Using Geosynthetics for Safety Mine Closure, Closure of Mining and Milling Residues and for Groundwater Protection

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Abstract
The reclamation of abandoned (or orphaned) mine sites requires a sustainable design accommodating the ecological and economical conditions, the possible course of construction works and the planned follow-up utilization. In the last two decades geosynthetics have been playing a substantial role by meeting high technical requirements and thus allowing the realisation of complex specifications under economical and also safety aspects. As two-dimensional products with a low mass per unit area and a low volume, geosynthetics can be easily integrated into the construction works, even over longer construction periods and under changing weather conditions. Besides sealing components (barriers), filtration, separation and reinforcement functions can be accommodated. A good integration of geosynthetics into the geotechnical constructions of closure works can support its long-term stability. This paper shows only several examples of the successful application of geosynthetics fulfilling the multiple requirements in the remediation of abandoned mine sites over the last two decades.

Key words: mine water and seepage water, mine water collection system, groundwater protection, tailings ponds, geosynthetics, geofilters, uranium mining and milling sites reclamation, radiation protection, open cast refilling, cover systems, safety mine closure, reclamation of mining and milling sites, covering of mining and milling residues, waste rock piles and mine residues dumps stabilization, reinforced earth construction, slurry dumps, long-term performance, long-term stability, long-term remediation tasks

Mine closure works
After the collapse of the Soviet Union and their allies, most of the uranium mining and milling sites were closed, also in Eastern Germany in the Wismut region. The legacies of the uranium production had to be rehabilitated in a safe and ecologically sustainable way. So it was decided to rehabilitate the tailings ponds by using the dry in-situ-method and to cover it by means of geosynthetics.

Reclamation of mill tailings ponds
The dry in-situ-method includes the steps: - pump off free water to the water treatment plant; - stabilization and dewatering of tailings; - covering of interim cover; - construction of the collection system for tailings water with water, - treatment plant; - the final cover with profiling of the site; - planting of grass and trees.
The stabilisation of the tailings surface was carried out with different layers of geosynthetics (see Fig. 1). The layers of geosynthetics include the functions:- stabilisation, capping of the contaminations and dewatering of the tailings. Through the stabilisation with geosynthetics of the tailings surface in connection with a small layer of minerals, the shear strength increased from < 2,5 kN/m^2 up to > 15 kN/m^2. Now it was possible to install the interim cover of mineral layer with machines and so on. The function of dewatering the tailings is fulfilled by installing vertical drains into the tailings, see M. Lersow, 2006. The covering with a combination of nonwovens/drainage mats, geogrids and vertical drains in connection with available soil materials has been proven to be the most economical and efficient construction method as to the construction techniques. Geogrids take over the static stabilization in this design.

Figure 1 *Interim cover on low bearing spigotted tailings beach (norm dimension 2), M. Lersow, 2006*

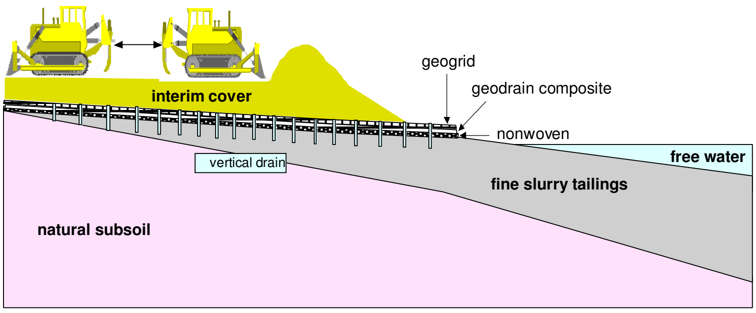


Figure 2 *Installation of vertical drains*

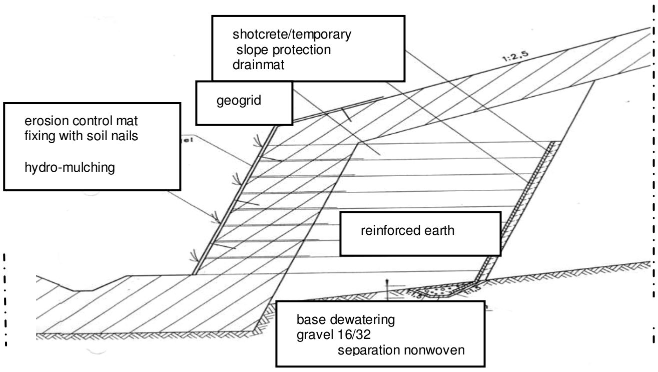
Figure 3 *Stabilization of bank areas by means of sandmats*

Before installing the geogrids, a separation and filtration nonwoven is laid on top of the tailings pond; in the later covering, this nonwoven will separate the fine slurry and the gravel. In order to ensure a sufficient safety for the construction staff, their equipment and for the cover, the employed geogrids must have a high flexural rigidity at low elongation as well as a high chemical and UV resistance. The geotechnical design has been described by Reuter et al. (2002) and defines the state-of-the-art for comparable applications. Other experiences led to the development of a geogrid with integrated geotextile (Combigrid) which allows a higher installation performance. In order to accelerate the consolidation of the subsoil in deeper layers, more than a million meters of specially developed Terrafix vertical drains have been supplied by NAUE GmbH & Co. KG to WISMUT GmbH since the beginning of the remediation works. These 15 cm wide vertical drains with a drainage core made of polypropylene and a filter nonwoven on both sides, made of polyester, are stitched into the tailings in a triangular pattern of 1.5 m up to a depth of 5 to 8 m (Fig. 2). In the direct transition area between the silt zone and the flat water area, stable sand mats Terrafix B 813 were used which were laid out up to the underwater region. This could prevent erosion caused by current forces and wave attacks. Figure 1 shows how the different geosynthetic elements were inserted in the whole geotechnical cover system. They are important elements for dewatering of the high grade contaminated uranium mill tailings and also an important factor for the consolidation and the long-term stability and safety of the whole cover system.

Remediation of waste rock dumps

In the mining town of Johanngeorgenstadt in the Erzgebirge region (close to the Czech border), from 1850 on mainly Wismut, cobalt, nickel and uranium were mined. In the time from 1945 to 1958 the intensive mining of uranium caused large impacts for the town: large slurry dumps in the town center, and subsidences resulting from these slurry dumps made the demolition of large parts of the old town necessary. Since the abandoned mine sites were not included in the Wismut law, the slurry dumps remained uncovered for a long time and the inhabitants were exposed to the leaking radioactive noble gas radon. From 2003 on the dumps were covered, and a reinforced earth construction with geogrids was used to stabilize the dump side slopes. In this special case, a 1 m thick clay sealing as radon protection had to be integrated into the reinforced earth construction in the front area performing statically. In experimental tests for this construction, specific values for the interlocking between the geogrid and the soil were determined in addition to the design approach. These specific values were taken as basis in analytical and numerical tests, and the results show that the reinforced earth construction achieves the required safety level. This construction prevented also that surface water seeps into the waste rock dumps. Additionally, on the slope base a surface drainage for the surface and seepage water was installed. So this water can be collected and drained off safely.

Figure 4 *Cross-section slope*



The reinforcement of the construction consists of 14 geogrid layers at horizontal distances of 0.4 m and with an embedment length of approx. 4 m per layer, thereof 3 m in the slope fill. In the area of the slope face, bended steel grid elements are installed directly on top of the geogrid reinforcement, and a sufficient interlocking between the steel grid and the geogrid has been proven. The steel grid elements in the facing area are lined on the inside with a separation nonwoven Secutex 251 GRK 4 preventing a rippling of the soil and providing a carrier material for the vegetation after termination (Fig. 6). With this solution the geotechnical requirements as to the statical stabilization of the dump side slope as well as to the geometrical characteristics at the bottom of the slope could be met in an economical way.

Figure 5 *Detailed system cross-section*

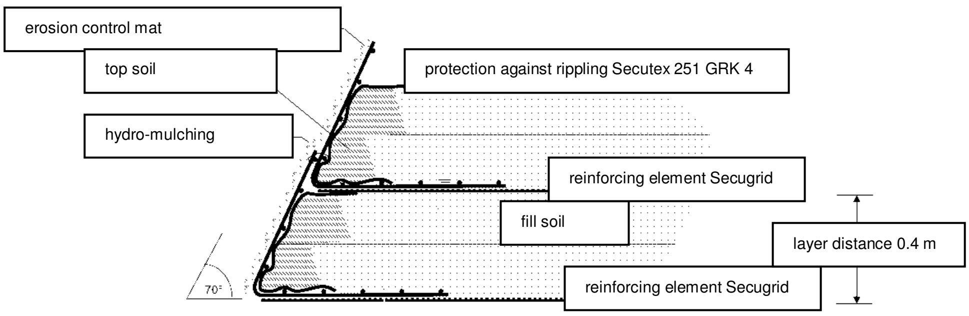
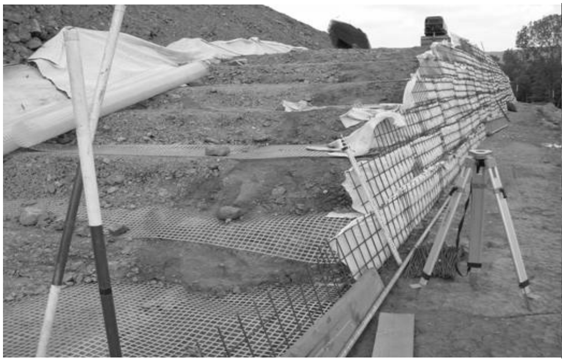


Figure 6 *Construction* ***Figure 7*** *Vegetation stage*



Remediation of backfill areas – Design for remediation of backfill areas prior to flooding

During the remediation and the later flooding of the former brown coal mining site Muecheln in the "Mitteldeutschland" mining area, the special task occurred to remediate the abandoned site of highly contaminated soil materials which due to their extent and the kind of contamination could not be removed, but had to be kept on site. To prevent a leaking of the hazardous materials into the later flooding of the entire mining site which would forbid a utilization as recreation area, a technology had to be found which would accommodate a safe storage of the hazardous material beneath the future pond ground. The plan was to seal the contaminations with a fine grain and extremely cohesive coal dust. This coal dust should be installed in a thickness of 0.5 m, and onto it a surcharge layer in a thickness of 1 m should be installed as upwelling and erosion control. But due to the extremely low subsoil stability of the former tailing pond, a special technology was needed to install the coal layer. The subsoil was partially so bad that even chain-tracked vehicles with a limited soil pressure of 40 N/m² drowned into the subsoil so deeply that the coal and soil materials could only be distributed by means of tracked vehicles. To provide stability for the vehicles to install the cover layers, additionally a sufficiently strong geogrid had to be installed in an area of approx. 100,000 m^2. The selected geogrid was Secugrid 80/80 Q6 which is a laid geogrid made of stretched monolithic PET flat bars. With its maximum tensile strength of ≥80 kN/m (md and cmd) and a tensile strength of 36 kN/m at 2 % elongation, this geogrid meets the high technical demands of the tender. Thus the use of high quality geosynthetics provided a safe and efficient storage of contaminated materials in time and the flooding of the lake Geisseltal can continue, it will be the largest artificial lake in Central Europe with its size of 18.4 km^2.

Figure 8 *Installation of geogrids* ***Figure 9*** *Laying of sealing material with tracked vehicles*

Summary

In the reclamation of former mining sites geosynthetics have proven to be essential construction elements excelling in economical, ecological and technical construction methods. Some projects would not have been feasible without geosynthetics. The experiences in the remediation of the impact of uranium mining sites in Eastern Germany may be trend-setting for other projects of this kind all around the world. In this paper only a small selection of the application possibilities of geosynthetics with the closure and follow-up utilization of abandoned mine sites are given. Thus our large, positive experiences have to remain unconsidered in the ranges stabilization of voids from mining works (stabilization of mine shafts and protection of traffic areas in former mining sites).

References

Daenecke, R et al. (1999) The application of geosynthetics in the rehabilitation of tailings ponds at Wismut GmbH, Water & Environment, 1999 IMWA Congress, Sevilla, Spain

Oswald, KD et al. (2006) Bewehrte Erde mit integrierter mineralischer Dichtungsschicht am Beispiel der Sanierung der Zentralschachthalde Johanngeorgenstadt. Bautex 2006, Chemnitz, Germany

Lersow, M (2006) Verwahrung von Wismut Tailing Ponds und Dekontamination der Frei-, Poren- und Sickerwaesser, 57. BHT, TU Bergakademie Freiberg, Deutsch-Polnisches Bergbauforum

Reuter, E et al. (2002) Geotechnische Entwurfsbearbeitung zur Überbauung von Schlammteichen und Tailings. Bauingenieur Band 77

Saathoff, F, Vollmert, L (2005) Sicherung von Bauzuständen durch Geogitter am Beispiel der Überbauung des Aschespuelteiches Tagebau Muecheln Conference Proceedings 2. Symposium Umweltgeotechnik DGGT, TU Freiberg