

Evaluation of sediment barriers in relation to the trap of soil particles

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PARAMETERS AND CONDITIONS FOR IMPLEMENTING SEDIMENT BARRIERS

Sediment barriers have the character of technical anti-erosion features, where their purpose is to drain or slow down surface run-off in a built-up area or landscape. This leads to sedimentation of entrained soil particles and reduces the overall damage caused by water erosion (Whitman et al. 2019). The presence of sediment barriers on the site is temporary in nature and is often based on a real need to address the current erosion problem (Liu et al. 2021). They are most often used to protect built-up areas, transport infrastructure, construction sites and in some cases on agricultural and forest plots of land (Zech et al. 2009; Wolka et al. 2018; Robichaud et al. 2019).

Compared to purely technical anti-erosion features, sediment barriers have lower capacity to accumulate surface run-off. However, their potential lies primarily in the possibility of efficient distribution of the source area of micro-basins, trapping and slowing of surface run-off with subsequent sedimentation of soil particles. Nevertheless, it cannot be said that all barriers are based on the same principle. Some are designed to filter water and trap eroded soil particles as much as possible, while others are used to safely drain surface run-off from the plot of land. This is directly linked to the way they are being implemented. Barriers are built with a slight longitudinal slope for surface run-off, usually 1 to 2% (Herweg & Ludi 1999). Conversely, for filtration and sedimentation, they are implemented in such a way that their layout corresponds to the letter J or C and a storage space is created (Zech et al. 2007; Girona-García et al. 2021).

The speed of making and creating the anti-erosion feature also plays an important role in terms of practical application. Machines that have made work much easier have already been developed or adapted for some

of the mentioned sedimentation barriers. An example is the Tommy silt fence machine, where the length of 30 m can be realized on the plot in about 20 minutes (EvTEC 2001). It is also possible to prepare soil bunds relatively quickly, using a modified plow to establish the embankment of the measure (Bado et al. 2016). The speed of implementation for some types of barriers depends on the availability of material and the possibility of using locally available materials. This applies, for example, to a straw bale barrier or vegetation barrier. If the intention to implement a sedimentation barrier is known in advance, it is possible to grow material for the construction of a sedimentation barrier or obtain it by modifying nearby vegetation.

The United States of America Environmental Protection Agency (USEPA) has established basic rules for the use of silt-fences and other sediment barriers. The basis is that the source area of the river basin should have an area of approximately 10 ares per 30.5 m of the sediment barrier length. The measures dimensioned in this way should not be damaged and should retain surface run-off if installed correctly. The established rule is widely accepted by the south-eastern states of the USA, regardless of the slope gradient and the length of the sediment barrier. The only exceptions are the states of Alabama and Tennessee, which allow a maximum catchment area of 20 ares (EvTEC 2001; Bugg et al. 2017). The maximum slope, on which it is no longer appropriate to use sediment barriers, is given in the range of 26° to 45°. These conditions of implementation were set primarily to ensure complete safety in the built-up area even for heavy torrential rains with a lower probability of re-occurrence. However, outside the built-up area, where there is no risk of significant damage to property and infrastructure, the conditions for implementation can be slightly less strict. This is evidenced by other studies where the catchment area was larger (Mishra et al. 2006; Robichaud et al. 2019).

OVERVIEW OF SEDIMENT BARRIER TYPES

SILT-FENCE

Description. This barrier consists of a woven or non-woven fabric, usually made of polypropylene, which is sunk into the ground and attached to wooden or metal support posts (Figure S1).

Application of sediment barrier. This barrier is used in places where the area-based surface run-off prevails. It is most often implemented around the perimeter of construction sites, in the vicinity of water recipients and running waters. This measure can also be used to capture and trap sediment on forest plots of land that have been damaged by fire. The implementation can be done in lines or in the shape of the letter J or C, when the anti-erosion element is equipped with a storage space.

Installation and removal. A tractor equipped with a special arm for sinking the fabric into the ground, the so called slicing method, can be used. Alternatively, the fabric can be placed in the excavated trench by a trencher machine. The parameters of the immersion depth are different according to the method used. In the case of the slicing method, it is most often around 0.3 m, and in the case of the trenching method, the ditch is deepened from 0.15 to 0.2 m. Subsequently, the corresponding ways fabric are sunk into the soil follow (Figure S2). Support columns need to be hammered into the soil for more than 0.2 m. Their spacing



Figure S1. Directing run-off through the silt-fence barrier

depends on the load and is in the range of 0.9–2.1 m. The fabric is attached with staples or PVC tapes. Disassembly consists in removing the support posts and pulling out the fabric by mechanized means. If the individual parts of the barrier are not damaged, they can be used repeatedly.

Maintenance. Checks for cracks, fabric slipping and its undercutting after torrential rains are carried out. This material must be removed if sediment accumulates to a height of more than 0.2 m.

STRAW BALE BARRIER

Description. This barrier is created by a linear wall of straw bales, which are stabilized by wooden posts (Figure S3).

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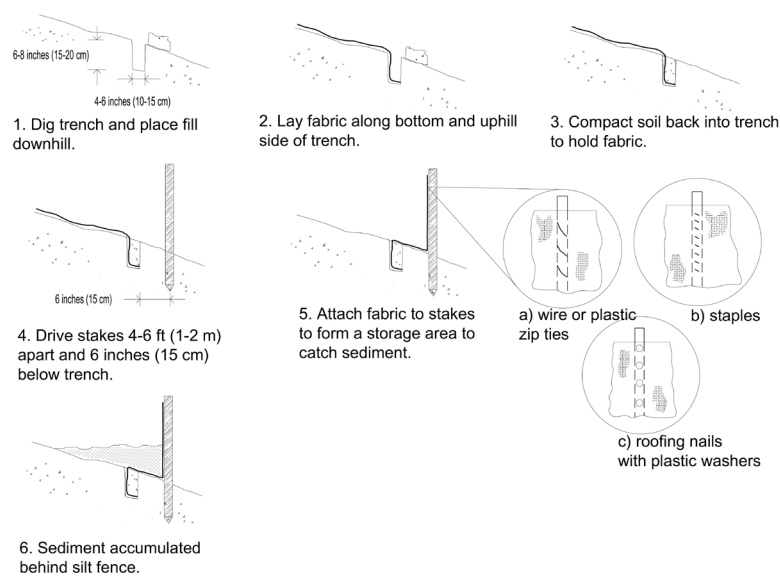


Figure S2. Silt-fence installation step by step (Robichaud 2002)



Figure S3. Profile of straw bale barrier

Application of sediment barrier. The straw bale barrier is placed in shallow ditches and valleys in order to interrupt surface run-off and retain entrained soil particles. This barrier is therefore also used in places of more concentrated run-off. However, some studies indicate that heavy rainfall often causes damage and repairs must be made. The cost of transporting and importing bales can be reduced by using locally available materials. The most common method of implementation is in the shape of the letter C.

Installation and removal. Prior to installation, it is necessary to create a basis joint with a depth of 0.1 m in which the straw bales are placed (Figure S4). Subsequently, the straw bales are stabilized by a wooden

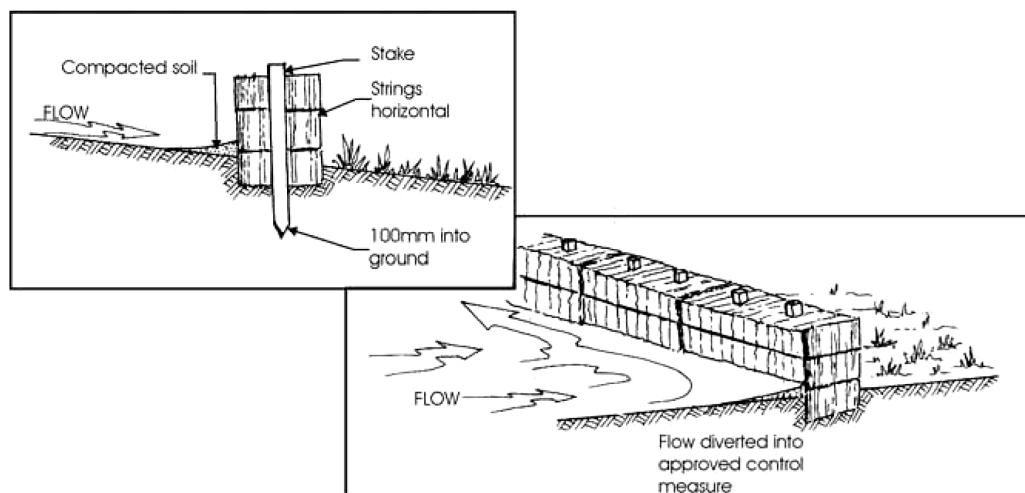


Figure S4. Method of straw bale barrier installation (Clemens & Dunphy 2010)

support column ($0.05 \times 0.05 \times 0.8$ m), which is incorporated into the straw bale, when only 0.1 m protrudes. Subsequently, the upstream side of the bales is covered with soil above the considered maximum level. This embankment should be slightly compacted with a roller. The most commonly used straw is rye or wheat. Rice straw degrades the least, but it is hardly available for most areas. In the event of removing the barrier, the support posts are pulled out, the string or wire is removed from the bales and the straw is spread over the land.

Maintenance. The individual bales are inspected for rot and moulder, in which case the defective bale must be replaced with a new one. In the case of accumulated sediment up to $\frac{1}{4}$ of the height of the straw bale, it is advisable to remove this sediment for the correct functioning of the measure.

SOIL BUND

Description. The soil bund is formed by an embankment of the topsoil horizon, which is compacted and subsequently sown with strengthening plants (Figure S5).

Application of sediment barrier. It can be used on soils with a sufficiently high topsoil profile. From



Figure S5. Soil bund with vegetation

the point of view of soil fertility, it is not appropriate if significant mixing of soil horizons takes place. The classification of soils according to the texture composition has a fundamental effect on the stability of the bund, i.e. especially suitable soils are sandy loam and loamy soils and, to a limited extent also clay-loamy soils. This anti-erosion measure is used on agriculturally farmed land, mainly in African and Asian countries. Long slopes are interrupted by a system of bunds (Figure S6). This barrier can be implemented in line, but it is also possible to create a storage space in the shape of the letter J or C.

Installation and removal. Specially modified plows are used to make the bunds, which are able to create a bund with a height of 0.35 and a width at the base of about 1.0 m. It is suitable to sow the bund, and grass mixtures are most often used. It is recommended to slightly roll the bund for better emergence of seed and strengthening. When establishing the bund, a suitable soil moisture content in the range of 10–20% should be observed, i.e. that the soil is not too dry, but also not significantly sticky. Removal is relatively easy, i.e. the bund is only plowed.

Maintenance. The soil bund needs to be checked for damage caused by small rodents - especially mice. If this is the case, then the mice population needs to be reduced. This is possible with the help of rodenticides or, in a more environmental way, plowing a re-building the measures. If sediments of about 0.15–0.2 m start to accumulate on the upstream side, depending on the height of the bund, it is necessary to promptly remove these sediments.

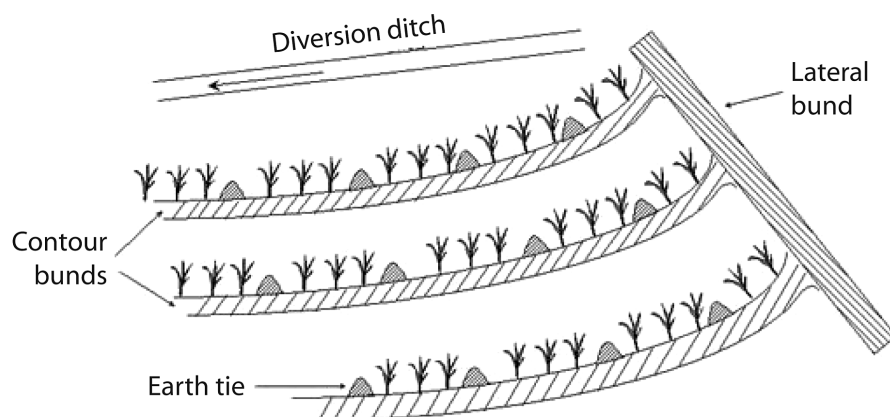


Figure S6. Soil contour bunds for field crops (Mati 2006)

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BRUSH BARRIER

Description. Barrier construction is formed by organic material most commonly from trees and shrubs (Figure S7).



Figure S7. Soil bund with vegetation

rier. The remaining organic material is composted, burned, or remains there to naturally decompose on the plot of land.

Maintenance. Regular checks of tightness and cavities, which need to be fixed after detection, are carried out. Once the sediments reach a height of 1/3 of the barrier, they must be removed. Ordinarily, after the installation, the brush barrier is relatively permeable. However, over time, the barrier becomes clogged and does fulfil better its anti-erosion function (due to the rising of the water surface and the sedimentation process).

SEDIMENT CONTROL LOG

Description. A cylindrical structure similar to a tree trunk, made of natural materials – straw, coconut fibre, and compost (Figure S8).



Figure S8. Sediment control log on an experimental plot (Bulnes Garcia 2013)

As soon as the sediment reaches the height of the barrier, it is removed. If the whole measure is made of biodegradable materials, it can be spread out and left on the place.

Maintenance. Regular inspection for decay, the presence of mold and rot. In case of damage, the defective piece is replaced with a new one.

Application of sediment barrier. This barrier is mainly used in places with enough material to create the barrier. In combination with other anti-erosion measures, it is most often used to interrupt the length of the slope in forests. Due to the natural degradability, it is not appropriate to implement brush barriers in places with too much concentrated flow.

Installation and removal. The installation can be carried out as a tangle of individual branches, in the form of dips anchored in the ground or as a mulch of organic material. The latter, i.e. mulch barrier must be further strengthened by a coating of the filter fabric. The fabric is incorporated into the soil a few centimetres or anchored with fixing staples. When removing, it is necessary to separate artificial or metal parts from the barrier.

Application of sediment barrier. This barrier is used to shorten the surface run-off path on erosion-threatened slopes, it is appropriate to combine it with other anti-erosion barriers based on surface coverage by plant residues. Although it initially permeates water and retains sediment, it becomes an impermeable barrier over time due to clogging. It is used on construction sites, around roads, in shallow ditches and is often used to break steep slopes.

Installation and removal. This barrier is most often brought to the plot of land in a rolled-up state. The best anti-erosion results are reached when the sediment control log is implemented perpendicular to the direction of surface run-off. The installation consists in laying the cylinder on the soil surface and its subsequent stabilization with wooden posts.



Figure S9. Triangular silt dike (Bulnes Garcia 2013)

TRIANGULAR SILT DIKE

Description. A triangular silt dike composed of urethane foam wrapped in a woven polypropylene fabric (Figure S9).

Application of sediment barrier. This technical measure is very resistant to deformation, so it is suitable to put it in places of concentrated surface run-off. This barrier fares well when driven over by heavy machinery, after which the barrier immediately regains its original shape. It is necessary to stabilize the triangular silt dike with staples, which hold and tighten the apron in front of and behind the barrier.

Installation and removal. It is suitable to stabilize the triangular silt dike by placing it 0.05 m into the soil. At the points of concentrated run-off, the centre of the dike must be the lowest point of the whole technical feature. The fabric in front of the measure must be incorporated into the ground to prevent the dam from underflowing. If no damage is found during removal, this anti-erosion feature can be stored and reused on another area.

Maintenance. Especially during machinery driving through the barrier, it is advisable to check whether the triangular silt dike keeps its shape. At the same time, the possible tearing of the fabric and the tension of the apron in front of and behind the barrier is checked.

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