New aspects of shore stabilization

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Abstract. The basis for a design of stabilization measures for banks of watercourses and reservoirs is an assessment of the bank from the perspective of the material it consists of, the existing slope inclination, and the current elements of natural or artificial stabilization. Another important step is to assess the potential cause of the bank damage, the probability of its occurrence, and the significance of possible damage with respect to the bank usage. If the basic assessment of the current state of the riparian area concludes it is really possible that erosion damage to the bank may appear and develop, one of the types of bank reinforcements has to be designed.

1. Introduction
Shoreline hardening practices such as bulkheading have several drawbacks. The structure may only assimilate 20 percent of the wave’s energy, which means the majority of the energy is forced back out toward the lake and bottom, thus creating scour at the bottom of the structure, or creating accelerated erosion across from or adjacent to the structure. The chemicals used in pressure treated lumber are harmful to the aquatic life of our lakes. Riprap (rocks/stone), under most circumstances, adequately stabilizes shorelines and does not share all the negative characteristics of bulkheading, however, it does not provide optimal wildlife and water quality benefits as vegetated shorelines. It is important to always install filter fabric under riprap to prevent soil from washing out from underneath the rocks. Vegetative and bioengineering solutions (biologs) stabilize the shoreline, provide aquatic wildlife habitat, and create beautiful landscapes of varied textures, colors, and flowers. Vegetated shorelines also filter lawn runoff and uptake nutrients prior to the runoff entering the lakes. This nutrient uptake will help to reduce algal growth evidenced in the lakes each summer [1].

The impulse for a more intensive research interest in this issue was the request of the commercial sector to develop, test and implement an appropriate stabilization technique for banks of flooded gravel pits and sand pits, where mining has ceased but the highly unstable banks continue landsliding. These sites are very often located within the interests of the environmental authorities, which – rightly – put a great emphasis on an appropriate inclusion of the anthropogenically influenced sites in the landscape [1, 2]. The designing a levee should take into account various technical aspects, as well as interference in the country and the impact on flora and fauna. Solution should be developed in alternatives; the resulting design should be the most suitable option in terms of reliability, of economy, efficiency and environmental acceptability. Technical stabilization elements are not accepted, and the recommended elements of biotechnical and biological bank protection do not work, or show a very
low efficiency at such sites [3]. The new approach to bank stabilization was thus oriented differently than most of the existing ones [4]. As said above, a slope of a beach type, reinforced with biological elements can resist damage to some extent. With the current two-meter high erosion wall at the experimental site, the slope of a beach type, i.e. approximately 1:10 to 15, would mean sloping in a length of 20 to 30 m. This is not possible in many cases. However, it is possible to design the so-called "half-dish profile" of the bank slope, which is based on three years of detailed monitoring at experimental sites of banks of sand pits near Hulin (Czech Republic) and others. The sloping in the form of three continual slope inclinations proved to be the best practice: 1:10, 1:5 and 1:2.

1.1 Importance of the stabilizing effect of vegetation
Bankside trees and shrubs are one of the building blocks of territorial systems of ecological stability (TSES). It is part of an ecologically balanced landscape, a form of spread green vegetation growing outside integrated forest complexes. It is created by tree species and herbs growing along streams. In relation to stream regulation, linear building along water streams etc., a lack of riparian and accompanying stands started to manifest negatively. We can say that only once it decreases, will we start to realize its indispensability in our landscape [5, 6, 7].

2. Material and methods
Apart from a construction of retaining walls and other purely technical elements of stabilization, the basis of a reinforcement is usually bank sloping, most often from 1:1.5 to 1:3. This is followed by a stabilization of the footslope forming the bank, or a direct stabilization of the bank at the site of the most likely damage. If it is possible to use technical elements of stabilization to the necessary extent (stone, concrete, steel elements or their combinations), a long term bank stability is not a problem. However, the situation is different if environment protection authorities are involved in the decision making process, i.e., if the stabilization is to be designed outside towns, in territories with some kind of protection, but also in areas that are inaccessible by machinery, etc. Even then, the basic schema is kept – a suitable sloping of the bank (see above). However, based on quite strict requirements of the authorities, the following stabilization is designed as only biological or biotechnical with the vegetation element dominating [4, 8].

However, a bank reinforced with the above mentioned procedures cannot resist long-term waving (meeting conditions 1 and 2). There is no available tree species in the Czech Republic whose root
system would be capable of withstanding the surface waving over the long term (demonstrated by the attempt to biologically stabilize parts of banks of Liptovska Mara Reservoir, Slovakia [9], etc).

More suitable than uniform slope inclination 1:1.5 or 1:2 is gradual inclination 1:1.5 (1:2) follows 1:5 and 1:10 shape “half-dish” (fig. 2)

Figure 2. Slope adjustment: A-slope 1:2, B-slope 1:5, C-slope 1:10, detail of slope adjustment (Hulin dam, Czech republic. [foto M. Slezingr 2017]

Five experimental plots were established: two with biotechnical stabilization, two with biological stabilization and a reference one [10,11].

We present experimental areas with biological stabilization:
Experimental plot 1 – sloping shaped like the above-described "half-dish"; the part with the smallest inclination was stabilized using a belt of willow stem cuttings, *Salix viminalis*, 4–5 m wide, in a quincunx pattern of 0.4 x 0.4 m. Above this stabilization structure, it is assumed that appropriate grass mixtures will be sown and individual or groups of shrubs will be planted [12,13].
Experimental plot 2 – sloping shaped like the above-described "half-dish"; the part with the smallest inclination was stabilized gradually. First, it was planted with reeds (namely *Typha latifolia*) - supplied from local sources; then a belt of willow stands, 4–5 m wide, was planted - species *Salix viminalis*, a quincunx pattern of 0.4 x 0.4 m.

3. Results of Monitoring
As regards the stabilization procedures described within the description of experimental plots, the most appropriate and most effective technique proves to be the following: a belt approx. 1–2 m wide of reeds (namely *Typha latifolia*) followed by a stand of shrub willows in at least 5–7 rows in combination with a gravel layer. A stand of shrub willows of several (at least five) rows acts as a natural breakwater on the erosion platform - i.e., where erosion damage has already occurred and developed. This was concluded after evaluating the effectiveness of stabilization after 15 years. Combined with the distribution of slope inclination, it is a very good biological protection of the bank, preventing the formation of erosion wall. As has been found, the waves do not reach the third, i.e. the steepest, slope section significantly (resulting in deformation). The steepest section had an inclination of 1:2 at the experimental plots. Therefore, the monitoring (of 15 years at experimental plot Brno) has shown that the slope inclination designed for this section is irrelevant.

The planting of a willow belt manifested good effectiveness; however, the effectiveness was better in combination with reeds.

4. Conclusion
The following approach appeal to be the most appropriate:
First, an inclination of 1:10, 5–6 m long, planted entirely with shrub willows, the water edge planted with a belt of reeds; followed by an inclination of 1:5 (can be also 1: 4), seeded with a suitable grass mixture; the third inclination within the "half-dish" 1:2 (can be also variable from 1:1.5 to 1:2 with respect to possible maintenance, access to water, etc.). Further, a possible access to water provided by an artificial sloping (lightning-shaped) path, approximately 0.8 m wide was tested. This path did not become a preferred path for water during a torrential rain, the water was converted to the stand. It had no effect on breaking waves.

The proposed bank stabilization in the form of a half-dish in combination with appropriate planting can be regarded as very effective; additionally, it meets the requirements of environment protection authorities.

5. References

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Acknowledgments

Supported by the Specific University Research Fund of the FFWT Mendel University in Brno, n. of Project: LDF-TP-2019002 Project FAST-S-18-5264. Thanks to The National Scholarship Programme of the Slovak republic there was opportunity to prepare this paper with the colleagues from University of Technology Brno.