



PROTECTING OVERFLOW DIKES FOR
CONTROLLED FLOOD AREAS IN BELGIUM

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I. Controlled Flood Areas

After the exceptional storm surge and ensuing flooding of 3 January 1976, the Belgian government decided to strengthen, widen and raise all dikes in the basin of the Tidal Scheldt on a systematic and uniform basis. It was also decided to create a number of "controlled flood areas" as part of the SIGMA PLAN, and to proceed at a later date to the construction of a storm surge barrier immediately downstream of central Antwerp (at Oosterweel).

The purpose of these "controlled flood areas" is to allow surge water from the river to flow onto nearby land and thus lower the height of the crest of the surge. The Tidal Scheldt basin comprises the Tidal Scheldt itself, and its tributaries namely, the Durme, Rupel, Lower Nete, the Greater and Lesser Nete Rivers, the Dijle and the Zenne,

A "controlled flood area" comprises agricultural or forested land lying alongside a river where the river embankment has been designed for overflow. The controlled flood area is encircled by a ring dike or embankment, which retains the flood water in the controlled flood area.

Table 1 lists the "controlled flood areas" in the Tidal Scheldt Basin.

Along the Tidal Scheldt		
1.	Tielrodebroek at Temse	(89 ha 79 a 09 ca)
2.	Grote Wal at Moerzeke	(30 ha 94 a 98 ca)
3.	Uiterdijk at Vlassenbroek	(10 ha 52 a 63 ca)
4.	Scheldebroek at Berlare	(30 ha 06 a 97 ca)
5.	Paardenweide at Berlare/Wichelen	(81 ha 35 a 97 ca)
6.	Bergenmeersen at Wichelen	(89 ha 95 a 50 ca)
Along the Rupel		
7.	Bovenzanden at Heindonk	(31 ha 38 a 19 ca)
Along the Lower Nete		
8.	Lier Polder at Lier	(23 ha 68 a 32 ca)
9.	Anderstadt I at Lier	(09 ha 84 a 22 ca)
10.	Anderstadt II at Lier	(10 ha 35 a 63 ca)
Along the Durme		
11.	Potpolder (flood basin) I at Waasmunster	(80 ha)
12.	Potpolder IV at Waasmunster	(80 ha 50 a)

Table 1

These 12 controlled flood areas total 517 ha 68 a and 97 ca and are now all ready for use. A thirteenth flood area is planned for the Kruibeke-Bazel-Rupelmonde polders which will have a total area of 591 ha.

The twelve operational flood areas will effectively lower the crest of the tidal wave in higher storm surges by 0,30 m, which means that with the planned dikes, storm surges of (+ 7,35) (T.A.W.) could be coped with, allowing for a margin of 0,5 m. The construction of the additional KBR flood area would lower the crest by a further 0,50 m, which would make it possible to cope with storm surges of (+ 7,85) (T.A.W.).

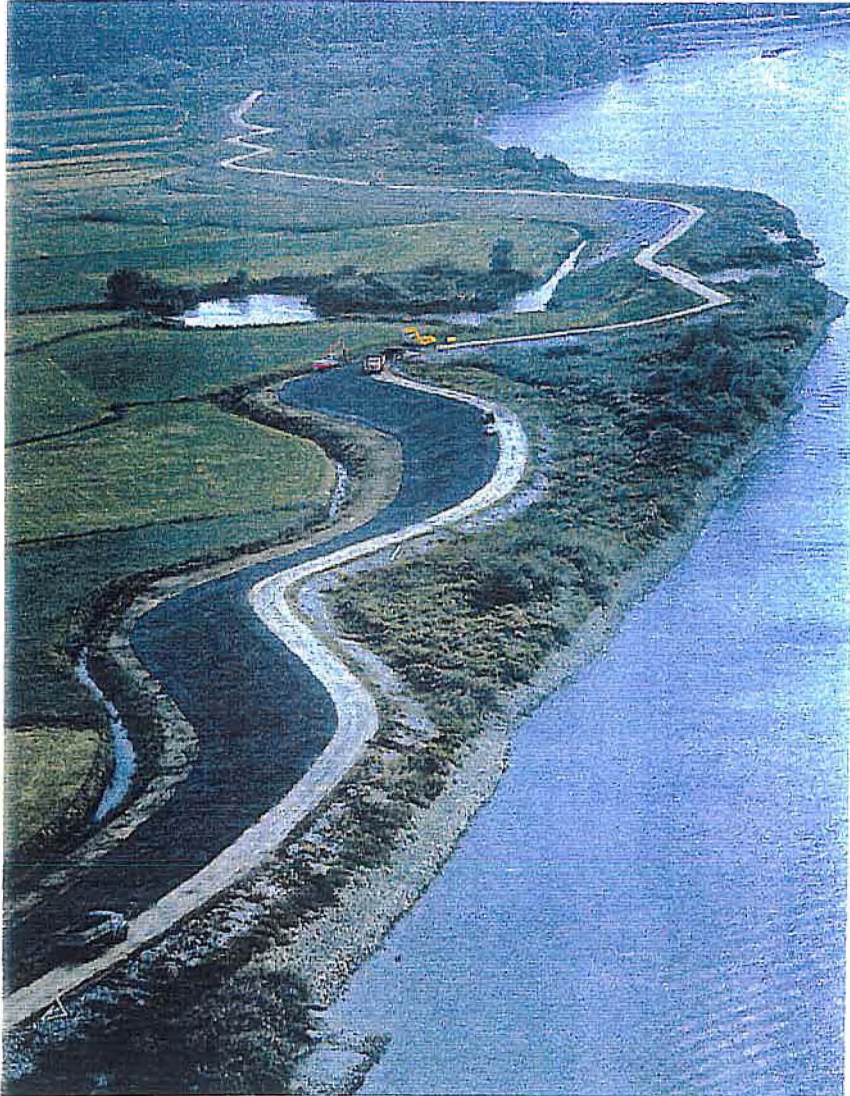


Photo 1 : Controlled flood area Tielrodebroek at Temse

The dike or embankment standing between a "controlled flood area" of this sort and the tidal river is called an overflow dike. These dikes are designed and built to be overflow dikes. They are first and foremost just like other dikes, a high primary barrier to the water in the river. However, this barrier function does not continue to the highest anticipated or indicative level used for the other, non-overflow, dikes but rather to a predetermined lower level. When an overflow dike is used for this purpose in tidal areas, the overflow dike turns all normal tides (including the highest spring tides) but does not turn storm tides. The purpose of the overflow dike is to take the top off the very high conditions of tide occurring during storm tides when and, only when, these occur. Such overflows of river water will thus only occur during a very limited period around the time of local high water.

Because of the agricultural importance of the land within the "controlled flood areas", and because of the impact of the overflow on reducing the highest conditions of tide during a storm surge, the crest of the overflow dikes is relatively high. Overspill thus only occurs in the winter months (early November to end March), so that there will be relatively little damage done to farmland in the event of a flood.

II. Theoretical Study and Model Tests

The reducing effect that the overflow over an overflow dike can have on the height of the storm surge water, depends on the difference in height between the water level at local high water in the river, and the crest level of the overflow dike, as well as on the overall length of the dike. The height difference between the height of the water and the top level will result in a given flow of water per running meter of dike, which will be withdrawn from the tidal river. In this connection, obviously, the capacity of the flood area will play an important role; the capacity being dependent on the ground level in the area and its overall size. However, practical experience has shown that the width of the selected flood area does not have such a great impact on capacity, but that their length, i.e. the length of the overflow dike, is of key importance.

The main questions which arise when determining the profile and the protection of overflow dikes are the following:

1. How great are the quantities of water flowing over the overflow dike?
2. How great are the current speeds which arise when water flows over the dike?

A first theoretical approach is given in hydraulic engineering manuals in studies of spillway design (fig. 1).

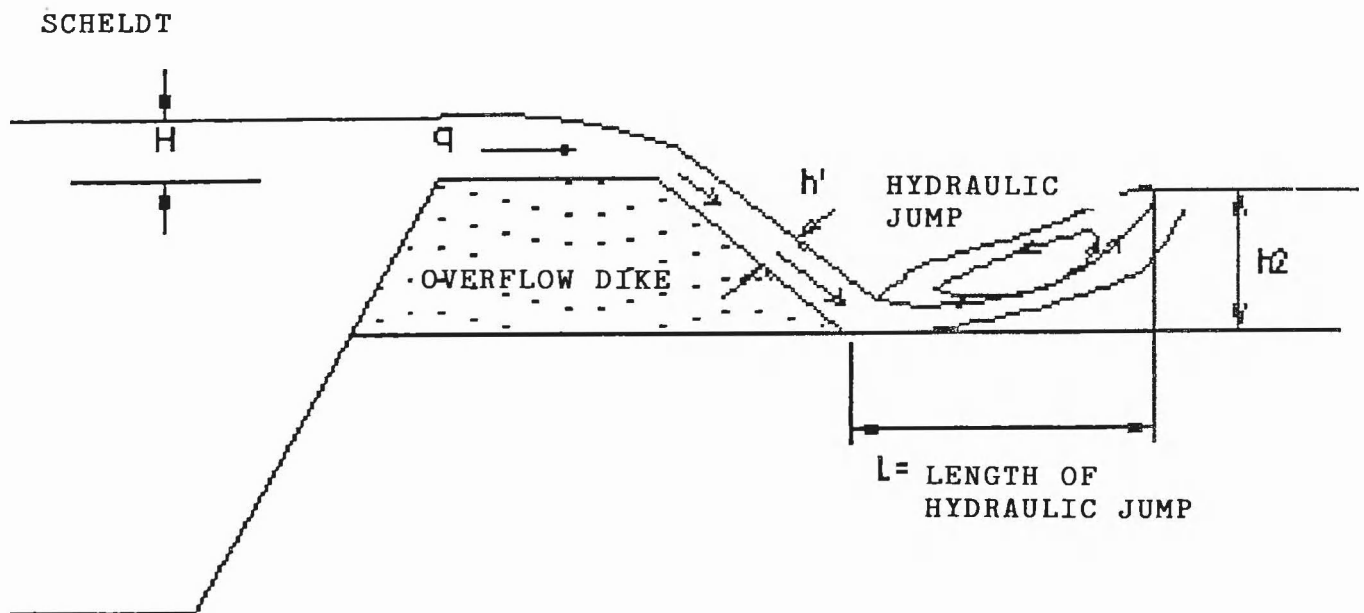


Fig.1

In general the rate of flow can be described as:

$$q = m \times H^{3/2}$$

where m is a dimensionless overflow coefficient which takes account of the critical height and the friction encountered by the water when spilling over the dike.

Laboratory trials showed that when the revetment of the overflow dike was artificial grass, the value of the overflow coefficient generally lay between 1,54 and 1,58.

Calculations and trials with models were carried out in the Flemish Hydraulics Research Laboratory "Flanders Hydraulics" to determine what the water speed and how thick the layer of water flowing over the landwards slope of the embankment would be.

At the foot of the slope of the dike the water must undergo a discontinuous change from a depth h^1 to a depth h^2 . Here the water forms a bubbling mass and rises to a higher level. This phenomenon is called hydraulic jump.

The hydraulic jump was likewise determined in the laboratory.

Trials on models were carried out at Flanders Hydraulics to study the water flow on overflow dikes.

The main conclusions of these studies are that:

1. when the level of water in the river $H = 0,5$ m above the crest of the overflow dike and the gradient of the landside slope is 16/4 :
 - the water will flow over the dike at $q = 0.53 \text{ m}^3/\text{s.m.}$
 - the thickness of the water layer on the landside slope $h^1 = 11$ to 12 cm.
 - the length of the hydraulic jump $L = 4$ to 5,50 m.
 - the water speed on the landside slope is 4,5 m/s.
2. when the level of water in the river $H = 1$ m above the crest of the overflow dike and the gradient of the landside slope is 16/4 :
 - the water will flow over the dike at $q = 1.54 \text{ m}^3/\text{s.m.}$
 - the thickness of the water layer on the landside slope $h^1 = 22$ cm.
 - the length of the hydraulic jump $L = 9$ to 13 m.
 - the water speed on the landside slope is 7 m/s.

III. Protection of the landside slope of the overflow dike

An overflow dike must, apart from meeting the requirements of stability, strength and rigidity demanded of all dikes, be capable of withstanding the very special loads imposed by the overflowing river water. Here it should be recalled that the water level in the river can rise to at least 1 metre above the top of the overflow dike, giving rise to extremely large flows down the slope.

As the object is to collect as much surge water as possible in the flood basin under certain extreme conditions of storm surge and as the overflow rate is directly proportional to the friction experienced by the water on the inland slope the following items must definitely be taking into consideration.

- the friction experienced by the overflowing water on the inland slope must be kept as low as possible. Tests indicate that grass is an efficient and environmentally attractive solution.
- however limited friction means high overflow rates, and high water speeds on the slope (4 to 7 m/s).

An ordinary natural grass covering (grass sown on a protective layer of clayey soil) can not withstand water speeds of 4 metres a second for any more than 2 hours. Should the water speed increase to 5 metres a second this falls to 1 hour and at a speed of 6 m/s the grass covering will not last 10 minutes. These figures moreover assume that the underlying layer of clay is dense and cohesive.

Apart from the high water speeds during overflow the inland slope of an overflow dike must also be capable of withstanding high hydraulic jump values at the foot of the inland slope. The turbulent zone may indeed be as much as 10 to 15 m wide.

In principle, designers must aim at avoiding the creation of a longitudinal trench running along the foot of the overflow dike.

Should, however, it become necessary to build a longitudinal trench at the foot of the overflow dike in order to facilitate the drainage of the flood area, the revetment of the inland slope must be continued over the intermediate berm and the edges of the trench (banks and bottom). The banks of a longitudinal trench of this sort lie in the hydraulic jump zone, and will become so saturated during overflow that the stability of the banks will be threatened, and in the worst case endanger that of the overflow dike itself.

Clearly the protection of the inland slope of an overflow dike (and of the berm between the riverside crest and the slope, as well of the landside berm at the foot of the dike must meet a number of specific requirements.

The protective revetment of the inner slope of overflow dikes must meet the following primary standards (functions):

- ELASTICITY :

needed in the event of differential settlements of the dike profile

- SEAMLESSNESS :

combats erosion, turbulence and water penetration during overflow

- RELATIVE SMOOTHNESS :

limitation of friction with overflow water, prevention of additional turbulence

- HIGH RESISTANCE TO WATER CURRENTS :

speeds of up to 7 m/s are possible

- DURABILITY :

to counteract effects due to heat, UV, vandalism, etc.

- STRENGTH & STABILITY :

to counteract forces due to turbulence and erosion and slippage of the revetment

- **RELATIVE IMPERMEABILITY :**

to prevent water penetration and lifting of layers further down the slope, although groundwater flows in the dike must be able to drain out adequately : **DRAINING**

- **SOIL RETENTION :**

to prevent particulate material in the substrate from being flushed away

- **PLANTABILITY :**

provision of environmentally attractive but stable grass cladding must be possible

IV. Fibrous open stone asphalt on geotextile

The solution for the protection of the landside slope of overflow dikes already used for a number of years by the Department of the Tidal Scheldt consists of protecting the landside slope (as well as the crest berm between the dike road on the crest and the landside slope, and the berm at the foot of the dike) with a water permeable but soil-retaining synthetic fibre textile on which fibrous open stone asphalt is applied as a 12 cm layer on a slope gradient of 16/4. The thickness of the layer is increased to 15 cm for the crest and land berms.

The aggregate size in the fibrous open stone asphalt is 20/32 mm.

This cladding has the following properties:

- Bituminous bound material, making it extremely flexible
- Seamless : The exposed welding seams are finished vertically in advance with a bituminous adhesive. Slab-like, homogenous cladding.
- Aggregate size : 20/32 m, making it relatively smooth. If we assume that a rip rap revetment has a surface roughness of 1, fibrous open stone asphalt can be assumed to have a surface roughness of 0,75.
- High resistance to currents: to 7 m/s.
- Durable protection requiring no maintenance
- Stable, even on slopes with gradients of 4/4
- Draining: Darcy permeability coefficient $k = \text{about } 5 \cdot 10^{-2} \text{ m/s}$
- Soil retaining: as a result of the underlying geotextile.
- Plantable: the voids (from 25 to 30%) in the mix make it possible to apply crumbled soil in and on the asphalt layer, permitting the formation of a mutually coherent whole by the asphalt, soil and grass. Soil and grass roots are anchored in the upper half of the open asphalt layer, while the lower layer remains open and draining. This anchoring means that the grass covering thus formed will not be easily washed away in the event of overflow (photo 2).

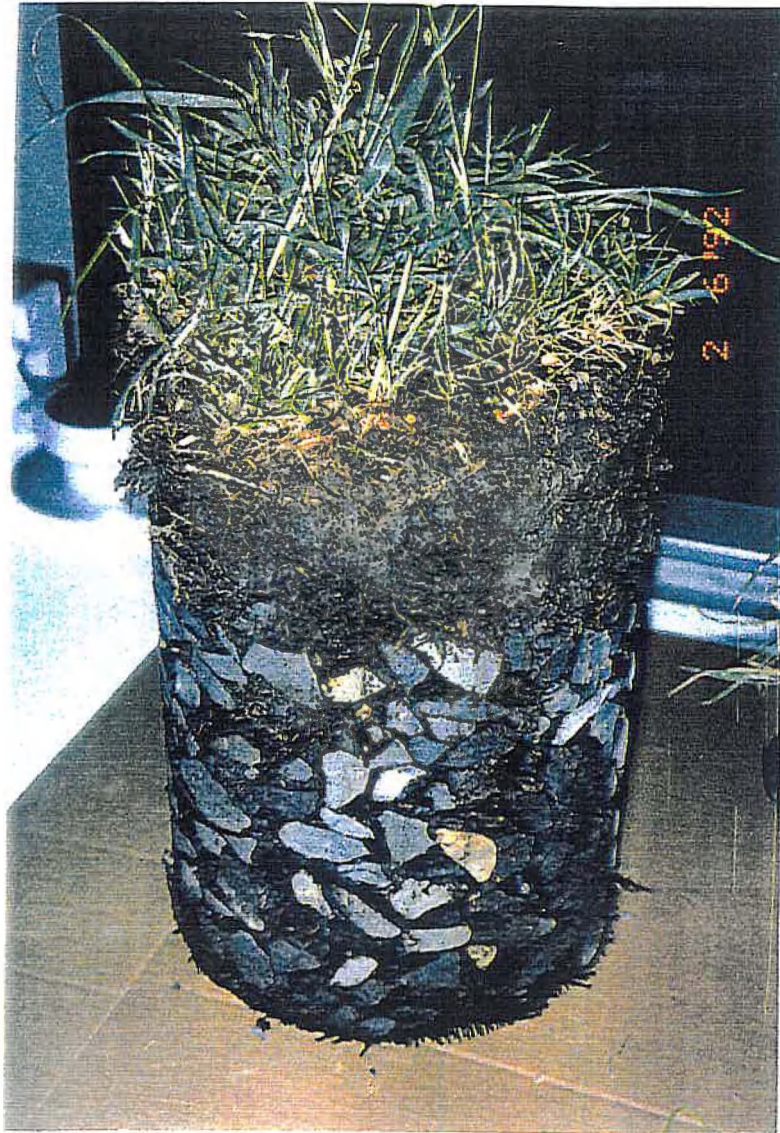


Photo 2

The combination of a geotextile textile, fibrous open stone asphalt, finishing layer in crumbled clayey soil, and grass forms a whole which has proved to be an protection cladding for overflow dikes. This cladding is both sufficiently permeable to water for the groundwater in the dike to flow out at the foot of the dike, while preventing an overabundant penetration of overflow water on the crest berm and at the top of the landside slope, thus guaranteeing the stability of the dike and the cladding in the event of overflow. This revetment meets the requirements of elasticity, seamlessness, smoothness, strength and durability. The grass layer ensures that the dike cladding fits in with the landscape and moreover remains very closely attached to the layer of fibrous open stone asphalt.



Photo 3

Installing the fibrous open stone asphalt revetment on geotextile



Photo 4

View of the finished landside slope after covering and sowing grass on the asphalt.

By the time of writing six overflow dikes have been provided with slope protection in fibrous open stone asphalt on geotextile.

Experience with numerous overflows indicates that so far these overflow dikes perform well when loaded and only limited damage to the turf on the fibrous open stone asphalt occurs. Furthermore this damage only occurs in the initial phase, i.e. when overflow occurs immediately after installation. (Which can be prevented)

Once the grass has become securely rooted in the asphalt annual maintenance is reduced to a minimum.

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RECENTE BORINGEN (JUNI 1992) VAN DE BEKLEDING IN OPEN STEENASFALT
MET TEELARDE EN BEGROENING :



WERF TIELRODE : Aanbrengen van de bekleding.



TIELRODE : Resultaat van de begroening (juni 1992).





P.I.A.N.C.

A.I.P.C.N.

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