Definition of Bioengineering

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Bioengineering is a part discipline of civil engineering. It pursues technological, ecological economic as well as design goals and seeks to achieve these primarily by making use of living materials, i.e. seeds, plants, part of plants and plant communities, and employing them in near–natural constructions while exploiting the manifold abilities inherent in plants.

Bioengineering may sometimes be a substitute for classical engineering works However, in most cases it is a meaningful and necessary method of complementing the latter.

Its application suggests itself in all fields of soil and hydraulic engineering, especially for slope and embankment stabilization and erosion control.

Fields of Application and Plants for Bioengineering Control Works

Bioengineering methods can be applied wherever the plants which are used as living building materials are able to grow well and develop.

This is the case in tropical, subtropical and temperate zones whereas there are obvious limits in dry and cold regions, i.e. where arid, semi–arid and frost zones prevail. In exceptional cases, lack of water may be compensated for by watering or irrigation.

In Europe, dry conditions limiting application exist in the Mediterranean as well as in some inner alpine and eastern European snowy regions. However, limits are most frequently imposed in alpine and arctic regions. These can usually be clearly noticed by the limited growth of woody plants (forest, tree and shrub lines) and the upper limits of closed turf cover The more impoverished a region is in species, the less suited it is for the application of bioengineering methods.

Functions and Effects of Bioengineering Structures

The objective of bioengineering construction work is that it fulfil important functions Among these, priority has always been given to:

Technical functions:

- protection of soil surface from erosion by wind, precipitation, frost and flowing water
- protection from rock fall
- elimination or binding of destructive mechanical forces
- reduction of flow velocity along banks
- surface and/or deep soil cohesion and stabilization
- drainage
- protection from wind
- aiding the deposition of snow, drift sand and sediments
- increasing soil roughness and thus preventing avalanche release

Apart from these, ecological functions are gaining more and more in importance, particularly as these can be fulfilled to a very limited extent only by classical engineering constructions.

Ecological functions:

- improvement of water regime by improved soil interception and storage capability as well as water
- consumption by plants
- soil drainage
- protection from wind
- protection from ambient air pollution
- mechanical soil amelioration by the roots of plants
- balancing of temperature conditions in near–ground layers of air and in the soil
- shading
- improvement of nutrient content in the soil and thus of soil fertility on previously raw soils
- balancing of snow deposits
- noise protection
- yield increase on neighbouring cropland

Landscaping functions:

- healing of wounds inflicted on the landscape by disasters and humans (exploitation of mineral resources, construction work, deposition of overburden, tunnel excavation material, industrial and domestic waste)
- integration of structures into the landscape
- concealment of offending structures
- enrichment of the landscape by creating new features and structures, shapes and colours of vegetation

Economic effects:

Bioengineering control works are not always necessarily cheaper in construction when compared to classical engineering structures. However, when taking into account their lifetime including their service and maintenance, they will normally turn out to be more economical. Their special advantages are:

- lower construction costs compared to “hard” constructions
- lower maintenance and rehabilitation costs
- creation of useful green areas and woody plant populations on previously derelict land

The result of bioengineering protection works are living systems which develop further and maintain their balance by natural succession, i.e. by dynamic self–control, without artificial input of energy. If the right living but also non–living building materials and the appropriate types of construction are chosen, exceptionally high sustainability requiring little maintenance effort can be achieved.

Planning of Bioengineering Construction Works

The early involvement of a bioengineer in the overall project is crucial for its success, at least in the case of large projects. This will not only result in considerably lower total costs but also in a better integration of the technical construction into the landscape.

In the past, bioengineering solutions were, unfortunately, sought only after classical engineering methods had failed.

The project should be planned in harmony with and close to nature, i e adjusted to the landscape and satisfying ecological needs.

First of all, this requires first stocktaking of the existing natural resources, assessment of the ecological conditions (site conditions) as well as identifying the causes for the absence of vegetation and for erosion.

Living building materials

Another equally important issue is the choice of the living materials to be used.

Autochthonous living materials, i.e. plants, seeds, parts of plants and plant communities from the construction site itself and from close around, are always suited best because they have already adapted to the site. This is why a first survey of the future constructions site must always include an inventory of the living building materials available on site. One needs to examine whether parts of the natural vegetation have to be removed in the course of construction and whether these can be reused later on.

Preferred candidates are pieces of closed vegetation, which are lifted off as transplants together with topsoil and roots, stored temporarily, if necessary, and then replaced.

Further material that suggests itself are shoot–forming parts of woody plants, which can be reused as cuttings, branches or twigs, as well as vegetatively propagating herbs and grass species as rhizome cuttings or divided stolons.

One crucial question is always where the living, shoot–forming material to be used for stable constructions comes from.

Normally, it is required in larger quantities. Natural poplar and willow stands are best suited because they not only provide all eligible species but also all age stages and branch diameters as well as the entire genetic potential.

Plants which are valuable, rare or worth protecting and preserving for other reasons can be dug out as individual plants together with their root balls and reset like transplants.

Purchased living building materials will have to be resorted to where they cannot be obtained from natural vegetation at the construction site. In large areas of south and central Europe, for example, natural willow and poplar populations no longer exist. It is therefore necessary to use older bioengineering works as secondary stock or to purchase the material from nurseries (willow plantations).

When purchasing living building material, every attempt should be made to make sure that it originates from areas that are largely identical to the site of application Moreover, compliance with national laws and regulations regarding quality and health has to be ensured.

To warrant sustainability of the living structure to be built, as many different “anabolic” species as possible should be chosen. The ecologically most efficient anabolic plants are those living in symbiosis with bacteria and fungi Mycorrhizae or nodule–forming bacteria live on the roots of plants and produce nitrogen, thus creating the effect of automatic permanent fertilization, which quickly leads to an improvement of soil.

For our purpose, alder and legumes are the most important species in Europe possessing these qualities. It should therefore always be considered, when making the choice, whether one of the three indigenous older species is eligible and which of the commercially available legumes are suitable for the composition of the seed mixture.

Regarding the choice of species to be used, there is ample literature which may be consulted.

Choice of the best-suited bioengineering construction method

The intended goal can usually be achieved by a variety of different construction methods. Therefore the choice should be made in favour of those that promise to be most efficient under the given conditions of the site employing those materials that can be obtained at the lowest possible costs. They are, at the same time, the most sustainable ones, require the least maintenance efforts and are therefore, last but not least, the most economical ones.

Timetable

A timetable for the procurement of the plant material as well as for the execution of the individual working steps is of utmost importance because neither of these activities can be carried out with sufficient success in every season. Furthermore, all operations have to be coordinated in time with groundwork and classical engineering work

General and detailed planning

It has turned out not to be practical in bioengineering construction works to plan everything in detail in advance as frequently unexpected changes occur during groundwork It is therefore advisable to start out with a general plan and to plan smaller details as the work progresses if the general plan is not sufficiently detailed.

Tending and Maintenance of Bioengineering Structures

It is a specific feature of bioengineering structures that their protective potential is initially low and that they develop their full effect as the plants develop To encourage this development and to shorten the period until full effectiveness is achieved, tending and maintenance operations are usually required The more extreme the conditions are for the survival of the pants the more intensive these will have to be.

In-process tending

This includes all measures which are required for a structure to reach a state at which it is ready for acceptance.

Works which have been assigned to special subcontractors for execution should be included as well. This not only clearly settles the matter of responsibility for remedial measures in case of poor workmanship but also for any necessary improvements until acceptance, such as reseeding, replanting, fertilization and pruning as well as mowing, mulching and watering, if necessary.

Sustained tending

This term includes all measures which have to be taken to preserve the vegetation that has developed and to maintain its technical and ecological functions Sustained tending is the responsibility of the client or it is put up for a separate tender.

Provided the right bioengineering methods as well as the right species of plants have been chosen, in most cases no further tending is required any more after two years. However, on extreme sites, such as very narrow brooks or locations that are exposed to permanent high stress, (e g ski slopes), annual tending measure may be needed.

Under normal circumstances, tending measures to preserve bioengineering works and their functions are required at mid–term or long–term intervals or after extraordinary events, such as natural disasters, fire or damage by third parties. Such tending and maintenance measures may include:

- prevention of game damage
- mowing including the removal of the mowed matter
- pastoral use, usually for a short time, by certain animal species, e g sheep
- mulching of woody plants, especially in dry zones
- watering or irrigation
- dewatering or drainage
- soil amelioration by fertilization, aeration and loosening
- wood pruning by removing dead or sick shoots for rejuvenation, thinning and encouragement of preferred woody species

Tending and maintenance schedule

For larger bioengineering structures, a tending and maintenance schedule should always be prepared, specifying mandatory measures for an extended period of time and containing information in which month the respective measures are to be carried out.

Service Life

Modern bioengineering structures are relatively young The oldest ones, which are well documented in publications by SCHIECHTL and which still exist, were designed by HASSENTEUFEL, KRAEBEL and PRUECKNER and date back to the nineteen thirties.

Numerous projects implemented by Schiechtl himself are fifty years old and still fully operative. Although most of them were little cared for and no major maintenance efforts were made due to the lack of money, they still fulfil their function today.

This is clearly the result of a correct assessment of the ecological conditions during planning as well as of the right choice of plants, construction method and workmanship.

Stable permanent states can be safely achieved, as is the case with other plant communities such as forests and grassland. Profound knowledge and consideration of the dynamics of artificial plant communities thus created (i.e. natural succession) will help to avoid unpleasant surprises and reduce maintenance costs.

Normally, pioneer vegetation develops via several phases of maturity up to a so–called state of climax, which is determined by local ecological conditions A climax community is a kind of permanent state, which changes only if conditions on site – especially climate – change.

If an intermediate stage of plant development is required for functional reasons, mid–term and, if necessary, even annual maintenance intervention may be required. The long–tem nature of such developments and the longevity of climax stages justify the assumption that living, bioengineering structures are superior to classical engineering works as regards their service life.

However, every living system depends on its own vitality This is why bioengineering structures will achieve their highest efficiency and longest service life where optimal growth conditions prevail.