISMUT remediation effort in engineering as well as in ecological and financial terms.

The former SDAG Wismut operated two hydrometallurgical processing plants at the Seelingstädt and Crossen sites for the production of uranium concentrate (yellow cake).



Figures 1 and 2. Location maps of former processing plants of Seelingstädt and Crossen.

At the Seelingstädt site (State of Thuringia), mill tailings were deposited into the Trünzig and Culmitzsch tailings ponds. Both facilities consist of two basins for deposition of tailings either from the acid or alkaline processing.

Mill tailings from the Crossen plant near Zwickau (State of Saxony) were deposited in the Dänkritz TMF (small ponds) and at a later period in the Helmsdorf TMF (single pond with carbonate tailings).

Parameter	Unit	Trünzig TMF (Basin A + B)	Culmitzsch TMF (Basin A + B)	Helmsdorf TMF
Tailings surface	ha	approx. 117	approx. 250	approx. 200
Total tailings volume	million m^3	approx. 19	approx. 85	approx. 45
Tailings solids	million t	approx. 19	approx. 91	approx. 49
max. Tailings thickness	m	approx. 30	approx. 72	approx. 55

Table 1. Parameters of tailings management facilities at WISMUT GmbH.

A brief explanation introducing the principles underlying rehabilitation of tailings management facilities, will be followed by an outline of the application of geosynthetics in the interim cover at the Helmsdorf site, location of the largest tailings pond of WISMUT GmbH.

REMEDIATION OF TAILINGS MANAGEMENT FACILITIES AT WISMUT GMBH

Following an analysis of environmental benefit and costs, the WISMUT remedial concept calls for dry in situ rehabilitation involving partial dewatering as the most appropriate option.

Major features of the remediation option include complete removal of pond water, measures aimed at intercepting and treating pond water and seepage as well as placement of a complex (multilayer) cover and contouring. Technical dewatering denotes removal of tailings pore water by technical means in order to ensure work safety during remediation operations and optimum long-term stability of embankments and surface covers.

A multi-layer cover system will be used in the capping of tailings. Placement of an interim cover layer is the initial step that will inhibit dusting from exposed tailings beaches. The interim cover also provides a platform for investigation and subsequent stabilisation measures. Over and above that, the load of the interim cover accelerates consolidation processes within the tailings and reduces the period needed for remediation to complete.

Following interim covering of exposed tailings (including investigation results and peripheral engineering designs) the TMF will be contoured in order to establish a long-term stable surface profile which will serve as the basis for the final cover. In this effort, interrelations due to real site conditions and connections with other remediation objects are to be given primary attention. Figure 3 shows the typical sequence of individual remediation steps.

- Inmediate remediation work (interim covering of exposed tailings beaches, seepage collection, analysis of dam stability during remediation period).
- Water treatment, discharge, water management (surface runoff, temporary collection of expelled pore water).
- Interim covering of exposed tailings surfaces.
- Contouring of tailings surfaces and dams.
- Final capping of contoured surfaces.
- Landscaping and rehabilitation.
- Post-remedial monitoring.

Figure 3. Sequence of remedial steps.

Tailings were deposited in the TMF via pipes from varying perimeter discharge points. During sedimentation of solids, part of the transport water was returned to the processing plant. Sedimentation of the tailings slurry was accompanied by classification of the material with coarse fractions sedimentating close to the perimeter and tailings fines in the pond centre. As a result, tailings beaches at the perimeter showed good bearing strengths followed by a transition zone and weak fine tailings (unconsolidated, highly water-saturated) in the centre.

Figures 4 and 5. Interim cover of geosynthetics and waste rock.

Placement of an interim cover on tailings beaches with high bearing capacity uses drainable waste rock material but no geotechnical products. Extension of the interim cover towards the pond centre, however, requires special measures to be taken in order to ensure investigation safety and stable covering of the soft areas. According to comprehensive practical experience use of geofabrics, geogrids, sand mats, and vertical wick drains will not only allow erosion protection and investigation of tailings layers having low initial shear strengths, but also permit placement of a mineral cover layer with shear strengths still being low (in the order of approx. 5 kPa in upper layers).

USE OF GEOSYNTHETICS IN THE INTERIM COVERS AT THE HELMSDORF TMF

Conditions at the Helmsdorf site

Construction of the Helmsdorf facility began in 1957 near the former village of Helmsdorf (north of Zwickau) by building embankments across two valley locations for the deposition of uranium mill tailings. In its present state, the Helmsdorf facility is surrounded by 6.5 km of embankments including the Main dam, the West dam and the Wüster Grund dam as well as by natural slopes in the South. Current interim cover placement activities focus on the Northern edge of the facility where shallow tailings areas are bordering the dams. The water treatment plant that processes pond water and seepage alike is located at the south-west of the facility.

Figure 6: Aerial view of the Helmsdorf TMF.

During the operating life of the facility from 1958 to 1989, approx. 45 million m^3 of carbonate mill tailings were deposited at Helmsdorf. At the beginning, discharge was from the crest of the main dam only. In later years, the discharge area was extended to the entire Northwestern front between the main dam and the west dam. This explains the irregular vertical and horizontal layering of the tailings in the Helmsdorf TMF. In the north of the facility, a relatively flat sloped tailings body consisting of sandy beach areas and the beginning of transition zones is overlaying the original valley morphology. Tailings in the adjacent transition zone extending to the south are characterised by steeper slopes towards the basin centre. Tailings thickness increases from north to south and from west to east exceeding 40 m. At a limited location near the south of the main dam, tailings thickness reaches a maximum of about 55 m.

Application of geosynthetics

Tailings deposition techniques caused classification of the tailings material. As a result of more rapid consolidation processes occurring in areas of mostly sandy tailings located near the embankment, these areas show more favourable bearing capacities than mainly silty and silty-clayey areas in the basin centre. Therefore it was possible to directly place cover material onto perimeter tailings using light-weight construction equipment.

As grain size declines with increasing distance from the point of tailings discharge, geotechnical parameters also get worse. The load induced by the self-weight of the placed cover fill and of vehicles might therefore cause failure of underlying tailings and/or of tailings slopes. For this reason, measures to increase bearing capacity are indispensable following careful geotechnical investigations of conditions in lower tailings layers.

For the benefit of example, Figure 7 shows the typical cross-section of an interim cover at the Helmsdorf TMF using geotextile materials and waste rock.

The subsequent description of interim cover placement will address details of geosynthetics applications such as:

- geofabrics and sand mats to stabilise exposed tailings surfaces
- geogrids to increase bearing capacities, and
- vertical wick drains to accelerate consolidation.

Application of geofabrics

Placement of an interim cover follows purposeful removal of pond water which will be processed in a water treatment plant prior to discharge. Tailings surfaces exposed as the pond water level diminishes will be stabilised by geofabrics which will be rolled out as the initial step of interim cover placement. Placement of the geofabrics will inhibit potential wind-blowing of sandy fractions from the tailings surface at strong wind events and allow man access to surficial tailings.

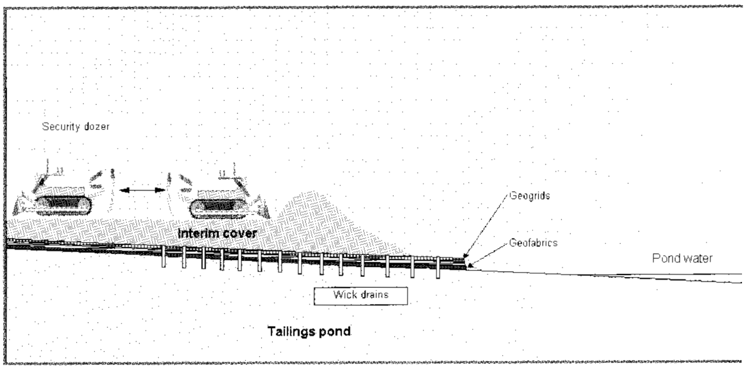
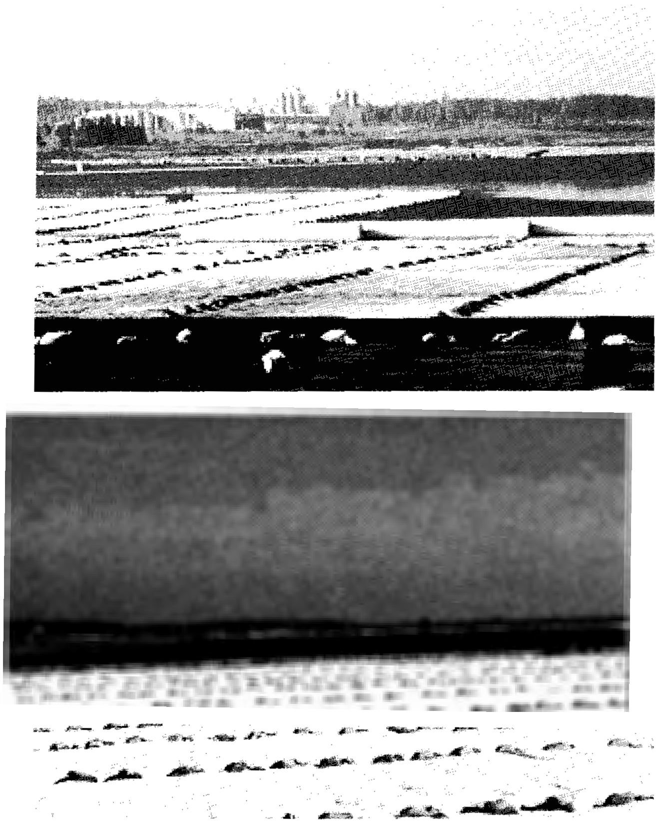


Figure 7. Interim cover design.



Figures 8 and 9. Geofabrics deployed on the Helmsdorf TMF.

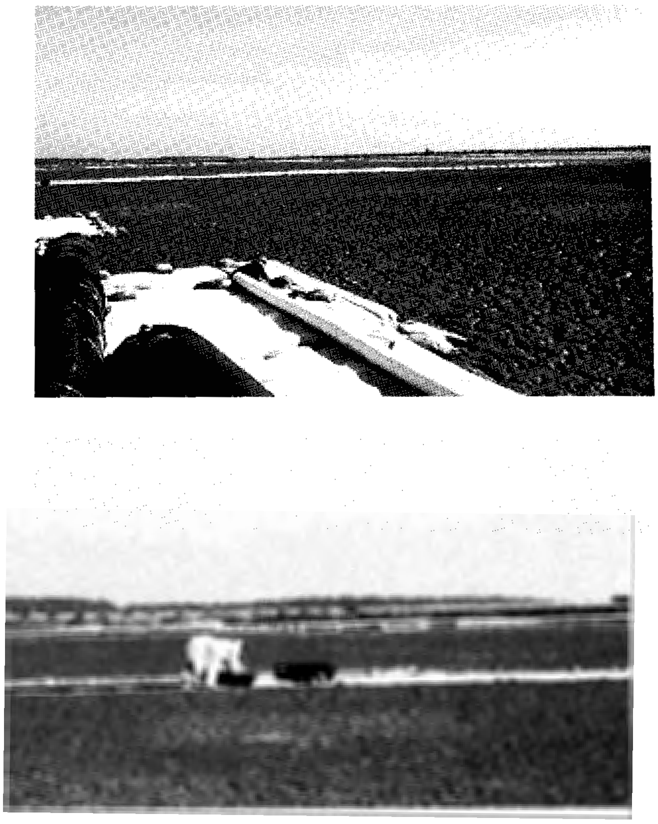
Geofabric panels of 100 m x approx. 6 m (thickness approx. 0.003 m) are delivered in rolls. As soon as tailings surfaces have dried up as a result of pond water edge retreat, geofabric rolls are placed onto existing fabric to run parallel to the shore line and then are rolled out perpendicular to the shore line towards the basin centre. A minimum requirement is man access to the tailings on load distributing geofabric panels. Remediation workers only move on rolled out geofabrics. Fabric layout ensures overlapping of 0.5 m at extensions and along panel seams.

Geofabric layers typically are covered by soil material immediately after placement. On the tailings pond, however, geofabric panels are exposed during the entire period of stabilisation work (e.g. placement of geogrids and installations of vertical wick drains) and investigation operations (shear vane testing to establish undrained shear strengths). Hence, the panels are exposed to insolation for weeks or months, respectively. The essential criterion next to their mechanical stability (geogrids are the reinforcement elements par excellence) is therefore the panels' resistance to UV radiation over such mid-term periods.

Geofabric panels are weighted by sand bags in order to ensure their reliable fixing and enhance their protective function against dust emissions in case of strong wind events. At a later stage, these sand bags will be placed on the geogrid level where they will be integrated into the cover fill.

Application of geogrids

Geogrids will be deployed on top of the geofabric level. Geogrids allow safe conduction of investigation work and the use of low ground-pressure equipment and constitute an important stability element for installation vertical wick drains and especially at the time of fill placement. The polypropylene grid panels measure 30 m x 4 m and are delivered in rolls. The placement pattern is similar to that of geofabrics. Panels are deployed manually towards the pond water edge with 0.5 m overlapping (extensions and seams). In this case too, workers only move on just rolled out grid panels. Geosynthetic panels then are seamed by positive and negative shedding.



Figures 10 and 11. Geogrid placement at the Helmsdorf TMF.

In the light of the typically extreme low bearing capacity of tailings during the period preceding fill placement and of the ensuing risk of bearing capacity failure and of sinking in of workers, equipment and fill material, it is of crucial importance to use geosynthetics of multidirectional load distribution. Geogrid panels have to be designed to support any equipment load required for the implementation of investigation work and wick drain installation. Fill placement uses waste rock material in a layer thickness of up to 2 m. In addition to this, the design computation will have to take construction equipment (low-weight swamp dozers) and its ground pressure at close distance to the advancing edge into account. Biaxially stretched rigid-knot geogrids are most suitable for such requirements, in particular for two-dimensional load distributions.

Following deployment and fixing of geogrid panels, undrained shear strengths are established at spacings of 20 or 10 m by means of a vane and torque measuring device. Vertical sampling is in intervals of 0.5 m down to depths of 6...10 m. This allows to thoroughly test the area relevant to the stability of the intended fill placement.

Evaluation of test results follows an interpretation procedure established in 1997 with regulatory approval for stability analysis of interim covers. The shear strengths established are integrated into the static model by relating them to crosscuts perpendicular to the fill edge. Stability calculations include anticipated loads, tailings slopes, geotechnical means and other boundary design conditions.

Results of test loadings were used to investigate and calibrate the geotechnical model up to the critical area of bearing failure. Conditions existing in the test field at the point of failure (among others no geogrid, full water saturation) were described in the back analysis by stability coefficients which fell very closely below 1.0. Simulated use of geogrids (e.g. assumption of 40 kN/m net tensile strength with all diminution coefficients included) identified increased safety margins of approx. 40% for the process of fill placement.

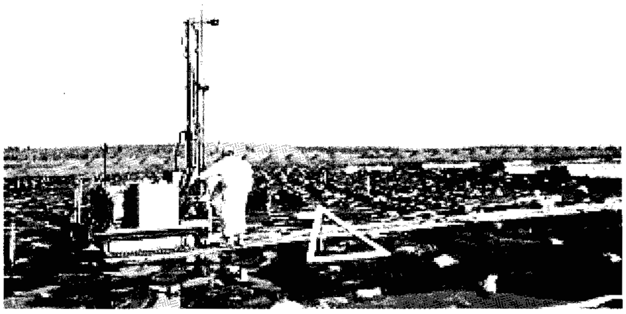
Application of vertical wick drains

Application of vertical wick drains is decided in the light of shear vane tests. In silty tailings or in tailings with alternate silty beddings these drains accelerate dissipation of load-induced pore water pressures and increase shear strengths in tailings layers relevant to stability.

Geotextile wick drains (width: 0.15 m, thickness: 0.01 m) are used upon tailings surfaces. Vertical wick drains are pushed down in a pattern of approx. 3 m drain/m^2. Typical spacing is 1.5 m in a equilateral triangle. In line with shear test results, the drains are pushed down to an average depth 5...8 m. Reduced spacing and installation depths were also investigated at other tailings sites which show different site conditions and consolidation properties.

Installation of vertical wick drains into interstratified tailings currently being covered and located between the beach area and the fine tailings zone at the Helmsdorf TMF will increase permeability within the lateral layering of the tailings body. This effect may cause shear strength increases in the layers encountered even without the placement of a surcharge load. Prior to fill placement the individual draining points will act as sinks into which the tailings body will discharge via shorter drain distances. Following desiccation of surficial tailings (appearance of a crust), the drains will provide the conductivities required for the pore water to be expelled to the tailings surface.

The situation is different in the slimes zones of tailings management facilities. Permeability and compressibility of fine tailings is determined by their relatively elevated pore ratios and water contents, respectively. Because void ratios are greatest in surficial layers, the greatest consolidation portion or shear strength increase, respectively, can be achieved in those areas. Peak hydraulic gradients develop during the dewatering process in the immediate vicinity of the drain. Therefore, the reduction of pore ratios and moisture contents will successively propagate from the drain. A more closed spacing and reduced installation depth of vertical wick drains will be more suitable for these conditions to be encountered as fill placement proceeds.



Figures 12 and 13. Installation of vertical wick drains.

Use of sand mats

Over and above of the typical interim cover design described above for the Helmsdorf TMF using geotextiles and waste rock material, sand mats are deployed across areas unsuited for waste rock fill for mainly geotechnical reasons in order to protect them against erosion and to ensure man access.

The diminishing pond water level exposes such zones in the South-east of the Helmsdorf facility. Due to their slope angle, their exposed situation and westward orientation, these zones near the embankment are exposed to windward wave attack. This wave action causes removal of predominantly sandy tailings from the water edge and their sedimentation mainly at the toe of the slope. Major wave events and the receding pond water level had created a stepwise profile on the slope.

In order to inhibit erosion by wave action, geotextile sand mats were deployed on the slope. These sand mats consist of sand-filled quilted geofabrics which are approx. 0.01 m thick and have a unit weight of approx. 6 kg/m^2. The mats are delivered in rolled panels of 30 m x 5 m.

Figures 14 and 15. Preparation and placement of sand mats.

Construction equipment ashore and an amphibious vehicle are used for the subaqueous placement of sand mats. The sand mat reel is picked up by a light-weight crane and placed in a delivery arrangement attached to the shovel of a low ground-pressure dozer. The dozer and the delivery arrangement are positioned perpendicularly to the placement edge. Prior to placement, the sand mat is stabilised by two flat irons bolted along the brim. Then a pulling rope from the amphibious vehicle's winch is attached to the sand mat.

GPS control enables the amphibious vehicle to adopt a position which is exactly in line of delivery progress. A cable winch at the amphibious vehicle slowly unrolls the sand mat and pulls it across the beach area into the pond water. Applied weight elements (e.g. sand bags) act to control slow and steady submersion into the pond water, while the total 30 m of the mat's length is deployed over the slope. GPS positioning of the delivery arrangement ashore and of the amphibious vehicle ensures minimum map overlapping of 1 m.

Figures 16 and 17. Delivery and submersion of sand mats.

As the pond water level continues to decrease since the first mat placement, the exposure of originally subaqueous slope areas testifies to the accuracy and quality of the test submersion of sand mats. Slopes in the area of wave attack have been protected against unintentional material removal since then.

SUMMARY

The application of geosynthetics in designing the interim cover of WISMUT-TMF's was represented in preceding examples. The design for specific use of geofabrics, geogrids, vertical drains and sand mats under the present geotechnic conditions have become a successful part in realizing the interim cover.

The common task is to adapt the use of geosynthetics on developed technologies for covering fine tailings with always more complicated geotechnical starting conditions. Technical procedures like the thin-layer technology or the subaquatic placement are common investigation points also with regard to the helpful application of geofabrics.