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TECHNICAL MEASURES OF RIVERBANK STABILIZATION IN ENGINEERING PRACTICE

A basic principle of good practice is to consider a range of alternatives in technical measures of bank protection proposal. There are several solutions of river bank protection and stabilisation. In the draft proposal all these alternatives have to be considered with respect the best practical environmental option. In this paper the overview of relevant engineering options regards to the most suitable and sustainable type of bank protection and stabilisation will be described.

Key words: erosion, abrasion, river bed.

Для розв'язання проблеми належить розглянути низку альтернатив з технічних заходів захисту берегів. Є кілька рішень щодо захисту берегів річок і їх стабілізації. У проекті пропозицій всі ці альтернативи повинні бути розглянуті для вибору найкращих практичних екологічних рішень. Проведено огляд відповідних найбільш прийнятних та збалансованих берегозахисних технічних рішень.

Ключові слова: ерозія, абразія, русло річки.

Introduction

Rivers are natural open systems that adjust their morphology to transmit the flow and sediment load delivered from their watershed. Over periods of thousands of years, the supply of sediment from upstream is balanced by a river's ability to transport it.

However, over shorter time periods, natural and man-made changes in a river's flow and sediment transport regime can induce erosion or deposition and associated changes in the river channel form, as the river adjusts to increased or decreased sediment loads or flows.

The physical appearance and character of the river (or geomorphology) is a product of channel boundary and slope adjustment to the present flow and sediment regime. River form and fluvial processes evolve simultaneously and operate through mutual adjustments toward self-stabilization.

Because river systems are dynamic, their pattern, dimension, and profile are a function of numerous process variables, with the result that a change in one variable sets up a mutual adjustment in others (Leopold et al., 1964). Channel stabilization methods must address these observable relationships to prevent the negative feedback mechanisms from the river from undermining the stabilization measures. In bank stabilization design, this is accomplished by comparing the observed morphological features of a river to those of known stable systems in order to account for the natural tendency of a particular river system or segment to adjust to a more stable channel form.

River bank erosion

Bank erosion is often caused by natural processes but it can also be due to by human activity, especially livestock management, vegetation management and river engineering. Bank erosion can result in a loss of land and can threaten property or structures. The deposition of eroded bank material further downstream can also cause damage, both to structures (e.g. sedimentation under bridges) and to the environment (e.g. smothering of spawning gravels by fine sediment). Natural bank erosion fulfils several purposes: it renews ecological habitats; it is part of the natural balance of rivers; and, crucially, as sediment is eroded, moved downstream and deposited, river energy is dissipated. Significant funds and effort are spent on engineering and maintenance to control and alleviate bank erosion. Halting erosion by using engineering has a negative impact on habitats, disrupts the natural balance of the river and, crucially, can make the original problem worse because the river has more energy. Also, some of the effort is ineffective because activities often treat the symptoms of erosion, without addressing the underlying cause. Bank erosion may then move elsewhere, making the original problem worse, adding to the economic burden, and causing further ecological damage.

In order to identify the best solution to erosion it is therefore critical to identify its cause, its value in terms of ecology and river function, and its impact on human activities, resources or health (SEPA, 2008).

Description of Potential Stabilization Techniques

Bioengineering techniques include use of natural materials and certain riparian vegetation as a strategy to control bank erosion and promote longer-term stability of the river channel and banks, while attempting to minimize the adverse effects of stabilization when possible. Such techniques can be grouped into two basic categories: those that reduce the force of water against a riverbank, and those that increase a bank's resistance to the force of water (available on web page http://www.nrcs.usda.gov, 2002). Both categories of bioengineering techniques employ riparian vegetation as a means of erosion control. Vegetative growth reduces local velocities against the bank, thereby reducing near bank shear stress. After time, as the vegetation grows and matures, the hard mass provided by plant roots can provide protection from erosion and collapse and increase internal bank strength (Rosgen, 2006; Wynn et al., 2004).

Many of the techniques that are designed to reduce the force of water against a riverbank do so by directing flow away from banks. Techniques designed to increase a bank's resistance to the force of water function in much the same way as traditional hardening techniques, such as gabions, riprap and concrete, by "armoring" a riverbank with materials that are more resistant to the force of water than native, in situ soil. Natural materials, such as coir fiber, provide flow resistance while also serving as a substrate for plant growth, or incorporate interstitial space to provide ground contact for rooting plants.

It should be noted, however, that any technique for bank stabilization would be intended, by design, to prevent any significant bank soil erosion and lateral channel migration, which are two key geomorphic processes that produce a heterogeneous mix of riverbank types, including vertical and undercut banks, that are critically important to many of the plants and animals that use the banks. Thus, while efforts can be made to reduce ecological impacts, it must be recognized that any bank stabilization techniques, including bioengineering techniques, would have long-term or permanent adverse ecological consequences. In some cases, bank stabilization methods are applied to only discrete portions of the banks along a given stretch of a river, which reduces the adverse ecological impacts compared to stabilizing the banks throughout the entire stretch of a river (AECOM Environment Westford, 2010).

Vegetation Measures (Green bank protection)

The planting of herbaceous and woody vegetation is one of the simplest forms of stabilizing a riverbank. The plant roots help stabilize the soil and control shallow mass movement by binding soil particles and by removing moisture from the soil.

One of typical vegetation measures are live stakes like dormant (but live) cuttings or branches feet in length that are inserted into the soil at or below bankfull elevation.

If correctly prepared, handled, and placed, the live stake will, under suitable conditions, root and grow. Only a few species will grow well from live stakes. Those species include willows, dogwoods, and elderberry. Live stakes can be used in conjunction with other techniques, including erosion control matting.

In Figure 1 a brush mattress is depicted (AECOM Environment Westford, 2010). It is a layer of live branch cuttings, placed perpendicular to the flow of the river on the bank, and held down in place with poultry netting or light gauge wire mesh to form a "mattress" of woody material (AECOM Environment Westford, 2010).

Fig. 1. Installed brush mattress

One-row or two-row branches hedge or willows cutting are very often used too and are depicted in Figure 2 and 3 (Sojková, Z., 2006).

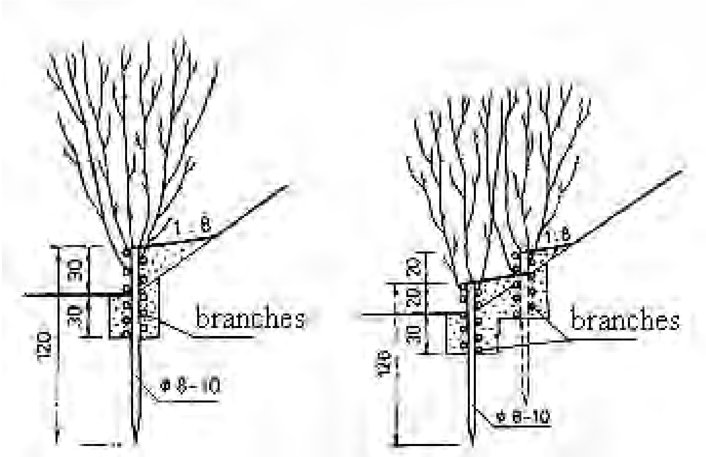

Fig. 2. One-row or two-row branches hedge

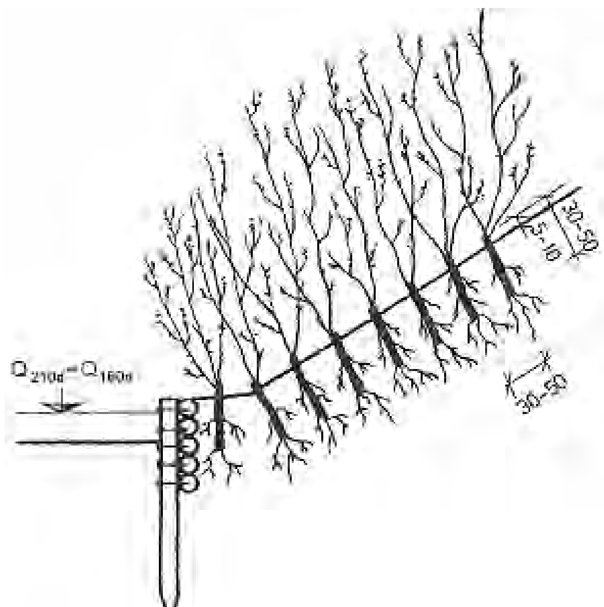

Fig 3. Willow cuttings

Coir fabric or coir matting is erosion control matting constructed of coconut fibers (Fig. 4) (available on web page: http://www.hellotrade.com/excelfiber/natural-knitted-coir-logs.html). The matting protects the banks while vegetation is established and biodegrades in about 5 years. Coir fabric is also used to construct a number of other bioengineering systems, including prevegetated mats, pre-planted coir pillow, and vegetated geogrid.

Fig. 4. Example of natural knitted coir logs

The most sophisticated use of coir matting is to construct vegetated geogrids. A vegetated geogrid consists of a wall composed of 1-foot “lifts” of compacted soil wrapped in coir fabric or geotextile (typically synthetic) fabric, with plugs, live stakes, or other plantings placed between each lift. This technique essentially replaces the riverbank with a newly constructed, reinforced wall that provides resistance to shear stress, while at the same time providing vegetative growth (AECOM Environment Westford, 2010).

Regardless of the technique employed, any trees and other vegetation on the banks would need to be removed to implement the remediation/stabilization. In addition, because any future windthrow and overtopping of trees would destabilize those banks and cause severe bank erosion, only herbaceous plants and shrubs, and not trees, would be planted in connection with any bioengineering technique, and an ongoing program to prevent the growth of trees on the stabilized banks would be essential.

The planting of a riparian stand whose main function is the stabilization of the slope and of the crest of the lined ditch slope (passage between the lined pitch and the berm) and possible stabilization of berm slopes must be designed also in the flow profile.

Behind bank lines, accompanying stand species, both trees and shrubs, should be placed in a belt whose width corresponds to the possibilities of a particular locality. Tree kind of stabilization is often known: using of self-seeding species and naturally spreading vegetation, using of accompanying vegetation on waterways and establishment of grassland (Šlezingr, M., Úradníček, L., 2003).

The grassland of a stream bank slope reinforces soil surface and, to a great extent, prevents the occurrence and development of erosion. It is necessary to realise that grassland composition, its endurance, overall involvement and consequential viability depends on the number of created and sufficiently developed individuals in the first two to three months after seeding. Although seeding is the most common method of establishing grassland, it is not the only one.

Traditional hardening methods (No-vegetation measures – Gray bank protection)

In areas that are subject to greater instability, such as where shear stress and channel velocities are particularly severe, vegetation (green bans protection) are unlikely to succeed (at least by themselves), and thus traditional hardening methods (e.g., use of concrete, riprap, and gabion baskets) are necessary to prevent bank soil erosion. Other techniques are: articulated concrete, rock riprap, retaining walls, reinforced earth, stone revetments, concrete revetment or non-biodegradable geotextiles (SEPA, 2008).

Practical examples of riverbanks stabilization provided in eastern Slovakia

In the following the practical examples of riverbanks stabilization provided in the selected villages in eastern Slovakia presented.

The first example is regulation of water flow Černinka (Fig. 5), right tributary of Ondavka river. Area of interest is located in the cadastral territory of Baškovce village. Starting point of adjustment (km 0,000 km) is in the village, under the road bridge near the main road direction to Černina and end of adjustment is about 480 m upstream water flow at the beginning of the village Baškovce (border of natural and urban area of the village). Creek in a given area has character of partially treated water flow with variable transverse profile, mostly grassed.

The proposed trapezoidal profile has the width of the channel b = 1.5 m in the upper and middle section (km 0.169 to 0.481) in the length of 312.00 m and b = 3.5 m in the lower section (km 0.000 to 0.100). Road bridge has rectangular cross-section b = 5.0 m (km 0.100 to 0.169) and it remains intact. Slope is suggested in variation 1:0.5, 1:1, 1:1.5 and 1:2. Channel capacity is rated at Q_{100} = 25 m^3/s, whereas it is a residential area of the village. Security level has a value of 0.5 m. The water level is calculated according to Chezy equation and reaches at maximum flow rate of 1.00 to 1.70 m for the individual cross sections. The slopes adjustment is proposed from quarried stone (Fig. 6).

Fig. 5. Creek Černinka – initial state

Fig. 6. Creek Černinka – adjusted state

The next area of interest is located in the cadastral territory of Vydrník village (Fig. 7). Top of the proposed modification (km 0,000 km) is in the central part of the village, over the Municipal Office, upstream of the piped stream. End of adjustment (km 0.1755 km) is upstream eastward, under a road bridge. Creek in the solved part has the character of raw water flow, it is deeply cut and the slopes are grassed. On the right side are private plots – gardens, the left bank is bordered by a local path.

A trapezoidal cross section is proposed (Fig. 8) with a width of at b = 1 m and with a slope inclination of 1:1.5 for the entire length of adjustment (km 0.000 to 0.1755). Channel capacity is rated at Q_{100} = 5 m^3/s, whereas it is a residential area of the village. Security level has a value of 0.3 m. The water level is calculated according to Chezy equation and reaches at maximum flow rate of 0.90 m. The solution of section adjustment is proposed fortification slopes and bottom-tiles from quarried stone with cement mortar grouting.

Fig. 7. Creek in Vydrník village – initial state

Fig. 8. Creek in Vydrník village – adjusted state

The next example of stream regulation is located in the cadastral territory of Udava village (Fig. 9). Top of the proposed modification (km 0,000 km) is in the village, under the road bridge near the main road direction Udavské – Papín. End of adjustment (km 0,554) is upstream of the watercourse, in the village Udavské. Creek in a given area has character of partially treated water flow with an irregular trapezoidal profile, with paved pavement slopes significantly impaired and grassed.

Slope of banks are proposed at 1:1.5. Channel capacity is rated at Q_{100} = 10 m^3/s, whereas it is a residential area of the village. The water level is calculated according to Chezy equation and reaches at maximum flow rate of 0.90 to 1.20 m for the individual cross sections. The solution of section adjustment is proposed as stone tile on cement mortar grouting for slopes and bottom walls (Fig. 10). Stone tiles of the paving stone are with a minimum dimension of 200 mm. The individual stones are stacked so that large gaps are 20 mm in diameter. Underlying of the pavement is 150 mm thick backing-gravel filter layer. Stone tiles with cement mortar grouting is stored above the surface of 100-year water – the entire bank slope is fortified and also a strip with a width of about 600 mm.

Fig. 9. Creek in Udava village – initial state

Fig. 10. Creek in Udava village – adjusted state

The purpose of the next presented work is the flood protection of village Vyšná Olšava against floods. The nameless stream (Fig. 11) flows through urban residential community in the length of about 300 m. Creek bed has been regulated in the past and in its upper part the capacity is not sufficient to protect against floods, the river bed is overgrown and clogged by suspended load. Beginning of the adjustment 0,0000 km is in the mouth of creek into Olšavka stream, end is in km 0.3950. According to hydrological data supplied by the Slovak Hydrometeorological Institute (SHMI) headquarter Košice the flow Q_{100} = 16 $m^3.s^{-1}$. The flow rate in accordance with applicable standard is the design flow to ensure flood protection of urban village.

Cross section is proposed as a trapezoid (Fig. 12). Bottom width, slope and depth of river bed respond to the proposed flow and real options of the location. Trapezoidal cross section is proposed with a width of b = 3.0 m, with a slope of 1:1 along the entire length of river routes. The solution of cross section and fortification of slopes is proposed of paving stone from the quarry to the cement mortar grouting.

Fig. 11. Creek in Vyšná Olšava – initial state

Fig. 12. Creek in Vyšná Olšava – adjusted state

Mainly fortification of the slopes increases stability of water streams, especially at a time of flood situations.

Conclusion

SEPA (Scottish Environment Protection Agency) define two categories of engineering for bank protection: green and grey. Green options involve engineering with biodegradable or living materials or un-mortared rip-rap restricted to the bank toe only. Grey engineering involves major bank modification, often using artificial materials. The causes of bank erosion and the methods of protection and stabilization are highly variable Engineering has to consider all external factors participated on calculations regarding on appropriate bank erosion measures selection.

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