Figure 1: Vegetated, erosion control on road embankment

Erosion-stable road embankments - Design and selection of system solutions

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Erosion often occurs on road embankments when there is a strong and constant impact of precipitation due to local weather phenomena. Likewise, dry periods cause the soil to hold together no longer in agglomerates due to a lack of cohesion of the soil particles but to fall apart. In the next step, high wind or water forces transport detached soil particles away. This may lead to visual obstructions due to dust accumulation or to silting and clogging by mud. If the transport forces decrease, the possibly contaminated soil material is deposited again in undesirable places. This triad of erosion, transport and deposition can lead to considerable problems.

Mechanisms of slope erosion

On slopes, surface or rill erosion usually occurs after a precipitation event has redistributed the surface. Figure 2a shows the raindrop transferring its kinetic energy to the slope surface as soon as it reaches the ground surface. In the process, the droplet disintegrates the soil particles. In Figure 2b. fine particles begin to clog the pores of the soil surface and reduce infiltration. Initial sloughing begins. Surface runoff has formed in

Figure 2c. and downslope particle removal begins. Erosion, the start of the movement and subsequent transport, leads to the familiar erosion phenomena, such as erosion rills and gullies or surface erosion.

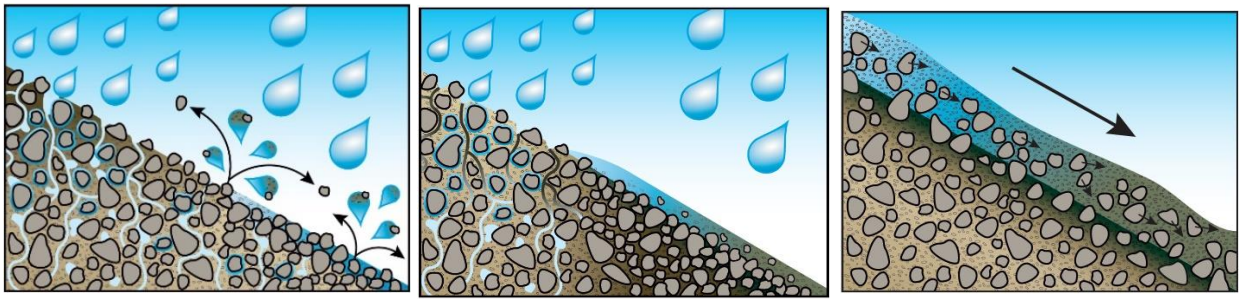

Figure 2: a. Erosive precipitation hits a slope surface b. Pore blockage c. Surface runoff with material transport

Slopes along heavily used traffic routes should be particularly protected against erosion. This is because spontaneous failure poses a risk to road users with costly consequences, e.g. expensive damage repair. Deconstruction costs can be high if deposited material impairs technical structures. It, therefore, makes sense to implement measures to reduce the erosion risk at an early stage. Thus, it is necessary to correctly understand the processes involved and develop targeted, project-specific solutions.

Erosion control for a better climate

For example, a slope planted with grass, as in Figure 1, is easy to maintain and blends well into the landscape. It provides infiltration capacity compared to the heavily sealed road surfaces. Infiltration is important for a good microclimate, and in a broader sense, also for groundwater recharge. Vegetated slopes support the microclimate through their interception storage effect. The roots of the plants hold the soil water in the upper soil. Through evapotranspiration, the plant leaves connect water exchange with the air. Many plants have a high surface area due to many leaves, and the wetting of the plants also has a positive effect. Vegetated slopes also contribute to biodiversity if different plant species (e.g. flowering plants) can integrate. A constantly vegetated slope thus offers an enormous advantage for the climate in contrast to sealed slopes.

Such green slopes can contribute to improving the climate worldwide and in large numbers. The temperature above such a vegetated slope is lower during hot spells, and the reflection of a green slope is lower than that of sealed or unvegetated slopes.

Systems for solving erosion problems

A good erosion control system has a surface erosion control product with associated fixings. The systems provide flat support, a good bond with the subsoil and secure protection against different types of erosion. These systems can be temporary or permanent; see Table 1.

Table 1: Erosion control systems

Temporary	**Permanent**
Natural fibre net, e.g. made from coconut fibres	Randomly oriented PP filaments
Natural fibre mat, e.g. made from coconut fibres	Reinforced randomly oriented PP filaments
Biodegradable randomly oriented filaments	Nonwoven with randomly oriented PP filaments
Biodegradable nonwoven	HDPE Geocell

Temporary erosion control

Biodegradable erosion control systems are natural solutions that hand over their function to the established vegetation. They provide protection for the initial vegetation and in the vegetative phase for the planting and reduce the energy of precipitation on the surface. The areal products are laid on the slope surface and secured against the wind with likewise biodegradable fixings. The erosion control system is thus completely biodegradable, and there is no need for removal. Depending on the raw material used, the functional life varies. Figure 3 shows a coconut fibre net. Coconut fibres have a high natural lignin content and therefore degrade slowly. The woven net structure has a shadowing effect due to the specific thread thickness, which positively supports the regulation of soil moisture. The openings of the net offer both monocotyledonous and dicotyledonous plants optimal space for rapid establishment. The natural fibre net is fixed with sharpened wooden stakes with cross-wood for an optimal bond with the substrate. The areal product is delivered without packaging, as a roll and should be installed quickly.

Figure 3: Functionality of a temporary erosion control system using the example of Secumat® Green Coco

Permanent erosion control

Geosynthetic erosion control systems have been used successfully for many years. The lightweight products can be easily and quickly applied to the top layer of soil. These systems are effective immediately after installation. The advantage of geosynthetic products over natural fibre products is their permanent protective effect, see Figure 4. Permanent products work reliably because soil capable of vegetation is very well bound and held in the open-pored filament layers. The filament layer corresponds to an artificial root network until the plants have developed roots. Unlike temporary erosion control systems, these permanent systems also fulfil their function when the vegetation on highly exposed slopes grow incompletely or fails after years of unusual dry periods. During heavy rainfall the system stabilises and reinforces the soil in addition to the natural root system.
A permanent fixing product is recommended to match the permanent surface product. Figure 4 shows a fixing in the form of a sharpened, isosceles u-shaped steel pin. This fixes the randomly oriented filament product positively to the substrate. This avoids heaving and facilitates filling with topsoil. The surface erosion control product is supplied in rolls, can be stored, and can be laid overlapping or side by side and quickly fixed in place.

Figure 4: Functioning of a permanent erosion control system using the example of Secumat® Classic

In addition, these products offer trickle protection for facing systems. There is also the option of using intelligent combination products. These can provide good erosion control for special requirements.

Design of an erosion control system

An engineering calculation must consider acting forces. On road embankments, erosive precipitation acts on unprotected soil surfaces. This results in soil erosion. The main factors are:

- the prevailing local situation of the slope, climatic zone, etc.
- the orientation of the slope (cardinal point or precipitation attack direction),
- the geometric form
    - slope length
    - slope inclination
- the structure of the slope surface (structure of planned or existing vegetation, terracing, etc.), the type and structure of the predominant soil material.

- Calculation of safety factors following regulations, codes of practice and standards.

Erosion control systems should therefore not be selected precisely without prior knowledge. It is recommended to also pay attention to the benefits and duration of function on such secured slopes. Software solutions offer the possibility to develop a customised solution with little effort. Software solutions can be used for this purpose, see Figure 5.

Figure 5: Naue Erosion Control Software (Version 1.0, 2022), Start page

An adapted erosion control system can be dimensioned safely and quickly with the appropriate software. The data to be included can be entered easily and site-specifically, see Figure 6. The output is an erosion control system tailored to the application, considering the aforementioned factors.

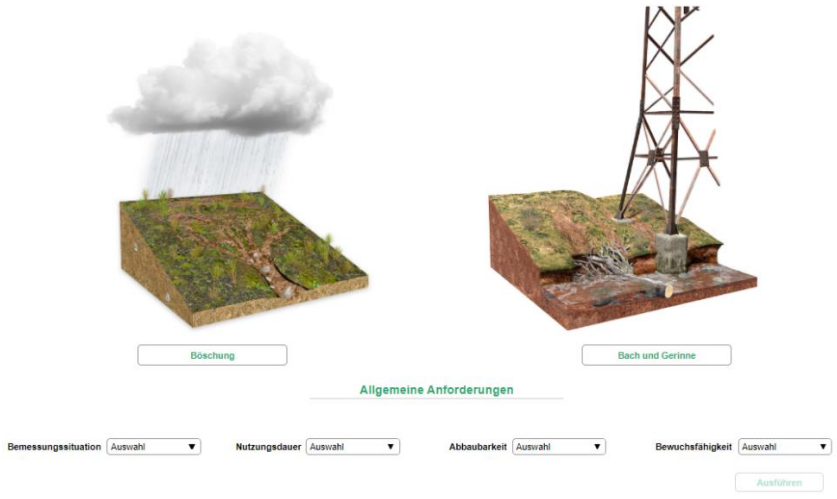

Figure 6: Selection of applications in software solutions using the example of Naue Erosion Control Software (Version 1.0, 2022)

Road embankments with protection against erosion

A vegetated slope not only looks beautiful: green slopes are sustainable. Erosion control systems can be adapted to any construction project and can be retrofitted to existing slopes. Retrofitting has the advantage that it can be implemented easily and quickly. The protection systems are installed in the topsoil layer, so no extensive soil excavation is necessary. In the case of newly created slopes, the erosion control system can be integrated into the topsoil layer at the end of a construction phase.

The slopes can be easily maintained by alternate mowing. Alternate mowing should be used so that insect habitats are not completely destroyed within one mowing cycle, as would be the case with complete mowing. Figure 7 shows a motorway embankment in construction condition, which will be equipped with a permanent erosion control system. In this case, a permanent layer of randomly oriented filaments with raschel fabric and suitable fixings is used. The slope is covered with topsoil suitable for vegetation. The illustration on the right shows a road embankment with a vegetated erosion control system.

Figure 7: a. Motorway embankment in construction stage b. Road embankment with erosion control

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