GRASS COVER AS A DIKE REVETMENT

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Grass cover as a dike revetment
Technical Advisory Committee for Flood Defence (TAW)

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A variety-rich, false oat meadow along the Maas river (management category A) with oxeye daisies, brown knotweed, common sorrel and wild onion

Cover photo: Ijssel dike at Olst, immediately after a high water period
The adjusted, agrarian-managed, completely green Wadden Sea dike at Blija (management category B)

Introduction

A large part of the Netherlands’ dikes are covered with grass. Dikes with hard revetments also have grass cover on a significant part of the dike surface, such as the crown and inner slope.

Research and experience since the mid-eighties have shown that grass coverings can be of high quality in terms of erosion resistance and encouragement of development of nature. This high quality can be achieved with suitable grassland management. Grass cover is a valuable type of revetment, just as cement blocks or asphalt. In fact, its strength can be even greater than some hard revetment types.

This brochure gives the most important information about the behaviour, laying and maintenance of grass coverings and refers to specialized literature for details.
What is a grass cover?

The revetment type ‘grass cover’ is comprised of grassland vegetation rooted in soil. Modern dikes generally have a covering layer of clay and a core of sand.

Structure and division of a grass cover

The soil near the surface of the top layer has a high root density, is elastic in moist conditions and porous. The underlying clay is, conversely, stiff (or plastic when moist or not yet aged) and usually somewhat less permeable. The erosion resistance of the covering layer, near the soil surface, is (usually) greater than at deeper parts of the layer. The upper, densely rooted part, with an irregular bed structure and a higher erosion resistance, is called sod.

A covering layer can consist of different soil layers: a top layer of sandy clay on a substrate of oilier clay. The ‘grass cover’ revetment type is divided into sub-parts, which are named in this figure.

Functions of the grass cover

Based on the main function of water retention it follows that one function of grass covers is as a revetment: protection of the dike body against erosion caused by loading from waves and currents. The Flood Defences Act [1] requires that other functions of the flood defence be considered and encouraged when placing or altering a flood defence. The functions are established through planning decisions made by the State, Provinces and Municipal authorities. A flood defence can have values in terms of nature, the environment, landscape and culture-history (abbreviated in Dutch as LNC). TAW 1998 [9], chapter 5, and TAW 1994 [10] indicate how these LNC values be assigned and then maintained and promoted.

‘Grass cover’ is a revetment type that can fulfil several functions simultaneously: combining erosion protection with nature or recreation.
The main function: water retention

The water that loads the flood defence, also subjects the grass cover to water pressure, waves and currents. The grass cover, as every other revetment, protects the soil body of the flood defence against erosion and also to some extent against high ground water level. Requirements for the grass cover need to be met in order to fulfil these functions.

Erosion resistance
Investigations and experience have shown that the resistance of grass cover to erosion can be controlled by how it is laid and grassland management. The latter has the most effect. Sod is more resistant to erosion as rooting becomes more dense. The rooting connects the small aggregates and soil particles and prevents them from being washed out. A good form of management leads to a well-rooted sod. Good grassland management ensures a relatively low availability of nutrients. This leads to a great diversity of plant species, both grasses and herbs. Because the plants have difficulty obtaining food, they invest in their root systems. The different plant species each have their own pattern of root growth, which leads to a well-rooted sod. Grass production is also low.

An adapted agrarian managed grass cover, with sheep pasture, on a highly erosion resistant clay substrate in a laboratory study was found to be resistant to erosion caused by 1.35 m high waves for many hours. The resistance of the revetment lies mainly in the sod. Because of this, for example, structured clay with little root penetration under the sod is eroded 15 to 50 times faster than good sod.

A sea dike grass cover in the Delta channel loaded by high waves
Conversely, a poor quality sod, such as one resulting from being mowed and leaving cuttings, is more susceptible to erosion than the original ‘good’ clay category 1 clay cover, in which the sod is rooted. The erosion resistance is then greatly reduced to a few decimetres by climatic influences and especially the digging of animals. The rooting is very coarse and poor. This has been observed both in laboratory studies and in the field.

‘Waterproof’
The degree of permeability of the covering layer cannot be controlled by adjusting clay composition or grassland management. The grass cover (and its clay covering) provides some resistance to water pressure with its permeability ($10^{-5}$ to $10^{-4}$ m/s), which is only a bit lower than that of clean sand in the core of the dike. Permeability can be lower immediately after laying because the clay is kneaded and plastic and still forms a whole. Later, however, the permeability of the clay above the (ground) water level increases because of ageing, along with crack formation and the activities of small soil animals. The relatively lowest degree of permeability for a specific clay covering can be attained by a good compaction of the clay and by not handling it when it is too wet (see Clay for Dikes 1996 [12]).

Sea dike sod wears very slowly (around 2.5 to 5 mm/hr) subject to wave loading: after 11 hours the grass plants are left on ‘stilt roots’ of a few centimetres

Stability
The grass cover naturally has to remain in place, especially under loading. Therefore, the covering layer must have sufficiently high internal soil-mechanical shear strength. The grass cover should also resist splitting under the influence of an upward groundwater hydraulic gradient, both during discharge (e.g., during a rapid fall) and under wave impacts. For steep slopes, both infiltration from wave overtopping and rapid falling of the outer water level lead to shearing of the sod over the clay covering. For very steep slopes (> 1:1.5), the soil itself can be
unstable and creep. This can be seen in the formation of small sliding marks, which are often evident before the development of sheep paths.

Although hydraulic gradients of discharging ground water caused by wave impacts are measured that crack un-rooted clay, a good sod appears to be sufficiently strong and elastic to resist cracking, even if there is some plastic deformation in the clay underneath. The stability of a grass cover is only jeopardised in the case of very steep slopes and under extreme ground water conditions.

**Laying grass covers**
For new construction or extensive reconstruction of dikes, it requires several years before the grass cover is ready. The laying of a grass cover is divided into three steps:
1. placing a clay covering that provides both a good growth area for the vegetation and having sufficient erosion resistance,
2. ‘sowing’ grass and herbs (by returning old topsoil or sod, spreading out hay of a desired vegetation from the surrounding area, or actually sowing), or seeding. Account is thus taken of the desired grassland type and the accompanying ultimate management.
3. knitting together of separate plants into a closed vegetation that is in equilibrium with the grassland management and growing area.
Steps 1 and 2 take place in the year the grass cover is laid. Step 3 takes a few years: 3 to 5 years is considered a minimum to achieve a reasonably well-closed sod. Laying a grass cover is thus not finished once the last earth-moving machines have disappeared from the work site! There can be setbacks during the laying: dehydration or freezing of the seedlings, or wash out of the upper seeded layer the first year. Laying would then require another year. Yet management must begin as of germination, so that after 1 or 2 years the definitive management strategy can be followed.

It is thus recommended, for example, that a future meadow first be mowed a few times until the sod is more or less closed. In the first years after having laid a grass cover, some protection during high water periods may be necessary, e.g., a temporarily placed, or biodegradable geotextile. Bare clay covering of clay category 1 is strong enough on river dikes during the first winter.

The soil in the sod plays a role in erosion resistance, although a minor one. During laying, it is recommended to use a maximum sand content of 50 per cent. Field experience and laboratory studies have demonstrated that grass cover on soil with higher sand content can be erosion resistant. In case of sufficiently low loading, a good grass cover on sand is also adequately erosion resistant, although laying a dike comprised entirely of sand is not recommended.

The sandier the clay, the more nutrient deficient it is. On nutrient-poor soil, the best-rooted sod with the greatest erosion resistance can develop. On nutrient-rich soil, obtaining such a sod demands much time and effort. Therefore, the covering layer is usually laid in two layers: an oilier substrate if necessary for residual strength or to process local clay, and a 0.25 m thick top layer, which is more sandy and less nutrient-rich, for robust vegetation development.
An extensively grassy and hay-covered outer slope on the Waal dike at Oosterhout (management category A or B); in the spring a dense mosaic of 40 plant species (‘false oat meadow’)

**Grassland management**

*Management categories*
Grassland, under Dutch climatic conditions, has to be grazed or mowed to avoid becoming rough and, via a thicket stage, ultimately develop into a wooded area. Pasturing or haying are known as ‘grassland management’ or ‘management’ for short. Strictly speaking this is regular ‘small maintenance’.

The composition and the structure of both the vegetation and clay and, thus, the strength of the sod are mainly determined by the method of grassland management.

Because management is very important for the grass cover quality, it has an important place in monitoring safety according to the Guide on Safety Monitoring [3]. For the sake of simplification, the different possible methods of management are divided into four management categories: A, B, C and D, which provide sod that decreases in strength and in ecological value from A to D. This division can also be used for design and laying. A description of these categories is given below, along with their management strategies and resulting vegetation.
Category A:
The management strategies included in this category lead to effective erosion-resistant grass revetments. The erosion resistance attained is such that few requirements need to be established for low loading of the substrate. **Hydraulic management** and **natural-technical management** are included in this category. Fertilisation and use of pesticides are definitely omitted from this category. The ecological value can be high.
- **Haying:** Mowing twice per year; more or less frequent mowing possible depending on production. In nutrient-poor situations mowing once yearly in the fall will suffice. Such a situation can also arise following years of hay management. A characteristic for haying is that after each mowing the cuttings are removed within about 8 days to, among other things, avoid nutrients being washed out of the hay. In time such hay management will lead to **diverse false oat meadows**. In the long term a development towards **river valley grassland** is possible.
- **Pasturing:** Periodic or continuous pasturing with sheep. The number of sheep is always matched to grass production. In continuous pasturing, pasturing takes place for the entire grass-growing season (from mid April to mid October) with a low livestock density. Additional mowing will be required for areas where the vegetation has not been grazed. In the long term this management can lead to a **diverse crested dog’s-tail grass meadow**.
**Crested dog’s-tail grass on a sea dike**

**Category B:**
This category includes forms of management that produce a well-closed, reasonably erosion resistant grass cover, but with a sod thickness and rooting that is actually not as much as in category A. For high loading, the strength may be insufficient. The ecological value of this and the following categories is low. This management form includes:

- **agrarian management**, for example by **pasturing with sheep**, continuously or periodically. Light fertilisation (up to 70 kg N/ha. per year) is applied. The difference with category A is that fertilisation is used in this case and livestock density is higher.
  
  The result of this management is a **non-diverse crested dog’s-tail grass meadow**.

- **lawn management**, consists of mowing 7 to 12 times per year and the cuttings are left in place. There is no fertilizer application in this category. Lawn management leads to a **non-diverse bluegrass-rye grass meadow**.
Category C:
The result of this management is a poor to mediocre erosion-resistant grass revetment. The sod is poorly to moderately rooted. Open areas can arise very rapidly due to intensive pasturing. These areas are hardly to not at all rooted and do not become further closed. Erosion resistance is largely derived from the clay in and under the sod. This is usually not sufficient in case of high loading and the usual covering layer thickness.
Category C consists of:
- **intensive agrarian management strategies** (usually pasturing), characterized by (intensive) fertiliser application.
The result for pasturing is a **non-diverse bluegrass-rye grass meadow**, and for haying, a **non-diverse false oat meadow**.

*A non-diverse false oat meadow on a Westerschelde dike; hayed, fertilised (management category C)*
An intensive agrarian managed estuary dike along the Westerschelde (management category C)

**Category D:**
Very poor erosion-resistant revetments are formed by:
- **neglecting annual management,**
- **mowing once to four times a year** without removing the cuttings (‘mulch mowing’),
- **burning** from time to time,
- **pasturing with cattle or horses,**
- **applying extreme amounts of fertiliser and intensive pasturing.**

The sod is very poorly rooted and has a low covering and many open areas. The first three management strategies produce a **vegetation with rough herbage** making the clay in the sod consist of loose, crumbly aggregates that are very easily washed away. Pasturing leads to large open areas that increase in size. These forms of management are not suited to water-retaining dikes.

A summary of grassland types, accompanying management strategies and the erosion resistance achieved is shown in the table below. This is taken from the TAW Technical Report: Erosion Resistance of Grassland as a Dike Revetment [4] in which more information can be found about erosion and the strength of grass covers. More information about the laying and management of dike grasslands, also in relation to surroundings (river or sea) and the desired vegetation type can
be found in: Laying and Management of Grassland on River Dikes, 1992 [5], Laying and Management of River Dikes [6], Green Sea Dikes in Northern Germany and Denmark [7] and Introduction of Native Flora [8].

<table>
<thead>
<tr>
<th>Grassland type</th>
<th>Indicative number of species per 25 m²</th>
<th>Erosion resistance of the sod</th>
<th>Ecological value</th>
<th>Grassland management</th>
</tr>
</thead>
<tbody>
<tr>
<td>False oat meadow with edge species</td>
<td>27</td>
<td>Good</td>
<td>Very high</td>
<td>Irregular haying, unfertilised</td>
</tr>
<tr>
<td>False oat meadow, diverse</td>
<td>32</td>
<td>Very good</td>
<td>Very high</td>
<td>1 to 2x haying, unfertilised</td>
</tr>
<tr>
<td>False oat meadow, non-diverse</td>
<td>13</td>
<td>Moderate</td>
<td>Low</td>
<td>Haying, fertilised</td>
</tr>
<tr>
<td>Rough meadowland</td>
<td>8 – 20</td>
<td>Poor</td>
<td>Low</td>
<td>Haying, heavily fertilised, or mulch mowing</td>
</tr>
<tr>
<td>Crested dog’s-tail grass, diverse</td>
<td>36</td>
<td>Very good</td>
<td>High</td>
<td>Pasturing, unfertilised</td>
</tr>
<tr>
<td>Crested dog’s-tail grass, non-diverse</td>
<td>15</td>
<td>Good</td>
<td>Low</td>
<td>Pasturing, lightly fertilised</td>
</tr>
<tr>
<td>Bluegrass-rye grass meadow</td>
<td>12 – 18</td>
<td>Moderate</td>
<td>Low</td>
<td>Pasturing, heavily fertilised</td>
</tr>
</tbody>
</table>

‘What should I do with my grass cover?’

**Safety monitoring**

A number of possibilities for the laying and management of grass covers on dikes have so far been provided in this publication.

Safety monitoring of a grass cover, after a rough assessment of empirical data, is assessed based on the management of the grass revetment. When the type of management is unknown, none of the categories are appropriate, or when more certainty is desired, a detailed assessment takes place. This is based on the existing vegetation. Of course, the grass cover can also be tested for its additional functions.

It goes without saying that a revetment able to fulfil civil engineering requirements and LNC values does not need to be replaced.
A roughened ‘meadowland’ where the cuttings are left in place in front of the fencing, 10 plant species (management category D); Rhine river dike

Improving or laying

A revetment that receives an ‘unsatisfactory’ score can be replaced, but grass cover is generally better, faster and less costly to improve by adjusting the management methods. If the management used is from one of the lower categories B, C or D, then there is a possibility that the strength of the revetment can be increased by adjusting management: switch to a higher management category that does provide sufficient strength.

Sod density and rooting improve within a few years. Adjusting the grassland type usually costs more time because the species composition must then be changed. The establishment of the desired herbs and grasses can be encouraged by scattering seeds throughout the existing grass cover. More information about this can be found in Introduction to Native Flora [8].

For a transition from an intensive to a non-intensive agrarian grazing management, undesired herbs, such as creeping thistle, sometimes establish themselves because of their growth structure or dissemination in the surroundings. Massive establishment can be prevented with an intermediate phase of a few years without fertilized haying or with extra mowing.

Monitoring, to effectively observe the effect of an adjustment to management, is possible by recording characteristics needed for a detailed assessment from the outset. It is possible to see changes in the covering, vegetative composition and rooting.
A maintained grass cover kept with an adapted and better form of management will usually remain stronger for about four years than a newly laid grass cover that has yet to gain its full root-strength.

The flow chart (see page 19) indicates when, how and with help from what sort of information (acts, guides, technical reports and brochures) grass covers can be assessed, laid and managed.

**More information?**

For more information about the strength, laying and management of grass covers on dikes, you can address the Road and Hydraulic Engineering Institute, Flood Defences Department, secretariat (+31 (0)15-251-8436 or 251-8437). At the same address you can also obtain more copies of this brochure. For problems with safety monitoring you can contact the Monitoring Helpdesk (+31 (0)15-251-8450).

**Literature**

For the TAW reports and guides listed below, the most recent publications provide the correct information: ‘new before old’. So, although requirements for clay are given in the Guide on River Dikes [10], the valid requirements are those from the Technical Report on Clay for Dikes [4]. This is even truer in the case of recommendations for grassland management: the TAW brochure ‘Agricultural and natural-technical management of river dike grassland’ is outdated for a number of important points; therefore no reference is made to it.

[1] Act of 21 December 1995, Staatsblad 1996, 8, maintaining general rules to ensure the safety of flood defences against inundation from outer water and regulation of several related matters
[6] Laying and Management of River Dikes, return of diverse grassland using specific measures, Polder district of Maas and Waal, Province of Gelderland, sa
[10] Handouts: Vision Development; Spatial Designs; Inventory and Valuing LNC Aspects; and Policy Analysis, TAW, Delft, April 1994
Flowers on the Waal dike at Millingen: water milfoil (white), tuberous pea (red) and tansy ragwort (yellow) beside false oat and English rye grass
Flow chart for monitoring, managing and laying of grass covers

<table>
<thead>
<tr>
<th>Administrative policy</th>
<th>Evaluation</th>
<th>Management action</th>
<th>Literature to use</th>
</tr>
</thead>
<tbody>
<tr>
<td>Five-yearly monitoring</td>
<td></td>
<td></td>
<td>Flood Defences Act [1]</td>
</tr>
<tr>
<td>Grass cover Satisfactory or good</td>
<td>Continue or improve (additional functions or limiting minor maintenance) management</td>
<td>TR Grassland as Dike Revetment [4]; Laying and Management of River Dikes 1992 [5]; Laying and Management of river dikes [6]; Green Sea Dikes in Northern Germany and Denmark 1997 [7]</td>
<td></td>
</tr>
<tr>
<td>Grass cover Unsatisfactory</td>
<td>Adjust management so strength increases, monitor</td>
<td>TR Grassland as Dike Revetment [4]; Laying and Management of River dikes 1992 [5]; Laying and Management of River Dikes [6]; Green Sea Dikes in Northern Germany and Denmark 1997 [7]; Introduction of Native Flora [8]</td>
<td></td>
</tr>
<tr>
<td>Grass cover Unsatisfactory and unimprovable with adjustment management</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Design a new revetment: grass cover or hard material. For a grass cover, choose a definitive management regarding main and additional functions</td>
<td>Place clay covering in 1 or more different layers, ‘sowing’, Manage for short and long term</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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