Stabilization of landslides with bio-engineering measures in South Tyrol/Italy and Thankot/Nepal

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STABILIZATION OF LANDSLIDES WITH BIO-ENGINEERING MEASURES IN SOUTH TYROL / ITALY AND THANKOT / NEPAL

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ABSTRACT

Soil bioengineering is a suitable technique to protect slopes against surface erosion, to reduce the risk of planar sliding and to improve surface drainage. It uses living plants and other auxiliary materials for construction. Plants for soil bioengineering purposes are selected for criteria such as pioneer plant character, dense and deep rooting system, potential of adventitious rooting system and fast and simple propagation. The research work at the Vienna Department of Soil Bioengineering and Landscape Construction was especially focussed on these criteria. Investigations carried out in Austria and South Tyrol (Italy) have made it possible to increase the spectrum of plant species suitable for soil bioengineering slope stabilization. In Nepal the objective of the research work was to determine whether plant species already used and found suitable for soil bioengineering works in this area are also suitable for winter plantation. Considering all available parameters, ten species can be recommended from the 20 plants tested in the surroundings of Besishar in the Mid Hills of Lamjung District. The second part of this paper discusses practical applications of soil bioengineering work for slope stabilization. A description and detailed documentation is given of vegetated cribwalls, vegetated slope grids, drain fascines and hedge brush layers implemented in South Tyrol (Italy). A practical application is then presented from Thankot (Nepal) which provides for completely different structural conditions. There, hedge brush layers and a vegetated bamboo cribwalls were used, the latter an entirely new modification. A monitoring system to be installed should produce results of whether bamboo can be a alternative to timber in Nepal. These practical examples i.a. are evidence that soil bioengineering methods can be applied nearly everywhere in the world, provided only that suitable plants and auxiliary materials are available.

KEYWORDS: soil bioengineering methods, slope stabilization, suitable plants, Central Europe, Nepal

INTRODUCTION

Since humans first settled in the Alps and encountered many natural hazards, many efforts have been made to protect forest and agricultural areas against destruction. The risks of landslides and erosion are reduced when the soil is covered by appropriate vegetation.

Soil bioengineering uses living plants and other auxiliary materials (logs, stones, etc.). The use of this technique is very old, as can be documented by the construction of cribwalls. These walls were

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constructed in Krajna (Slovenia) already back in 1700. Today many different soil bioengineering methods are applied, depending on the kind of erosion and failure process. Much research work has been done in Central Europe by Schiechtl since 1950. At the Department of Soil Bioengineering and Landscape Construction at Vienna University of Agricultural Sciences, one of the main objectives of research was to expand the plant species spectrum which can be used in the field of soil bioengineering.

Similarly, in Nepal considerable soil bioengineering work has been carried out during the last 20 years. The Austrian Federal Ministry for Education, Science and Culture financed a development aid project in Nepal. The objective of this project was testing different plant species already used and found suitable for soil bioengineering, for winter plantation in the Mid Hills of Nepal. First results of these investigations and two practical implementation projects of soil bioengineering works in South Tyrol / Südtirol (Italy) und Thankot (Nepal) respectively are presented in this paper.

INVESTIGATIONS OF THE SUITABILITY OF PLANTS FOR SLOPE STABILIZATION IN CENTRAL EUROPE

Plants which are used for soil bioengineering methods increase the stability of slopes and prevent erosion of soil material with their above- and below-ground development. Schiechtl (1973) did much research work on how to best apply stem cuttings for engineering purposes. Below, two more recent research projects undertaken by the Vienna Department of Soil Bioengineering and Landscape Construction are introduced. The investigations are focussed on:

1. amount of adventitious roots from different plant species,
2. plant species spectrum for soil bioengineering methods,
3. determination of the root to shoot ratio of three and four year old hedge brush layer structures.

Therefore rooted plants were tested using the hedge layer technique. The research work was done at the testing ground of the Vienna University of Agricultural Sciences. The research period comprised one vegetation season and the sample consists of 100 pieces per plant species. Beginning in June, excavations were done monthly. The figure below shows one example of an excavated plant (*Corylus avellana*).

Fig. 1 Adventitious roots and trunks of *Corylus avellana* (Mogg, 1996)

Several theses on this subject were done by Mogg (1996), Leitner (1996), Thurn-Seebacher (1997), Koblmüller (1996), Grohmann (1999), Gerstbach (1998), Wunderer (2001) and Deutsch (2001) and led to the following results in terms of plant suitability:

Table 1 Suitability of adventitious roots developing from rooted plants (Sucessful proportion represented as percentage of the sum of used plants)

Proved and excellent	**Sucessful proportion**
Alnus glutinosa, incaca, viridis	100%
fraxinus excelsior, ornus	100%
Populus alba	100%
Acer pseudoplatanus	100%
Prunus padus	100%
Sorbus aucuparia	100%
corylus avellana	100%
Cornus sanguinea	100%
Evonymus europaea	100%
Lonicera xylosteum	100%
Rubus caesius	100%
Rubusidaeus	100 %
Viburnum opulus	100%
Viburnum lantana	100%
Cornus mas	94%
Proved and good till fair	
Betula pendula	58%
Carpinus betulus	54%
Acer campestre	40%
Acer platanoides	32%
Prunus avium	32%
Tiliia platyphyllos	28%
Tilia cordata	22%
Proved and poor till very poor	
Prunus spinosa	0%
Sorbus aria	0%
Sorbus intermedia	0%
Sorbus torminalis	0%
Populus tremula	0%

For investigations of the development of three and four year old hedge brush layer structures in South Tyrol (Italy), Grässer (1994) assessed the rooting performance and dry weight of roots and shoots. An example of a four year old *Salix purpurea* showed an average root to shoot ratio of 0.47, which can be characterised as excellent. A three year old plant from the same species showed an average root to shoot ratio of 0.26, which means that the roots have one-fourth the weight of the shoots. *Prunus padus* und *Alnus incana* showed a value of 0.38 and 0.35 respectively after four years, which is much lower than the *salix* species of the same age.

INVESTIGATIONS OF THE SUITABILITY OF PLANTS FOR SLOPE STABILIZATION IN NEPAL

Comprehensive soil bioengineering work has been carried out in Nepal during the last 20 years and large experience has been collected in slope stabilization using vegetation (Howell, 1999). Generally, the Department of Roads (DOR), part of His Majesty's Government of Nepal Ministry of Works and Transport, did most of the soil bioengineering works during the premonsoonal time, mainly in June. The problem with such constructions is that the soil surface is vulnerable to erosion, since the time necessary for natural compaction of the upper soil layer is not allowed for before the heavy monsoon rain sets in. In addition, the plants cannot provide anchoring and soil binding as root systems cannot be sufficiently established in this short period.

The research work of the Department of Soil Bioengineering and Landscape Construction, by Spindler (2001) and Molon (2001), was focussed on testing plant species already used and proved satisfactory in soil bioengineering works in this area, for their suitability for winter plantations. In December 1999 and January 2000, almost 2000 plants of 20 species were planted as stem cuttings, root cuttings or rooted plants on six different plots in the surrounding of Besisahar in the lower Mid Hills of Lamjung District. Different layer constructions were carried out using employed help in December 1999 and January 2000. Their growth performance was observed and measured until May 2000, when 30% of the plants were excavated to observe the roots. The following parameters were determined in order to assess their suitability for winter plantations:

- length and diameter of trunk,
- survival rate,
- length and number of shoots per planted trunk,
- number of adventitious roots per trunk,
- average length of adventitious roots per trunk,
- average thickness of adventitious roots/trunk,
- distribution of adventitious roots on the earth-covered trunk,
- branching of adventitious roots.

The following table provides an overview of the plants tested and their evaluation as a mean value of the observed parameters. More detailed information on the evaluation method for the plant species is given in the thesis by Spindler and Molon. In conclusion it can be stated that winter plantation can be carried out successfully. This research work shows that at least ten of the tested species are suitable for a stabilization method during the dry winter season in the lower Mid Hills of Central Nepal.

Fig. 2 Root development of *Salix tetrasperma* (cutting) in May after 4 months of growth (Spindler, 2001)

Table 2 Comparative evaluation (1- excellent, 2 – good, 3 – fair, 4 – poor, 5 – very poor) of all tested species for winter plantation; species printed red were planted as rooted plants.

plant species	evaluation
Morus alba	1,0
Salix tetrasperma	1,0
Pennisetum purpureum	1,3
Salix babylonica	1,3
Populus x euroamericana	2,0
Alnus nepalensis	2,0
Brassaiopsis hainla	2,3
Callistemon citrinus	2,3
Duranta repens	3,0
Erythrina arborescens	3,0
Ficus lacor	3,3
Hippophae salicifolia	3,7
Vitex negundo	4,0
Adhatoda vasica	4,3
Ficus auricolata	5,0
Ficus semicordata	5,0
Jatropha curcas	5,0
Prunus cerasoides	5,0
Rubus ellipticus	5,0
Thysanolaena maxima	5,0

SOIL BIOENGINEERING IMPLEMENTATION: EXAMPLES IN SOUTH TYROL (ITALY)

Two practical soil bioengineering works show different methods of slope stabilization. The first example is the soil bioengineering work at the area of the Suldenbach stream (Italy), which can be flooded by heavy rainfall. The embankment fails and tends to generate land slides. As a first measure, check dams were constructed to consolidate the embankment of the stream. Previous landslides had left large quantities of loose material, which were stabilized with hedge layer techniques. Vegetated cribwalls were constructed to prevent additional landslides. Drain fascines were put up to drain very wet areas.

A similar failure process operated at the second example, a landslide in Langtaufers in South Tyrol (Italy). The area is located in the western part of the Ötztal Alps, where on account of its location in the Central Alps precipitation is usually very low. The valley bottom is filled up with postglacial talus cones and slope talus material (Hammer, 1923), through which the Karlinbach stream has dug a deep bed. June, July and August of the year 1987 were highly unusual in terms of the weather: Melag recorded a precipitation of 373.8 mm, or more than half of the entire annual rainfall (Hydrologisches Jahrbuch, 1987, Fliri, 1975). On three days in August 1987 (23, 24 and 25 August) there was more than 65 mm of rain (Hydrologisches Jahrbuch, 1987), which caused a flood of the Karlinbach stream and led to an embankment failure on the right hand bank next to Kapron (1700 m a. s. l.). The embankment failure in turn produced a landslide of 3,700 m^2 with a slope of 35 till 55 degrees. The first measuring activities took place in the same way as described in the above project.

First the river bed was stabilized with check dams and soil bioengineering structures were raised on the site of the landslide.

The soil bioengineering concept provided for the following steps: Vegetated cribwalls of a length of 130 m were placed in the upper areas of the landslide (slope angle of 48 degrees). These cribwalls were used as a basis to install vegetated slope grids, which covered an area of 960 m². The figure below shows the locations of the different soil bioengineering structures. In the following sections the soil bioengineering works of these two projects are explained in more detail.

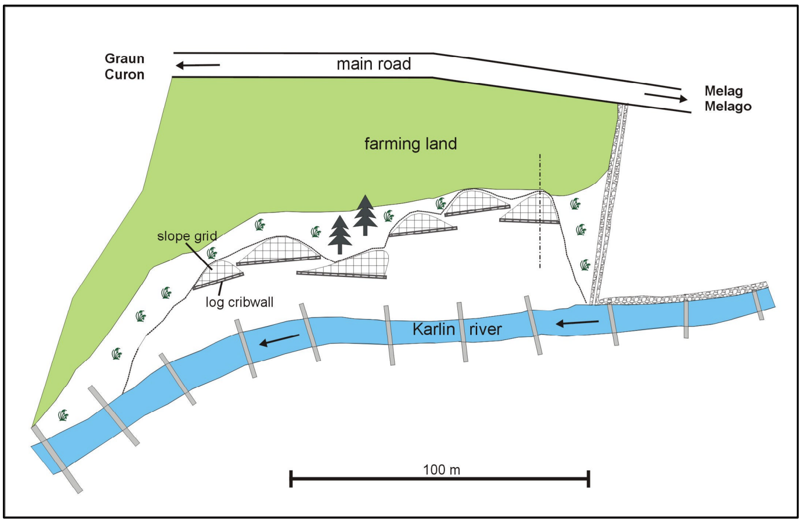

Fig. 3 Overview of the project area of Karlinbach in Langtaufers (Italy)

Hedge Brush Layer (Suldenbach)

In the spring of 1989 and 1990, hedge layer structures were built at the landslide site of the Suldenbach stream to fix the loose materials. Terraces of a depth of 0.5 to 1.5 m were dug out with machinery. The platform of the terraces sloped up by at least 10 degrees to the outside. Living cuttings and rooted plants were placed in parallel to each other, spaced at 5 to 10 cm. The plants used extended by about 10 cm from the terrace edge. For better stabilization, timber was fitted additionally. Finally the lower ditch was filled with excess material from the ditch above. The same procedure was repeated till the top of the slope was reached. The distance between terraces depended on the slope angle and varied from 1 to 2 m.


Fig. 4 Overview of the project area Suldenbach (Italy) beginning with the implementation of hedge brush layers (left)- 1989 and after developing 3 years (right) - 1992

Drain fascines (Suldenbach)

Drain fascines are used in structures to stabilize and drain wet slopes. Thus, vertical lines were dug and fascines inserted in them. Fascines consist of live branches of willows tied together with wire. The lowest third also contained dead branch material which channels the water without obstruction. The tip end of the branches were pointed in the flow direction. The fascines were typically 30 to 60 cm in thickness and of varying length. They were put into ditches and covered with soil, so that all the branches were embedded and could develop roots and grow. To prevent the fascines from sliding or being washed away, they were fixed with wooden poles at a spacing of 2 m.

Fig. 5 Overview of the project area Suldenbach (Italy) beginning with the implementation of drain fascines (left)- 1990 and after developing 2 years (right) - 1992

Vegetated cribwall (Suldenbach and Karlinbach)

Vegetated cribwalls were constructed using timber (Larix decidua) and the logs and anchor logs held together with nails, and were placed horizontally on the slope but at an angle of 10–15% toward the slope. The space between logs was filled with soil material. To achieve vegetation quickly, strongly rooted pioneer plants were used. In both projects autochthon plants (*Sorbus aucuparia*, *Prunus padus*, *Alnus incana* and *Salix appendiculata*) were applied. The plants were placed so that they did not stick out of the wall for more than a quarter of their length.

Fig. 6 A detail of a vegetated cribwall after 6 months (left)–1994 and after 4 years developing (right)-Suldenbach-1998

Vegetated Slope Grid (Karlinbach)

In Langtaufers, the very steep slope upwards of the cribwalls was secured by vegetated slope grids to protect this area from additional erosion. Therefore horizontal logs (*Larix decidua*) were nailed on vertical logs and rooted plants were inserted using the hedge layer technique. The rooted plants were the same as those used for the cribwalls. The whole construction was fixed into the ground with iron poles and covered with soil.

Fig. 7 Construction of a vegetated slope grid based on a vegetated cribwall – Karlinbach 2001

SOIL BIOENGINEERING IMPLEMENTATION: EXAMPLE FROM THANKOT (NEPAL)

The Himalayan mountain environment is one of the most dynamic and active landscapes of the world. The combination of young folded mountains still undergoing uplift, a humid climate with seasonal monsoon rains and intense land use ensure that the Nepalese Himalayas are among the most unstable landscapes worldwide. Phenomena such as landslides, debris flows, soil erosion, earthquakes and river flooding are natural and common hazards.

An overview of the landslide in Thankot is given in the following figure. Thankot is located 12 km to the west of Kathmandu. The project area is at an altitude of about 1750 m above sea level.

Fig. 8 Overview of the landslide in Thankot (Nepal) - 2002

Civil engineering work had already been started with the construction of gabions. Now soil bioengineering measures were to enhance these structures by protecting them and maximising their effectiveness. On the basis of research work by Spindler and Molon (2001), plant species suitable for winter plantation were applied with different soil bioengineering methods. The practical work was carried out by Keuschnigg and Leiter (December and January 2000/2001) and Lammeraner and Wibmer (December and January 2001/2002), and will be completed by the end of 2002. All the practical work was done in co-operation with the local people of Thankot (Women Forest User Group). Below, two different soil bioengineering structures (hedge brush layer, and bamboos cribwall) used on this site are described in detail. The following table shows the plant species for winter plantation which are used for this site:

Table 3 Used plant species for winter plantation in Thankot

Cuttings	Rooted plants
Adhatoda vasica	*Alnus nepalensis*
Erythrina sp.	*Fraxinus floribunda*
Morus alba	*Prunus cerasoides*
Prunus cerasoides	*Schima wallichii*
Salix tetrasperma	
Salix babylonica	
Sepium insegne	

Hedge Brush Layer (Thankot)

The technique used for this structure was the same as in South Tyrol (Italy). The cuttings and the rooted plants were laid in lines across the slope. This method forms a strong barrier and prevents the development of rills and keeps small terraces tap material from moving down the slope. The figure below shows the hedge brush layer structure shortly after construction (left) and after about one year (right), when the shoots of Salix tetrasperma reached an average length of 65 cm. The maximum was measured at a length of 120 cm.

Fig. 9 The hedge brush layer construction shortly after completion (left)- 2001 and about one year later (right) –2002 in Thankot (Nepal)

Vegetated Bamboo cribwall (Thankot)

In Nepal it is not possible to use logs or anchor logs as auxiliary material for a cribwall. So a new method was developed which uses bamboo trees as construction elements for a vegetated cribwall. Three bamboo elements were tied together with wire. These elements aimed to stabilize the structure until the soil was mechanically reinforced by the root system of the plants. Rooted plants were placed between the horizontal bamboo elements. This was a completely new type of construction, which was developed in January 2002 by Wibmer and Lammeraner together with the local people. So no experience is yet available on the mechanical effects and durability of bamboo. A monitoring system will be installed to obtain more knowledge on the propagation of bamboos. In Nepal, bamboo could well be a useful alternative to timber.

Fig. 10 Vegetated bamboo cribwall constructed in Thankot (Nepal)- 2002

CONCLUSIONS

Soil bioengineering is a suitable technique to protect slopes against surface erosion, reduce the risk of planar sliding and improve surface drainage. It is a technique that can be applied nearly everywhere in the world, provided that suitable plants and auxiliary materials are available on site. Implementation of soil bioengineering methods creates a living and complex system which is very sensitive to environmental impacts. The success of this system depends on the growth performance of the plants. The length and quantity of shoots and roots are an excellent indicator for biomass development, factors which indicate their suitability in terms of soil and climate for the area.

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