REHABILITATION OF WATER BODIES BY BENEFICIAL RE-USE OF THE SEDIMENTS IN GEOTEXTILE TUBES

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Abstract. The scope of this paper is to illustrate the beneficial re-use of dredged lake sediments as a construction material for bank protection by means of geotextile tubes. This application allows a pragmatic and cost-efficient way to re-model the shape of a water body. The principal workflow of the geotextile tube system is shown and the advantages of the system are demonstrated by the example of the executed project "Schmelzteich Bernsdorf". In this project a private fishing society was required to maintain one of its a fishing lakes. Due to a sedimentation problem several issues, such as danger of inundation and reduced water quality had to be overcome. At the same time the local recreation quality had to be improved.

Keywords: dredged material, geosynthetics, geotextile tube, flood protection, bank protection, relocation

1. Introduction

The "Schmelzteich" is a fishing lake in the middle of the small town Bernsdorf (6700 inhabitants) in Saxonia, 50 km North of Dresden. The size of the lake is about 2 ha, and is part of the local system of lakes, streams and ditches with the particular feature of it being its urban location in the middle of the town of Bernsdorf (see Fig 1).

The lake is the private property of the "AVE - Anglerverband "Elbflorenz" Dresden e.V.", which is the head organization of the local fishing societies with more than 15,000 members. All expenditure of the AVE is funded privately by its members.

Due to the progressive sedimentation and the consequential reduction of the lakes storage capacity the AVE was asked by the authorities to rehabilitate the lake. The company pmr - Planungsbüro Röllich, was charged with leading the rehabilitation project and to supervise the execution.

Fig 1. Aerial View of the Schmelzteich lake.

2. Issues

The fact that the capacity of the old outlet of the lake was insufficient led to inadequate current in the lake. As a consequence sedimentation occurred and the lakes storage capacity was continuously reduced.

In 2010 high water inflow to the lake led to inundated urban areas around the lake. Due to its location in the town several streets, houses and a factories were flooded. The lake siltation was enhanced by leaf debris originating from the numerous trees surrounding the lake (see Fig 2).

Fig 2. Trees at the lake shoreline

Apart from common reasons for eutrophication (e.g. nitrogen input due to farming, etc.) this enhanced the eutrophication process of the lake, resulting in a serious oxygen-deficiency.

The planned actions to overcome these issues are introduced in the following chapters 3 and 4, based on Röllich (2013).

3. Goals of rehabilitation from the lake owners perspective

The lake owner, who leases the lake to the local fishing society, is interested in providing an attractive fishing spot to its members and a local recreation area to the public. Therefore the principal aim of the rehabilitation is twofold; to achieve a sustainable aquatic habitat as well as provide an attractive surrounding for recreational purposes.

3.1 Water depth

In order to create versatile refuges for the flora and fauna a lake with shallow and deep water areas is required. This enables the fish to hibernate. In addition the varying water depths across the lake produces different habitats which allow for the establishment of an increased number of species. Planned shoreline and water depth are presented in Fig 3.

3.2 Water quality

The amount of organic material, especially leaves, which gets into the lake should be reduced. The oxygen content of the water should be at an adequate level for Fauna and Flora. These goals should be achieved by the establishment of a clear main flow path along the lake which will create a stronger current, increasing the water circulation inside the water body.

3.4 Installation of new fishing spots

To improve the attraction to fishermen new fishing spots had to be installed at the shore. Fishermen and also the public should be able to reach these spots easily and safely regardless of the prevailing weather conditions.

The re-shaping of the lake involved the demolition of a decrepit bridge enabling the access to the small lake island. As there is no plan to rebuild a bridge, the loss of fishing spots on the island has to be compensated by the construction of additional facilities along the lake banks. (Fig 3)

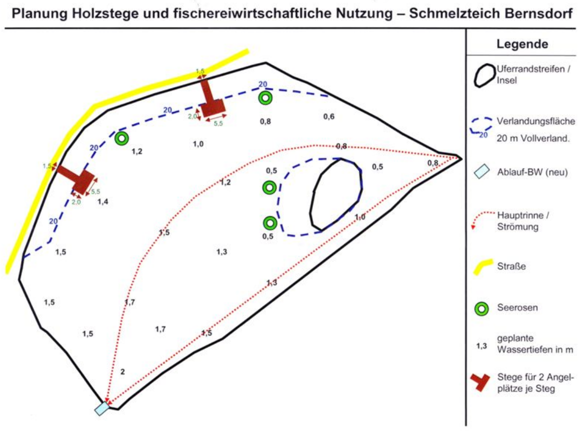

Fig 3. New shoreline (dashed blue) and new fishing spots (red)

3.4 Economical aspects

As a consequence of the economical situation of the lake owner as a privately funded organization, financial resources are limited. The engineer in charge was asked to search for simple and pragmatic solutions in which literally the manpower of the members of the fishing society can be deployed to cut expenses wherever possible. The great personal effort of all persons involved is applauded by the project owner.

Furthermore a sustainable lake sediment management was essential in order to keep the costs at a low level.

4. Goals of the rehabilitation with regards to urban design

4.1 Flood protection

Many of the described issues were basically caused by the insufficient drainage capacity of the lakes old outlet. In the course of the rehabilitation a new outlet was constructed (see Fig 4) and the old outlet was closed (Fig 5). The prevention of future flooding of surrounding areas and a balanced sedimentation and erosion process are direct consequences of this measure. Details of this construction will not be discussed in-depth within this paper.

Fig 4. New Outlet construction

Fig 5. Shutting down the old outlet

4.2 Establishment of a walking path

The Schmelzteich lies within a five minute walking distance from the center of Bernsdorf. In order to improve the recreation quality it was intended to integrate the lake into the network of local footpaths. Therefore a path all around the lake had to be installed.

4.3 Conservation of the lakes island

In the future the environment on the island was required to develop without any direct human impact. As already mentioned the only access to the island, an old bridge, would be taken down with regard to this requirement. Moreover it was intended to increase the area of the island by using the available lake sediment.

5. Relocation of material and reshaping of the water body

Apart from the construction of the new outlet, the relocation of sediments has been the most important measure in the rehabilitation of the Schmelzteich. Concerning the amount of work to be carried out as well as with regard to the costs.

The planned solution specified two areas in which the sludge had to be removed. The first area was located close to the inlet in the southern corner of the lake and the second area located in the north-western part, close to the new outlet (see Fig 6). It was intended to treat both areas separately. The preferred and chosen method was to drain the lake before starting relocating the sludge. Conventional construction machinery (e.g. excavators) was planned to be used to move the sludge where possible. In areas where the bearing capacity was too low for enabling the access of heavier construction equipment the sludge was to be hydraulically dredged.

Fig 6. Planned relocation of sludge

The first and smaller construction phase included the removal of sludge from the inlet to the northern side of the island. This area was to stay permanently submerged as reed bed brake area. As the ground level in this new island area was to be raised by one meter and due to the low angle of inner friction of the material, a shoreline stabilization/reinforcement became necessary.

In the second construction phase sludge from the north western part of the lake was to be moved to the eastern shore. The plan aimed at to project the shoreline about 20m towards the lake center. Thus the amount of leaf debris falling into the water would be greatly reduced. The area behind the new shoreline would also be raised between 1.0m and 2.0m. About 2/3 of the area was planned to be vegetated by reed beds. By designing the reclaimed areas as inundation areas for floods the lake shape and its total surface area, compared to the initial situation, become the same again during flood events.

A direct benefit due to the split of the construction process into two phases was the possibility to apply insights and experiences gained from the first stage to the second phase.

6. Sludge containment in geotextile tubes in general

Geotextile containment elements, normally filled with sand, have undergone an increased application for hydraulic engineering. With regard to this application geosynthetic tubes have been widely used for bank protection of all kind of water bodies. The biggest benefit of the sand fill is the fast water drainage capacity which minimizes subsequent settlements after proper filling to a minimum. The first experiences with this system can be dated back to the late 1960's, see Zitscher (1971) and Erchinger (1972). A detailed description of the system can be found in Wilke, Hangen (2011).

The most common way of tubes used in combination with sludge is as a dewatering device. The processed sludge is pumped into a tube where the solids are captured inside. Due to the permeable dewatering fabric the water is able to drain through the system. In principal the processing of the sludge consists in the addition of a flocculation aid which enhances the dewatering process by accumulating the finer solids to larger flocs. By this process of agglomeration the "water release capacity" of the sludge is massively increased. In most cases, the application of polymers primarily enables the dewatering process. These flocculation aids can be produced from different raw materials.

The principal two functions, sludge containment and construction element, can also be combined. In the following the system set-up and the adaption of the conventional elements to the Schmelzteich-Project will be explained in greater detail.

7 Adaptation of the systems to the Bernsdorf project

During the planning process the use of geotextile tubes turned out to be the most economic solution to stabilize the new shoreline. The benefit consists in the re-use of available sediment as construction material as well as avoided costs for transportation and deposit of the sludge. The sludge is contained inside the tubes permanently and the tubes become a structural element of the shoreline after the sludge has dewatered and stabilized.

The costs for reinforcing materials and labour for the installation were considered similar to conventional wooden solutions. The dimension of the geotextile tubes was designed to the desired height while allowing manually placing without the need of machinery.

7.1 Dredging and relocation of sludge

The sludge hauling was performed by an amphibious multi-purpose dredger (see Fig 7). It was operating in the area close to the new outlet of the lake, where a minimum water level was maintained in order to make hydraulic dredging possible.

For construction phase 1 only the later filling of the tubes was produced this way. The mass of 1270 m³ sludge was moved by a caterpillar to form the canebrake at the northern side of the island (Fig 8).

In construction phase 2 5.500 m³ were relocated with excavator and dumper. Only the fill of the tubes and a minor part of the mass behind the tubes have been placed hydraulically.

The sludge was flushed by the dredger through a DN 100 pipe. As a consequence of the required length of the dredging pipes (maximum 310m in phase 1 and 400m in phase 2) the medium pump rate was $q = 30$ m³/h. During execution the medium concentration of solids in the pumped sludge was $DS = 10$ % by weight.

Fig 7. Amphibian dredging device

Fig 8. Mass removal of sludge with bulldozer

7.2 Soil Improvement

With respect to the lakes usage as a fishing lake chitin based flocculants were used to enhance the mechanical properties of the dredged material. The flocculants were added inline of the sludge-stream with a constant flow rate. The size of stable flocs was observed by sampling the improved sludge directly before the sludge was pumped into the tubes (see Fig 9).

During execution a total amount of 275 liters of flocculent solution with 1% active ingredient were used for construction phase 1. For construction phase 2 1.115 liters were mixed into the sludge.

Fig 9. Sludge after addition of chitin based flocculant for soil improvement

7.3 Design of tube dimensions

The design of the required tube dimensions was a part of the planning process. For a desired height of 1,0 m after dewatering and consolidation the tube circumference of 6.0 m was determined with the aid of the software *GeoCoPS*. *GeoCoPS* is a common tool for calculating the required tensile strength of the tube shell. In addition the approximate shape of the tube after filling can be predicted (see Fig 10). The design basics and the design theory can be found in Leshchinsky (1996). The corresponding width of the chosen tube circumference at the design height is 2.5 m with a cross-sectional area of 2.1m². Transferring the cross-sectional area of the tube into the storage capacity per linear meter leads to a volume of 2.1m³/lm.

The different tube lengths were adapted to the specific needs for reproducing the desired shape of the reclamation areas. Therefore the tube lengths varied between 15m and 55m (see Fig 11). In order to guarantee a continuous barrier overlaps of neighboring tubes with a length 0.5 m were provided.

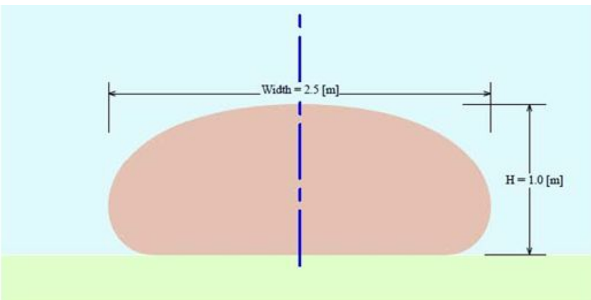

Fig 10. Cross-section of geotextile tube according to GeoCops

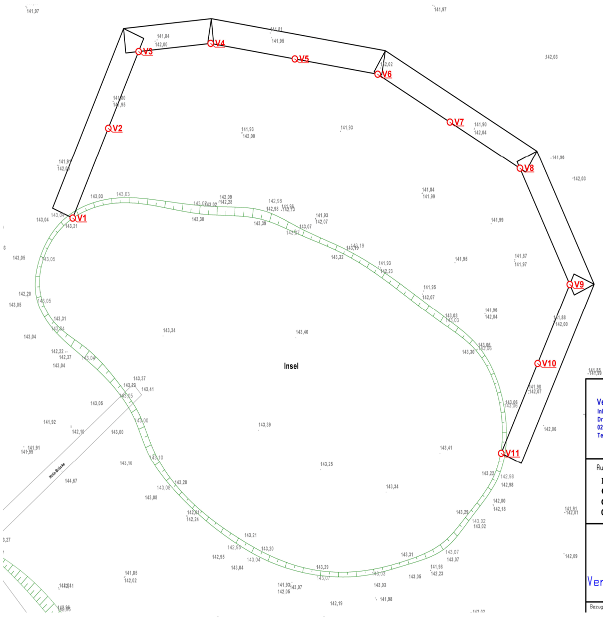

Fig 11. Layout plan of the tubes for the island reclamation area

7.4 Disposal of sludge in tubes

A survey of the shore line was executed in advance to construction. Prior to tube installation a non-woven geotextile was placed at the tube locations. This geotextile was cut to size to allow encapsulation of the tubes after they had completed filling. By this measure the additional protection against any potential damage of the geosynthetic tube by UV rays was assured (see Fig 12).

In construction phase 1 a total length of 105m of new shore line was constructed. After the end of the consolidation process about 100m³ of dewatered and stabilized sludge was stored in the tubes of this section. With an achieved storage capacity of 1.0m³/lm the concentration of solids was determined approximately to DS = 40 % by weight inside the tubes.

Evaluation of construction phase 2 showed that a volume of 560m³ remained in the tubes after consolidation. The total length of the reinforced bank was 280m. (Fig 13 and Fig 14). With the solid concentration again being around DS = 40 w-% the achieved storage capacity was 2.0 m³/lm. This was a consequence of adjustments in flocculation and a sustainable improvement of the filling process. Apart from the ameliorated filling process the tubes were modified to the specific requirements of the project: the tubes were furnished with special straps at the tube top in order to keep the fill pipes in place. The continuous improvement of all project components finally led to a great project success.

Fig 12. Placed non-woven and tubes in construction phase 2 before start of filling process

Fig 13. Tubes during filling process and new fishing spots still under construction

Fig 14. The new north-eastern shoreline of the Schmelzteich

8. Conclusions

1. The use of geotextile tubes as shore line reinforcement was a crucial point in putting the owner of the lake into the position to implement the project by himself.
2. Together with other measures like the construction of a new outlet and the redesign of the local water management all goals with regards to urban design and the requirements of the fishing society were fulfilled.
3. The structural concept introduced here helped to keep the expenses affordable for the project owner.
4. Geotextile tubes can play a role as permanent elements not only in coastal protection projects at the seaside, but also in the field of water rehabilitation.
5. It has to be kept in mind, that the personal energy and working power of many people involved was free of charge. The simple and pragmatic approach of decision-makers on the planning side as well as the executing side, in combination with intense conversation allowed the project to be to executed the with great success.

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