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The use of biodegradable geotextiles in hydraulic engineering

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ABSTRACT
Because of the trend towards sustainable development and integral chain management, there is a growing demand for products made of renewable materials such as vegetable fibres. In the field of civil engineering there is an increasing demand for biodegradable geotextiles, mainly to fulfill temporary functions or for use in temporary constructions. In the fields of geotechnical, road and hydraulic engineering the biodegradable geotextiles used are manufactured from vegetable fibre such as coir, sisal, jute, flax, hemp and miscanthus but also from other natural materials such as wool. Users lack knowledge and experience of the applications. For these reasons CUR and the NGO (Dutch Geotextile Ogranization) have made an overview of the potential uses of biodegradable geotextiles in hydraulic engineering is presented.

Introduction
Environmental policy demands carefully considered management of interactions with the natural environment and the economical use of raw materials. Sustainability and multi-functionality are the keywords to this new approach. This implies that the design of hydraulic engineering constructions involves not only economic factors, but also aspects of the ecology of the landscape and water systems. Banks are no longer considered to be well-defined, sharp transitions between land and water, but as an integral part of a water system. Another facet of sustainability is the way materials are used. The economical use of raw materials and energy, the recycling of materials and avoidance of the creation of waste materials during production, construction or demolition are now important issues in hydraulic engineering.

Many products manufactured from renewable raw materials have such advantageous properties that their increased use is desirable. The use of geotextiles manufactured from natural fibres is one of the ways in which renewable materials can be incorporated in geotechnical, road and hydraulic engineering. This involves the use of fibres such as coir, sisal and jute. In addition fibre produced in Europe, such as flax, hemp and miscanthus, are also suitable for use in geotextiles.

In the past, up to 20 or 30 years ago, geotextiles made of coir or jute were very often used in geotechnical, road and hydraulic engineering. Owing to the discontinuation of the use of these materials, actual and potential users now lack both knowledge and experience of their applications. This led to the preparation of a actual updated review of potential uses of biodegradable geotextiles. A complete review of their use in civil engineering works is included in the CUR/NGO Report "The use of biodegradable geotextiles in civil engineering" (in preparation).

Materials and their properties
The differences between biodegradable geotextiles and synthetic geotextiles derive from the properties of the raw material from which they are manufactured. The biodegradable raw materials used are given in table 1. In addition materials as cotton and hemp can be used.
Formerly, synthetic geotextiles were often used because they are both stronger and more durable than biodegradable geotextiles. For temporary structures, or for permanent structures in which the geotextile

Tabel I Biodegradable geotextiles

Material	Type	Length roll [m]	Width roll [m]	Cellulose [%]	Lignin [%]	Weight [g/m^2]
Cellulose	non-woven	50	3,5			300
Sheep wool	non-woven	30	2			100-1200
Flax	non-woven		2	70	2.3	400-1400
Wood chips	non-woven	30-55	1-2			250-880
Reed	mat		2			
Straw	non-woven	25-60	1.2-2.4			800-1000
Miscanthus	mat		2.5			2000-2400
Coir	woven/non-woven	25-50	1-5	35-45	40-45	200-1400
Jute	woven/non-woven	7-300	1-2.4	70	13	390-1000
Sisal	woven	120	4	73	11	400-800

has a temporary function, the use of a biodegradable geotextile has various advantages such as:

1. The use of a biodegradable geotextile does not have a detrimental effect on the environment,
2. In nature-friendly structures the use of degradable geotextiles increases the ecological value of the structure.
3. It is not necessary to remove the geotextile after completion of the construction work because the material will be degraded by natural processes.

When using geotextiles manufactured from vegetable fibre it is essential to take into account the effects of changes in the loading and strength parameters over time. The rate at which a geotextile of natural fibres is degraded depends on:

- the acidity and humidity of its surroundings;
- micro-organisms (humus content and oxygen content);
- UV-radiation.

Two important factors which influence the lifespan of a biodegradable geotextile are the mass per square metre (g/m^2) and the composition of the fibre. Usually fibres with a higher mass per square metre have a lower degradation rate. The composition and structure of the fibre, especially its lignin, pectin and en hemi-cellulose content, influences its lifespan. Usually lignin breaks down very slowly, while pectin and pectin and hemi-cellulose have a relatively high rate of biodegradation.

In the Netherlands much effort is put into the design and construction of ecologically sound bank protection (Boeters et. al., 1994). Banks are transitions between water and land, or, in other words, the transition from wet to dry. Sloping and border environments usually have a high natural value, because of which, banks provide important habitats in the Dutch landscape. In addition, owing to the continuous character of their banks, the Dutch surface waters provide important corridors for plants and animals. The large variations in exposure, substrate, physical processes, layout and management of the water and land is enhanced by the wide variety of gradients in the bank environment. Compared to the adjacent land and water systems, the bank system is generally small in area, but it is of intrinsic value to the survival of certain organisms both on land (migratory birds, amphibians) and in the water (fish).

The design, construction and management of hydraulic structures in or along fairways requires an integral approach both in the sense that all possible functions of the fairway and structure are considered and in the sense that the different stages in the process must be treated in relation to one another, rather than independently. In this context one element is the reintroduction of vegetation along banks and shores. From several investigations it has become clear that reed zone plants can give a substantial and lasting protection to banks and similarly a turf (grass) cover protects dikes. Although wave damping capacities are not very spectacular, the soil- strengthening abilities of the plants (stems and root system combined) are quite impressive. However it is also obvious that in many situations the plants need some assistance, especially immediately after planting. Furthermore, regularly occurring wave loads on plants should not be higher than 0.25 m and incidental loads should not exceed 0.40 m (Boeters, 1996). Depending on the quality of the turf cover, it will be able to withstand continuous current velocities up to 1.5 to 2.5 m/s for 100 hours, which is more than adequate in relation to the use of grass on slopes of banks and dikes (CIRIA, 1987).

Potential uses in hydraulic engineering

In recent years experience has been gained from various experimental project in the Netherlands, in which biodegradable geotextiles were used for bank protection constructions. In all these situations the geotextiles had a temporary function. The biodegradable geotextile provided protection against erosion immediately after the completion of the construction providing shelter for the developing vegetation. When the vegetation has reached maturity it should be able to withstand the hydraulic load.

Pond bank structures

In the Netherlands, nowadays the banks of many inland waterways and lake shores consist of an unprotected slope with a gradual transition from land into a shallow water zone that is bounded by a protective structure, such as sheet piles or a rip-rap dam. In the shallow water zone and on the slope, vegetation, such as reed zone vegetation can establish itself and grow in a more or less natural way.

Along the larger waterways the protective structures on the banks are permanent in character (Fig. 1 and 2).

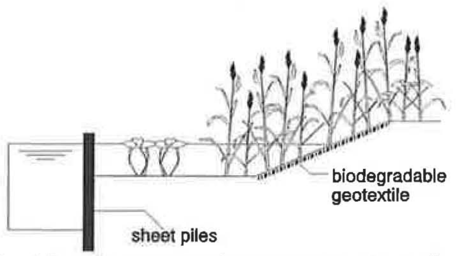

Fig. 1 Permanent protective structures: sheet piles.

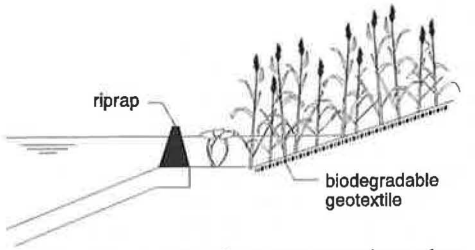

Fig. 2 Permanent protective structures: riprap dam.

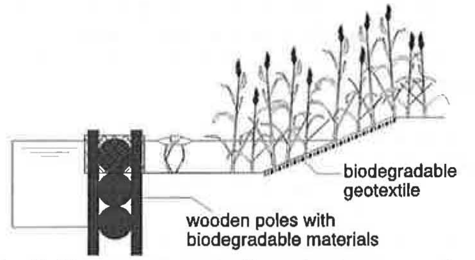

Fig. 3 Temporary protective structure: wooden poles with biodegradable materials.

For the smaller waters the protective structures may be temporary in nature (Fig. 3). If, after completion of construction, the load will of such a nature that reed zone plants need some protection, a biodegradable geotextile can be used.

Vegetation mattresses
On poor soils and on banks that are subject to attack by currents or waves it is difficult for new vegetation to develop. If it is considered that a fully developed vegetation cover will provide adequate protection for the slope a special mattress, surrounded by a biodegradable geotextile, can be used as the growing medium for the shore vegetation. In a nursery the bank vegetation sewn or planted in such a mattress can reach maturity in one growing season. By this time the roots of the bank plants have penetrated through the mattress, after which it can be placed on the bank. Together the mattress and the roots form a filter through which the underlying material remains stable. After some time the mattress will degrade, while the roots will continue to extend and take over the function of the mattress. Because the vegetation quickly takes hold such a mattress is suitable for use in urban areas and in places where it is necessary to restore damaged banks.

Fascine collars and mattresses
A modern fascine collar or mattress may consist of a framework of fascines under which a synthetic geotextile can be placed. Biodegradable material may also be used instead of the synthetic geotextile. Sand retaining capacity of the mattress used can be increased by placing several layers on top of each. For the same reason a biodegradable non woven material may be placed under the mattress (Fig. 4).

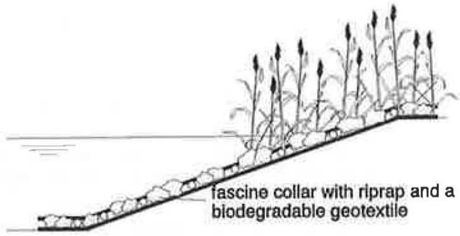

Fig. 4 Fascine collar with riprap.

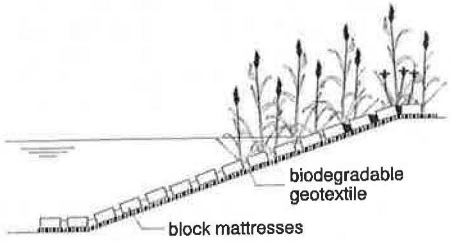

Fig. 5 Block mattresses.

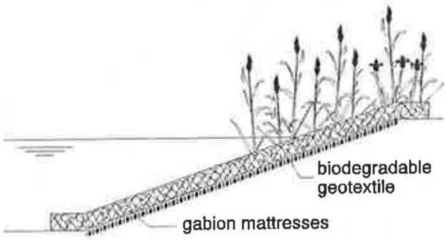

Fig. 6 Gabion mattresses.

Block mattresses
Block mattresses are used on slopes that are exposed to currents and wave action. Various types of mattresses with already fixed blocks are available. The filter constrution underneath the block mattress can be made of biodegradable materials. If spaces are left between the blocks or if the blocks have holes in them an open slope cover can be created (Fig. 5). Reed zone plants can grow through between these elements so that the function of the biodegradable geotextile can be taken over by the vegetation.

Gabions
A gabion consists of a basket filled with rubble or armour stone. The wickerwork prevents washing away of the rubble. To ensure the stability of the soil under the gabion it is necessary to have either a filter or a vegetation cover with good root penetration. The root system of the vegetation forms a filter between

the underlying soil and the wickerwork mattress (Fig. 6).

Slope protection above retaining walls/ sheet pile walls
When little space is available for bank construction a retaining wall can be built with a relative short slope above it. For this a closed pile row or a retaining wall of piles and backed by planking can be used. Synthetic geotextile material is often used to ensure that soil does not escape through the retaining wall. Immediately after the completion of the construction the slope must be protected against erosion caused by rain and water splashing. A biodegradable geotextile can be used to stimulate plant growth and prevent erosion by wind, rain and water splashing.

Turf (grass) revetments a dike slope
The function of a turf revetment on a river dike is to protect the dike body from erosion. The turf revetment is placed over a layer of light or medium weight clay. Because it is possible that high water may occur, work on dikes takes place during the growing season. Usually grass is sown at the beginning of August and when sowing takes place up to mid-September there is some doubt as to whether cover will be sufficient by October. When sowing is late the growing conditions for the turf are less favourable and the chance of high water is increasing. Moreover the seedbed is often poor and difficult to work due to the effects of construction work that has taken place.

A biodegradable geotextile can be used to ensure that the turf revetment can maintain its protective function in the initial stages (fig. 7). The geotextile provides protection against erosion until the grass cover is complete. After some time the geotextile will decay so it is not necessary to remove it.

Vegetated floating units
In places where it is difficult or impossible to provide a cover of natural vegetation on the bank plant covered floating units may be used. Floating units are mainly used for aesthetic or ecological reasons, for example, in urban or recreational areas. In addition to their asthenic function they may provide nesting sites for birds and spawning grounds for fish.

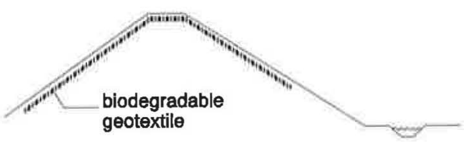

Fig. 7 River dike.

Conclusions
This paper illustrates the use of biodegradable geotextiles by drawing on the practical experience gained during a number of experimental projects. This set up was chosen because up to the present there is still too little experience of the use of biodegradable geotextiles on which generally valid design criteria and methods can be based. The many favourable results of previous experience will certainly lead to the increased use of biodegradable geotextiles in the future. Adding the results of new practical experiences to existing knowledge will bring about a quick growth in understanding of the necessary design criteria and the applicability of biodegradable geotextiles.

In addition to practical experience it is necessary to acquire insight into the specific properties of biodegradable geotextiles. For design and construction based on the use of biodegradable geotextiles it is necessary to have insight into the specific properties of the materials concerned. Research into product specifications and the changes in their properties in time under field conditions will increase insight into the possible ways of using these materials.

References
Boeters, R.E.A.M. The use of reed zone plants as bank protection. The first European conference and trade exposition on erosion control, IECE, Barcelona, 1996.
Boeters, R.E.A.M., H.J.N. Meesters, G.J. Schiereck, H.E.J. Simons, J. Stuip, A.T.P. Swanenberg, H.J. Verheij and G.J. Verkade. Waterways with room for nature. 28th International PIANC Congress, Seville, June 1994.
CIRIA. H.W.M. Hewlett, L.A. Boorman and M.E. Bramly. Design of reinforced grass waterways. Report 116, London, 1987.
CUR. The use of biodegradable geotextiles in civil engineering. (in Dutch), Gouda, in preparation.
CUR. Manual on ecologically sound bank protection. (in Dutch) Report 168, Gouda, 1994.