GEOSYNTHETICS FOR DEWATERING AND COVERING OF TAILINGS SLUDGE

Expert paper
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Abstract: *There are several methods used for tailings disposal and the most common method is the disposal of tailings slurry in impoundments. Modern impoundments are engineered structures for tailings disposal. The management of tailings facility includes different phases such as planning, design, construction, operation, closure and long term after care. Geosynthetics have been used successfully for mine related applications including the capping of sludge lagoons, geogrid reinforcing of retaining structures, including dam walls, reinforcement of access roads, and lining of tailings storage facilities. This paper introduces the concept of permanent safe closure of tailings ponds through geosynthetic capping system and of dry tailings storage through the use of geosynthetic dewatering tubes. The basic working principles and a case study of remediation of tailings pond from uranium ore treatment.*

Key words: DEWATERING TUBES, GEOSYNTHETIC CAPPING SYSTEM, WOVEN GEOTEXTILE, TAILINGS POND

INTRODUCTION

Tailings, by ICOLD's definition [5], include all waste material (or "tail" products) from any activity. There are several methods used for tailings disposal and the most common method is the disposal of tailings slurry in impoundments. Modern impoundments are engineered structures for tailings disposal where actual designs are highly site-specific [4]. Many factors should be taken into account such as the characteristics of the tailings, the climatic, topographic, geologic, hydrogeological and geotechnical characteristics of the disposal site, regulatory requirements and to environmental [10]. More recently, with the structural failures of tailing storage facilities concerns have been raised about the stability and environmental performance of tailings dams and impoundments.

Geosynthetic dewatering tubes provide an environmentally sustainable solution for the dry storage of tailings. The use of geosynthetic tubes is one alternative method that can be used to dewater large quantities of sludge and at the same time create a stable structure for the permanent containment of the tailings [11]. This solution has been implemented successfully in the Talvivaara Mine since 2013 were the geosynthetic dewatering tubes are used as permanent storage of the gypsum tailings.

On the other hand, inactive tailings impoundments also are receiving more attention. One of the main concern is that due to the rainfall infiltration the material inside the impoundment never reaches a completely solid state so that the lining system or a dam failure always can cause the uncontrolled release of toxic sludge [9]. Other long-term effects of windblown dispersal, ground water contamination, and acid drainage should be also taken into account. In many cases, the costs of remediation can be considerable, exceeding the costs of original design and operation of the tailings impoundment [10]. Most of the time, mining sites and the environmental problems associated with them are in the care of public institutions. The aim is to consider closure and reclamation design into account for old mining sites and to design them from the early beginning of the project for the new ones. Therefore, closure and reclamation considerations have become the most important driving factors in the selection of the site, design, and permitting of mining projects [1].

Capping systems represent one of the most common remediation technique. Nevertheless, the construction of a cover system on top of a weak and heterogeneous tailings can be a challenge and the use of geosynthetics in such systems provides the most economic and feasible solution.

In this paper, the remediation concept of geosynthetic sludge lagoon cover system is presented and the application to the settling basin of residues of the uranium ore treatment of the Wismut company is described.

THE DEWATERING TUBE SYSTEM

Geotextile tubes are large high strength textile modules whose function is to retain and consolidate the solids while the water flows out from the geotextile shell. Geotextile tubes are manufactured using high tensile strength fabrics, assembled into a tubular shape with a customized length, width or height.

For treatment the processed sludge is pumped into the geosynthetic dewatering tube. Within this geotextile containment and dewatering element the solid-liquid separation takes place. Due to the particle retaining ability of the fabric, the solids deposit inside the tube and the water is able to drain as a result of the fabric permeability. Initially the process is mainly a suspension filtration. During this period small amounts of fines might escape the tube. After the initial startup phase of tube operation a natural filter cake develops on the inner side of the tube shell. This significantly increases the degree of separation. Practically, dewatering by means of geosynthetic tubes comprises a cyclical process, schematically shown in Figure 1. During the first filling cycle the dewatering tube is filled to the given maximum initial design height, and the filling is stopped. The static drainage of the sludge commences as soon as the filling process is halted and following a degree of dewatering the tube can be re-filled. During this cycle the water within the sludge is extracted, therefore the volume is reduced and the solids concentration of the residual dewatered material is increased. The principal process is repeated until the tube is completely filled. If the tube stays in place for an additional period of time, a subsequent consolidation and further desiccation occurs.

Finally, the tube can be opened and the dewatered material with a solid state can be re-used or disposed. A substantial advantage of the dewatering tube system is the stacking availability. By arranging the single tubes in a pyramidal stacked group pattern with several layers the footprint can be effectively reduced and the storage volume increased.

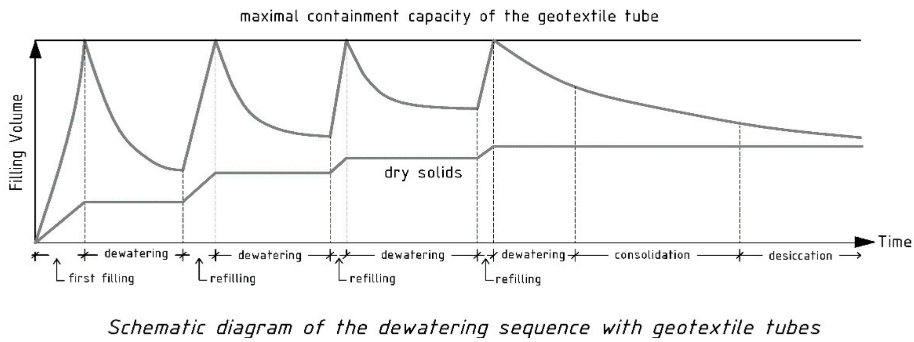

Figure 1, Schematic dewatering cycle by use of geosynthetic tubes (adapted and modified from Lawson [7]*)*

The main system components required for operation are briefly explained in the following sections.

DEWATERING TUBES

After filling dewatering tubes are almost elliptically shaped long geotextile containment elements designed with a dewatering and storage function. By use of high strength seams for connecting the specifically developed filter fabric sheets, this tubular element is formed.

Normally dewatering tubes are furnished with inlets, distributed along the longitudinal axis of the tube. The tube filling is undertaken through these nozzle inlets with the processed slurry.

FLOCCULATION AIDS

There are several ways to agglomerate fine suspended solids in order to increase the water release capacity and enhance the dewatering performance of slurries. Two basic physical bonding or agglomeration principles exist: coagulation and flocculation.

DEWATERING AREA

The dewatering tubes have to be placed on a prepared area which is capable of bearing the expected loads. Additionally, the dewatering area has to allow for sufficient drainage capacity of the effluent water. Normally the dewatering pad consists of a containment bund, a flexible membrane liner and a gravel drainage layer (rounded gravel e.g. 16/32 is preferable). The protective gravel layer is optional and is beneficial if the prepared area is going to be used for several dewatering tube cycles.

IMPLEMENTATION OF DEWATERING TUBE SYSTEM AT TALVIVARA MINE

The Talvivaara Mine is considered to be the largest opencast nickel and zinc mine in Europe. In November 2012, the mine experienced a leak in their gypsum ponds that was quickly located. As response to this problem, the use of geosynthetic dewatering tubes as a remediation solution was adopted.

Figure 2 shows a typical geosynthetic tube installation with pyramidal stacking pattern on top of the dewatering areas. The areas are lined with a 1.5mm to 2.0mm thick HDPE geomembrane. The recommended maximum slope inclination was taken into account. For discharge of the filtrate a lined drainage trench was incorporated into the field. Apart from one field the standard dewatering area geometry is rectangular.

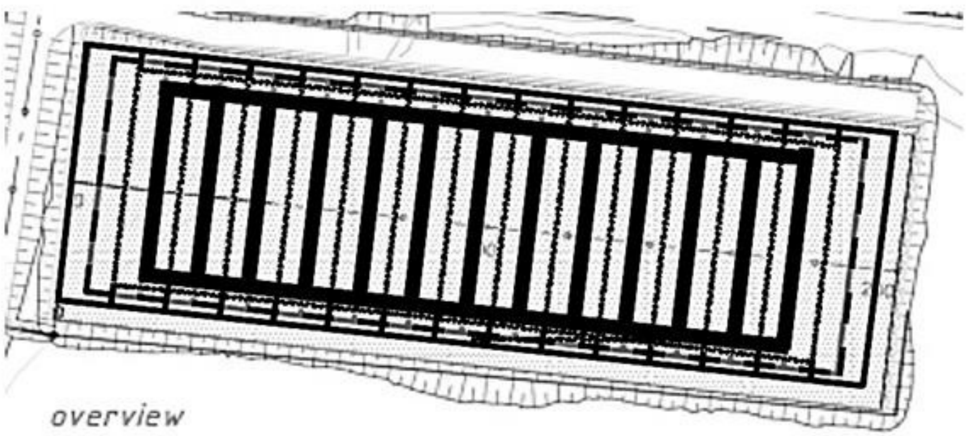

Figure 2, Typical pyramidal stacking pattern top view: First layer (continuous line), second layer (dashed line), third layer (hatched line), fourth layer (tick continuous line).

In order to be able to place a tube layer on top of the lower layer, the top layer tubes are shortened by at least 5m in order to avoid so called "overhead sliding".

DEWATERING TUBE OPERATION

The sludge is transported into the dewatering tubes on the dewatering area by a manifold system. The flow can be diverted in a controlled manner to every tube by use of several valves.

The geosynthetic dewatering tube system has been successfully implemented at the Talvivaara Mine in Finland. Due to preventing measures the whole system can also be operated during winter time and the completed field reached the fifth tube layer (Figure 3).

a) *b)*

Figure 3, a) The dewatering solution at Talvivaara during winter
b) Completed dewatering field with fifth tube layer

GEOSYNTHETIC SLUDGE LAGOON COVERS

GENERALITIES

The main aim of impermeable cover systems of sludge lagoons or tailings impoundment facilities is to secure the long term stability and environmental safety of structures. The philosophy of closure is to minimize the release of contaminants to an environmentally acceptable level.

Generally speaking, sludge lagoon cover systems consist usually of different layers to isolate disposed tailings and preventing new leakage formation by limiting the infiltration of water into the pond. The combination of different mineral soil and geosynthetic materials is required to guarantee the proper sealing, drainage, filtration, separation, reinforcement and landscaping functions.

According to the tailings characteristics, the regulations in force in the specific lands and the final use of the site after remediation, the thickness of the different layers may vary but in general the entire package is not thinner than 1,5 m – 2 m. The main challenge by the design of such structure is the construction of such system on top of a very soft and extremely heterogeneous soil. In fact, according to the deposition history, dewatering and weather conditions, the hydraulic and mechanical characteristics of the tailings may differ in depth and across the area. In this case, geosynthetics for reinforcement as for example geogrids or woven geotextiles with adapted design strength might be used.

For the technical design of the capping system an intensive investigation of in situ soils is required. The following data are requested:

- Geotechnical parameters of tailings / fill material
- Stratification of the subsoil
- Tailings pond size
- Free water level
- Live load of construction machinery

GEOSYNTHETIC REINFORCEMENT DESIGN

Currently there is no established method available to design the geosynthetic reinforcement according to these membrane-like loading effects. Edil and Aydilek (2001) described a design procedure or Espinoza et al. (2012) presented a case history and a more sophisticated design method. These designs are based on bearing capacity (rutting) analyses, the latter in combination with membrane contribution of the reinforcement. Additionally Bishop's method can be used for the stability analysis to enabling to consider mud waving in front of the filling progress at the edge of the geosynthetic.

Sometimes analysis based on wedge or slice methods (e.g. Janbu) may be advantageous compared to circle methods (e.g. Bishop, Krey) because of the better considerations of the forces of the geotextile reinforcement. Within the circle design methods the reinforcement is taken into account as a moment that is strongly influenced by the choice of the midpoint and so by the length of the lever arm. This can lead to inadequate consideration of the horizontal forces of the geotextile. Regarding the stability of the system, the stratification of the cover layers and their soil parameters have to be checked carefully in each stage of filling. Especially the first soil layers up to 0.3 to 1.0 m may become critical. At this stage the shear resistance of the weak sludge as well as the counter pressure activated by surcharge is negligible small to prevent ground failure.

SETTLEMENT ESTIMATION

Settlement due to consolidation may be significant and they should be assessed and consistent with the allowable deformation of the sealing system. Soil investigation should contain consolidation tests to specify settlement during and after construction period. If there are no data available a settlement assumption has to be done based on experience in comparison with similar soils. It may be useful to install measuring points on the surface of the sludge to allow control of settlement during the filling process and verify the settlement prediction thereby adjusting the gradient if necessary.

CHOICE OF RAW-MATERIALS AND TYPE OF REINFORCEMENT

Typically woven fabric or geogrids or combinations like woven/geogrid or geogrid/non-woven can be selected for the capping system. The main function of woven fabrics and geogrids is to transfer tensile stresses resulting from soil and traffic load across a larger area, into the anchor trench. In addition, non-woven can also work as separator and filter to keep sludge in place below the geotextile. As sludges can have different origins like mining, heap leaching, harbour or river sediments, wastewater treatment sludges, they can have very diversified chemical properties. Depending on the chemical characteristics of the sludge different raw materials should be selected. Normally polypropylene (PP), polyesther (PET, PES), polyethylene (HDPE) and polyvinylalcohol (PVA) can be used in a normal pH-range from 4 to 9.5. In areas with pH 2-4 or 10-13 only PP and PVA may be used, if long term stability has to be considered in the design.

LAYING OF GEOTEXTILES

The installation of the geosynthetics depends on the size of the pond and on the tailings characteristics (Figure 4). It can be done by sewing a large panel pulled by external edges into the pond (Figure 4a) or by unrolling and overlapping them (Figure 4b).

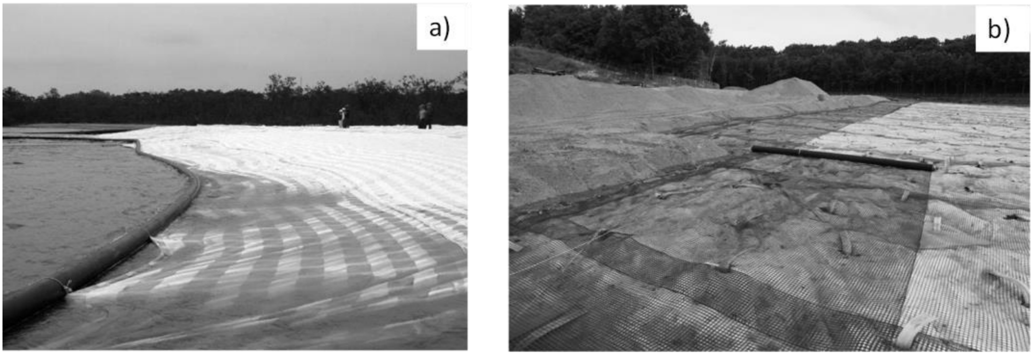

Figure 4, Examples of installation methods of geosynthetics in tailings ponds:
a) assembling of large panels;
b) unroll and overlap of geosynthetic reinforcement elements

In case large panels are foreseen, the materials used are woven fabrics that can be sewn and provide good seam strength. Installation by ropes and electric winches, maybe supported by two excavators at the lagoon edges. Once installed, the panel has to be anchored and soil installation can start with light machinery within one or two days after panel installation. During this process workers are not needed to walk on the lagoon or onside the panel, and this represents an important aspect for safety at work.

CASE STUDY: URANIUM ORE TREATMENT TAILINGS PONDS REMEDIATION THE “POND 4“ OF WISMUT COMPANY

In the past, the eastern part of Germany (the former GDR) had been the world’s third largest producer of uranium. As consequence of uranium operations the uranium ore, pits, open-pit sites and tailings remain as old-polluted sites. The “Pond 4” is a tailings pond in Freital built in 1957 as a settling basin for residues of the uranium ore treatment of the Wismut company (Koß, 1997). In 2006, the authority of water management declared the Pond 4 as contaminated site to be remediated. The remediation concept consisted of an impermeable capping with the dual purpose of long term reduction of contaminant release and of providing the basis for subsequent landscaping.

Depending on the position, the stored tailings differ in their physical behaviour. According to the tailings characteristics, three main different areas can be identified. While the tailings in the outer edge and middle region can be considered as partially dewatered and partially consolidated, the tailings located in the central area under the free water level is mainly very fine-grained material that can be considered in saturated and unconsolidated state.

The cover consists of the succession of mineral soils and geosynthetics and is designed according to the storage and evaporation principle with a total thickness of ca. 2 m (Figure 5).

In Pond 4, despite the very soft subgrade the construction of the cover system has been made possible thanks to the introduction of geosynthetics into the system combined with the use of vertical drains in some areas of the pond. The final cover system results of the following layers (from the bottom to the top):

- tailings
- nonwoven
- 2 layers of geogrids (installed perpendicularly to each other – T-dimension)
- vertical drains (in the middle and central regions)
- mineral drainage and bearing layer
- mineral sealing layer
- soil cover

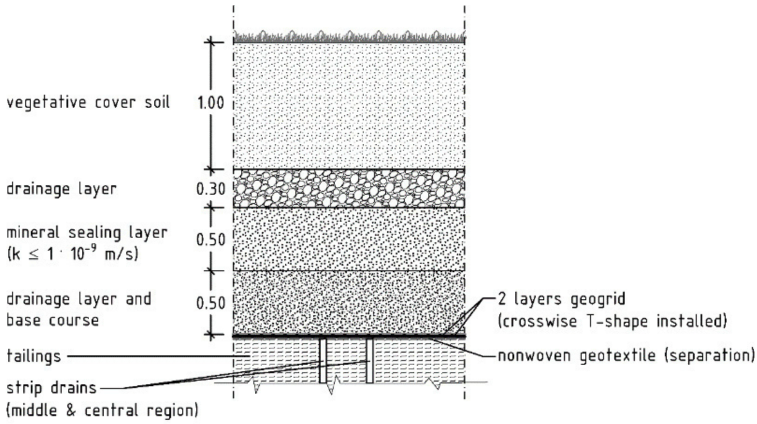

Figure 5, Typical cover system cross section

Figure 6 illustrates an aerial view of the site before and during the installation of the geosynthetics.

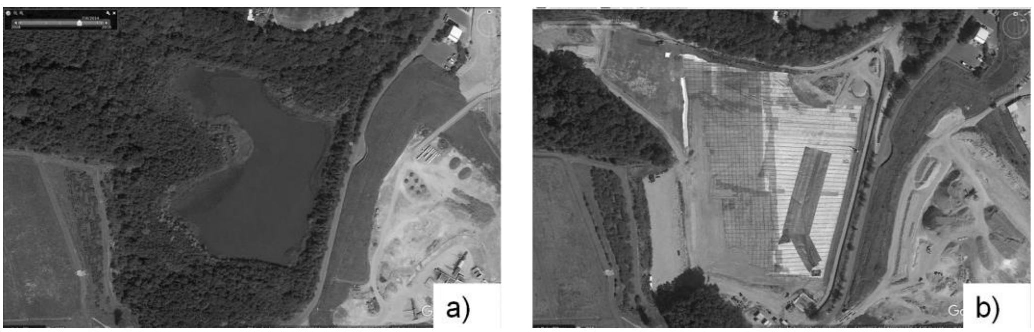

Figure 6, a) Pond 4 before remediation works started (~50.000 m^2 – April 2016), b) Impression of Pond 4 during installation phase (August 2016)

Nowadays, the geosynthetic cover system of Pond 4 is successfully installed and the site remediated.

CONCLUSION

The use of geosynthetics in mine related applications can massively reduce the potential risk of failures for the environment caused by sludge impoundments.

In particular, the geosynthetic dewatering tube system offers, among others, the following advantages:

- Higher process capacity and lower investment and maintenance costs;
- Increased storage flexibility by adding an additional tube layer or additional tubes;
- Demobilization of the tailings by water extraction;
- Encapsulation and permanent storage of the dewatered material inside the tube;
- As a result of the tailings being stored in a solid state the risk of environmentally detrimental spillage is drastically reduced;
- Tube operation is possible also during winter;
- Tube drainage water can be rapidly recycled and re-used in the mine process;

Each sludge lagoon is unique and each project has its own specifics regarding geology, products and construction but thanks to a wide range of different raw materials and customized installation methods, the use of geosynthetics represents the most economic and feasible solution for a safe final closure of tailings ponds.

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