VGT: A BIOENGINEERING AND PHYTO-REMEDIATION OPTION FOR THE NEW MILLENNIUM

Diti Hengchaovanich
APT Consult Company Limited
Bangkok

Abstract

The new millennium ushers in a new era of man-made high technology that greatly affects facets of our lives. Yet mankind is still bound by nature, as is evident in areas such as alternative medicines, herbal treatments and the like. In a similar vein, the use of vegetation to integrate in construction (also known as bioengineering) and for remediation works (phyto-remediation) on contaminated sites, landfills and wetlands has also attracted tremendous interest in recent years thanks to public consciousness of environmental issues. Touted as a "miracle grass", with early success for soil and water conservation in the agricultural sector, vetiver has increasingly found new applications for bioengineering and phyto-remediation globally, following ICV-1. Once convinced of its amazing properties, more technologists worldwide will adopt and employ this new tool in their fields of endeavour. Moreover, not only because it is effective and environmental friendly, vetiver grass technology (VGT) also affords huge cost savings compared to the "hard" or conventional engineering solutions. VGT in this context stands for a sustainable, green technology highly appropriate for the developing countries beset with scant resources.

Introduction

In the last two decades, we have constantly heard of rapid advances or breakthroughs in the fields of computer or information technology, collectively known as 'high technology'. These discoveries and inventions no doubt affect and greatly facilitate our lives, yet we also find that they are not a panacea to all our problems. In medical treatment, despite research and advances, people are still resorting in large numbers to alternative medicines, acupuncture, herbs and the like for their efficacy and benign results, often at low cost. This, in fact, is a return-to-nature approach; for certain problems, nature already has clues or answers. The onus is on us human beings to know or to seek appropriate solutions to meet our own needs. Bioengineering and phyto-remediation offer such solutions.

Bioengineering, or strictly speaking soil bioengineering (in order to distinguish it from the term used in medical or genetic science), is a relatively new sub-branch of civil engineering. It attempts to use live materials, mainly vegetation, on its own or in integration with civil engineering works to address the problems of erosion and slope stabilization. The term was coined, as an inversion, from the German word *ingenieurbiologie*; since this technique, although used over the centuries, evolved more systematically in the Germanic-speaking countries in the 1930s. In the late 1980s and in the following decade, due to heightened awareness of environmental issues and availability of knowledge and parameters of plants that can aid as well as lend credence to the designs, bioengineering became better known and accepted. This is evident from a number of conferences or workshops organized during that period, the most recent one being the First Asia-Pacific Conference on Ground and Water Bioengineering held in April 1999 in Manila.

Phyto-remediation refers to a green technology that uses plants to decontaminate polluted soils and water. It has gained popularity by leaps and bounds in the last few years because of the rediscovery of the vast potential of plants to do very effective jobs at low cost compared to the conventional cleanup solutions using mechanical or chemical means.

Vetiver grass technology (VGT) is a low-cost, low-tech approach introduced in the early 1980s through the World Bank by Dick Grimshaw, first for soil and water conservation in the agricultural sector. It started to gain impressive ground in other fields during the mid 1990s after some breakthrough research revealed the unique properties of this grass. *Vetiveria zizanioides* lends itself ideally to bioengineering and phyto-remediation purposes and thus is touted as a miracle grass or wonder grass or super grass. It is believed that as more information and records of its successful application come to light, it may become not only *an* option, but rather *the* option for bioengineering and phyto-remediation.

Bioengineering as A Tool for Environmental Conservation and Protection

From studies carried out in the United States (Goldman et al. 1986), it is reported that construction activities contribute some 20 times the rate of other forms of erosion attributable to land use on the average. A separate survey in Guangdong province of China showed that non-agricultural practices caused 72.0% and 89.4% of total erosion area and soil loss respectively (Xu 1999). From these statistics, it can be inferred that the non-agricultural sector is actually the “culprit” which causes severe environmental degradation. With rapid development of infrastructure in some countries, this problem is worsened.

Over the millennia, nature has “designed” vegetation as a means to blanket and stabilize the good earth. In the tropical and subtropical regions, this has evolved into forests of big trees, shrubs and leaf litters covering the organic humus-rich topsoil and offering excellent overall protection. In the light of the current awareness of environmental issues, the preferred option to address the above problems would be to go back and seek the solutions that nature has provided in the first instance. That is, to reinstate those areas ravaged by human beings by way of re-growing vegetation, i.e. the “green” or “soft”, environment-friendly approach. This is in contrast to the conventional “hard” or “inert” engineering solutions using stones or concrete for protecting slopes.

The re-vegetation of slopes can be by means of grassing or leguminous cover crops (for minor surface movement) or the use of fast-growing shrubs and trees for the mitigation of deep-seated erosion in the order of 20-150 cm depths. Tree or shrub roots are able to grip and bind the soils needed to prevent the deep-seated surface slips in the event of heavy and prolonged rainstorms, while normal grasses are unable to do so. This is because roots or “inclusions” impart apparent cohesion (c_r) similar to “soil nailing” or “soil doweling” in the reinforced soil principle, thus increasing the safety factors of slopes permeated with roots vis-à-vis no-roots scenario (Gray 1994).

Notwithstanding their virtues, trees and shrubs inherently have several drawbacks in that they are too slow to establish to become effective (even with fast-growing species this process will take about 2-3 years) and are in danger of being uprooted, in cases of heavy storms, typhoons or cyclones.

Vetiver, although known as a grass, does possess several tree-like features. It therefore becomes an attractive alternative to trees or shrubs when it comes to bioengineering applications

Vetiver Grass as A Bioengineering Option

At the time of the First International Conference on Vetiver (ICV-1) held in Chiang Rai in February 1996, there were very few papers on the bioengineering aspects of vetiver grass (Chomchalow and Henle 1998). However, a few years thereafter there have been a number of conferences and workshops on vetiver and the topics receiving most attention always concerned vetiver in engineering applications. Last April, a major international bioengineering conference was held in the Philippines in which vetiver was featured prominently, and in bioengineering conferences in El Salvador and China in 1999, vetiver was the only subject discussed (TVN 1999). In January 2000, the journal of the International Erosion Control Association will publish an article featuring the attributes of vetiver grass. Why then has vetiver commanded such great attention in the last few years for bioengineering applications?

First, it has to do with the unique characteristics of the grass itself. For the sake of completeness, its main characteristics are reiterated here below:

- The grass grows upright and is able to form a dense hedge within 3-4 months, resulting in the reduction of rainfall runoff velocity and formation of an effective sediment filter. The hedgerow can adjust itself in tandem with trapped silt by forming new tillers from nodes on the culm of higher branches, thus ensuring that it will never be buried alive.

- It has a vigorous, massive and dense subterranean root system that reaches vertically 2-5 m depth depending on soil types.
- The roots are very strong compared to other hardwood species (see Table 1), having average tensile strength of 75 MPa or approximately $1/6^{th}$ of mild steel.

As such, the remark of His Majesty King Bhumibol of Thailand, made a few years ago, that "vetiver is a living wall" is indeed very illustrative and enlightening from the bioengineering perspective. One can visualize that while the above-ground wall (i.e. hedgerow) caters for erosion control, the underground wall (i.e. roots) simultaneously enhances slope stability.

Other salient characteristics are its ability to survive in conditions of extreme drought (including bush fires) or total submergence and flood, and its tolerance to high acidity, alkalinity, salinity, sodicity, etc. It can tolerate temperatures ranging from -15^{o} to $55^{o}C$, although it will mostly thrive in the tropical and subtropical regions of the world. It will grow very rapidly and become effective in only 4-5 months versus 2-3 years for trees or shrubs. This is a big plus when in many civil engineering projects one of the reasons being cited for the reluctance to use bioengineering ("soft" or "green") measures is that they are too slow to become effective.

Table 1: Tensile strength of roots of some plants

Botanical name	Common name	Tensile strength (MPa)
Salix spp.	Willow	9-36*
Populus spp.	Poplars	5-38*
Alnus spp.	Alders	4-74*
Pseudotsuga spp.	Douglas fir	19-61*
Acer sacharinum	Silver maple	15-30*
Tsuga heterophylia	Western hemlock	27*
Vaccinum spp	Huckleberry	16*
Hordeum vulgare	Barley Grass, forbs Moss	15-31* 2-20* 2-7kPa*
Vetiveria zizanioides	Vetiver grass	40-120 (Average 75**)

* (Wu 1995) ** (Hengchaovanich and Nilaweera 1998)

In addition, from observations in Malaysia, Australia and China, it was found that in those locations planted with vetiver, favourable microclimates would be induced that led to subsequent colonization of other plant species, thus enhancing the greening of the environment.

The second reason for the attraction of vetiver grass is the cost advantage. It has been published that in China where labour cost is not high, a "soft" or "green" solution using vetiver would cost approximately 10% of the corresponding "hard" or "stone" solution (Xia et al. 1999), while in Australia where labour cost is indeed high, the vetiver approach would cost 27 to 40% of the "hard" conventional technique (Bracken and Truong 2000). In other countries, from unpublished reports, costs vary somewhere in between.

The last and not the least reason why VGT becomes better known and accepted in bioengineering is the diligent efforts by The Vetiver Network (TVN), including its regional allied network, the Royal Development Projects Board, through the publication of its newsletters and technical bulletins as well as the dedication of many concerned individuals. They all have been responsible for the promotion of the bioengineering aspects of this miracle grass.

Where Can VGT be Applied in Bioengineering?

The scope of applications is varied: foremost is the erosion control and stabilization of steep grounds such as slopes of cuttings and fills on highways, railways and dams. High bridge approaches are good locations to try vetiver bioengineering. Highly erodible and unstable slopes, where previous usage calls for gunite/shotcrete slope protection, can and should be planted with vetiver at much lower cost. Property boundaries or filled-up lands with or without structures can be stabilized with vetiver to keep their sitting structures, physical shapes and real-estate value intact. Rivers, levees and reservoir banks can be strengthened and stabilized to prevent undue sedimentation or to mitigate flooding disaster. Pipeline projects for oil and gas which normally pass through pristine forests, whether on flat or hilly terrains, can make use of vetiver to rehabilitate the disrupted environment. Vetiver can also complement "hard" engineering solutions of stones, gabions and mattresses to strengthen all these structures/revetments and make them function even better.

Phyto-remediation

Phyto-remediation (Greek: *phyton* = plant; Latin: *remediare* = remedy) is the use of plants and trees to clean up contaminated soils and water. It is an aesthetically pleasing, passive, solar energy-driven cleanup technique. It can be used along with or, in some cases, in place of mechanical methods. This "green", "clean" technology is very popular in the United States nowadays, not only because it is environmentally friendly, but also because it costs around one-tenth to one-third of conventional remediation technologies. It is expected that in the United States the use of phyto-remediation techniques will increase more than tenfold in the next few years. For the rest of the world, it is likely that this trend will also be followed.

Constructed wetlands are also considered one of the phyto-remediation techniques. However, the plants employed in the process have to be wetland plants. Constructed wetlands have been found to be effective in the treatment of contaminated wastewater.

VGT as A Phyto-remediation Option

As mentioned in the earlier section, plants are used for the removal of contaminants. Most plants used in the western world are poplar trees, some other grasses and wetland plants. Research over the last few years, in particular that conducted by Truong and Baker (1998), shows that vetiver is an ideal plant for such purpose. Their findings show that it is highly tolerant of toxicity from heavy metals such as Al, Mn, As, Cd, Cr, Ni, Pb, Hg, Se and Zn. It is capable of absorbing dissolved N, P, Hg, Cd and Pb in polluted water. Moreover, being a wetland plant itself, vetiver can also be used in a constructed wetland system.

A significant amount of work has been done in Australia and South Africa to rehabilitate gold, platinum, coal and other mines using vetiver, which was found to be effective (Truong 1999).

For landfills and other contaminated sites, some work has been done in a 20-year-old landfill in Australia and vetiver was found to be able to suck up the leachate substantially. In China, small-scale planting was carried out on a garbage dump in Guangzhou city and it was found that vetiver could survive on top of the dump site and seemed to be able to eliminate some of the associated bad odours as well (Xia 1998). A recent Chinese study also told of the successful use of vetiver as a wetland plant to remediate animal waste from a piggery (Liao 1999).

In Thailand, it was reported that vetiver could decontaminate agrochemicals, especially pesticides, and prevent them from accumulating in crops, polluting streams and other ecosystems (Pinthong et al. 1996). Some experiments were also carried out to determine the possibility of using vetiver grass to treat wastewater and it was found that vetiver could uptake significant amounts of N, P, K, Ca, Mg, Pb, Cd and Hg (Sripen et al. 1996). Laboratory results also showed the ability of vetiver to absorb heavy metals (Roongtanakiat et al. 1999).

At a major landfill at Kamphaeng Saen, 90 km northwest of Bangkok, where 5 000 t of garbage is being dumped daily, a test section has been earmarked for the planting of vetiver. Planting was carried out in July 1999. After four months, it was observed that the plants were able to survive fairly well, despite the presence of leachate and toxicity normally expected of such a dump site. Field studies as well as parallel laboratory experiments are being conducted at Chulalongkorn and Kasetsart

Universities using modern nuclear and conventional techniques to assess its performance. As the experiments are still proceeding, part of the results will be displayed in poster presentations at the Second International Vetiver Conference (ICV-2) (Chanyotha et al. 2000). It is anticipated that the outcome will reveal the practicality and effectiveness of vetiver grass for the remediation of landfills. As there are currently 50 landfills in Thailand, findings from this research will have positive repercussion on measures to overcome this problem now besetting many communities.

Conclusion

Vetiver grass, although known in India centuries earlier and applied in specific locations with indigenous knowledge, only became known worldwide through the initiative of the World Bank in the 1980s, mainly in the agricultural sector. Later as the unique characteristics of vetiver became better known through scientific research, vetiver has emerged as an ideal plant for bioengineering and phyto-remediation. The last years of the 20th century were the years of R&D – the test-and-try period. The next century should see large-scale and practical implementation. With its low-tech simplicity, low cost, effectiveness and sustainability, VGT should be the technology of choice, by means of bioengineering and phyto-remediation, for the conservation and protection of the environment, especially for cash-strapped developing countries.

References

Bracken, N.; and Truong, P. 2000. Application of vetiver grass technology in the stabilization of road infrastructure in the wet tropical region of Australia". Proc. ICV-2, ORDPB, Bangkok.

Chanyotha, S. 2000. Phytoremediation by vetiver grass: field and laboratory investigations. *In:* Abstracts of Poster Papers presented at ICV-2, p. 15. ORDPB, Bangkok.

Chomchalow, N.; and Henle, H.V. (eds.) 1998. Proc. ICV-1, ORDPB, Bangkok.

Goldman, S.J. et al. 1986. Erosion and Sediment Control Handbook. McGraw-Hill Inc., New York, USA.

Gray, D.H. 1994. Influence of Vegetation on Stability of Slopes. *In:* Vegetation and Slopes. Institution of Civil Engineers, London, pp 2-25.

Hengchaovanich, D.; and Nilaweera, N. 1998. An assessment of strength properties of vetiver grass roots in relation to slope stabilization. Proc. ICV-1, pp. 153-158. ORDPB, Bangkok.

Liao, X. 1999. Personal communications.

Pinthong, J.; Impithuksa, S.; Udomchoke, M.; and Ramlee, A. 1998. The capability of vetiver hedgerows on decontamination of chemical residues. Proc. ICV-1, pp. 91-98. ORDPB, Bangkok.

Roongtanakiat, N. et al. 1999. Heavy metals absorption by vetiver grass and its impact on growth characteristics. Poster presentation at the Third Thai National Workshop on Vetiver, Kasetsart University, Bangkok.

Sripen, S.; Komkris, T.; Techapinyawat, S.; Chantawat, S.; Masuthon, S.; and Rungsuk, M. 1996. Growth potential of vetiver grass in relation to nutrients in wastewater of Changwat Phetchaburi. Paper presented at ICV-1. *In:* Abstracts of papers presented at ICV-1, p. 45. ORDPB, Bangkok.

Truong, P.; and Baker, D. 1998. Vetiver Grass System for Environmental Protection. PRVN Tech. Bull. No. 1998/1. ORDPB, Bangkok.

Truong, P. 1999. Vetiver grass technology for mine tailings rehabilitation. Proc. First Asia-Pacific Conf. on Ground and Water Bioengineering for Erosion Control and Slope Stabilization, Manila.

TVN. 1999. The Vetiver Network website. http://www.vetiver.org.

Wu, T.H. 1995. Slope stabilization. *In:* P.C. Morgan and R.J. Rickson (eds.) Slope Stabilization and Erosion Control: A Bioengineering Approach. F.N. Spon, Chapman and Hall, London.

Xia, H.P. 1998. Vetiver and rubbish dump clean up. Vetiver Newsl. 19: 39-40.

Xia, H.P.; Ao., H.X.; Liu, S.Z.; and He, D.Q. 1999. Application of the vetiver ecoengineering for the prevention of highway slippage in South China, Proc. Proc. 1st Asia-Pacific Conf. on Ground and Water Bioengineering for Erosion Control and Slope Stabilisation, Manila, pp. 522-527.

Xu, L.Y. 1999. An overview of the use of vegetation in China. Paper presented at the International Conference on Vetiver Bioengineering Technology for Erosion and Sediment Control and Civil Construction Stabilization, Nanchang, China.