VGT: A Bioengineering and Phytoremediation Option for the New Millennium

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1. INTRODUCTION

As we are now in the threshold of the New Millennium, it dawns on us to reflect on what the New Era will bring. In the last two decades, we constantly heard of rapid advances or breakthroughs in the fields of computer or information technologies, collectively known as 'high technology'. These new discoveries or inventions no doubt impact and greatly facilitate our lives, yet we also find that they are not panacea to all our problems. As in medical treatment, despite researches and advances on the one hand, people are still on the other hand resorting in large numbers to alternative medicines, acupuncture, herbs and the like for their efficacy and benign results, often at lower costs. This, in fact, is a return-to-nature approach; as for certain problems, nature has already clues or answers to them. The onus is on us human beings to know or to seek appropriate solutions to meet their own needs. Bioengineering and phytoremediation are some of the cases in point.

Bioengineering, or strictly speaking, soil bioengineering (in order not to be confused with similar term being used in the medical or genetic sciences), is a relatively new subbranch 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 stabilisation. It was coined, as an inversion, after the German word *ingenieurbiologie*; since this technique, although used over the centuries, evolved more systematically in the Germanic-speaking countries in the 1930s. In late 1980s and 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 more well known and accepted. This is evident from a number of conferences or workshops being organised during those periods, the most recent one being the First Asia-Pacific Conference on Ground and Water Bioengineering held in April 1999 in Manila, the Philippines.

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

Vetiver Grass Technology (VGT) is a low-cost, low-tech technology 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 grounds in other fields during the mid-1990s arising from some breakthrough researches that reveal the unique properties of this grass, *Vetiveria zizanioides*, that lends itself ideally for bioengineering and phytoremediation purposes (hence touted as a miracle grass, wonder grass or super grass). It is believed that as more information and records of its successful application have come to light, it may become not only *an* option, but rather *the* option for bioengineering and phytoremediation measures in the New Millennium.

2. BIOENGINEERING AS A TOOL FOR ENVIRONMENTAL CONSERVATION AND PROTECTION

From studies carried out in the U.S. (Ref. 1), 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 the non-agricultural practice caused 72.0% and 89.4% of total erosion area and soil loss respectively (Ref. 2). From the above statistics, it can be inferred that the non-agricultural sector is actually the ‘culprit’, which causes severe environmental degradation. With rapid development of infrastructures in some countries, this problem is therefore even aggravated.

Over the millennia, Nature has ‘designed’ vegetation as a means to blanket and stabilise the good earth. In the tropics or subtropical region, this has evolved into forests comprising big trees, shrubs and leaf litters covering the organic humus-rich topsoil that offer excellent overall protection. In the light of current awareness and conscientiousness 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 revegetation of slopes can be by means of grassing or leguminous cover crops (for minor surficial 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 surficial 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) in 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-root scenario (Ref. 3).

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 the 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 come to bioengineering applications

3. 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 bioengineering aspects of vetiver grass (Ref. 4). However, a few years thereafter there have been a number of conferences/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 with vetiver being featured prominently, whereas in bioengineering conferences in El Salvadore and China in 1999, vetiver was the only subject discussed (Ref. 5). In January 2000, the journal of the International Erosion Control Association (IECA) 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?

Firstly, it has to do with the unique characteristics of the grass itself. For the sake of completeness, some of 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 vigorous massive and dense subterranean root networks that reach vertically from 2~5 m depths 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 1/6th 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 visualise that while the aboveground wall (i.e. hedgerow) caters for erosion control, the underground wall (i.e. roots) simultaneously enhances slope stability.

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**)

* (Ref. 6) ** (Ref. 7)

Other salient characteristics are its ability to survive in conditions of extreme drought (including bush fires) or total submergence and flood, its tolerance to high acidity, alkalinity, salinity, sodicity, etc. It can tolerate in temperatures ranging from –15 C to 55 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’) measure is because it is too slow to become effective.

In addition, from observations in Malaysia, Australia and China, it was found that those locations planted with vetiver, favourable microclimates would be induced that led to subsequent colonisation 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 that high, a ‘soft’ or ‘green’ solution using vetiver would cost approximately 10% of corresponding ‘hard’ or ‘stone’ solution (Ref. 8), while in Australia where labour cost is in the other extreme, the vetiver approach would cost in the order of 27% to 40% of the ‘hard’ conventional technique (Ref. 9). In other countries, from unpublished reports, costs vary somewhere in between.

The last and not the least reason why VGT becomes more well known and accepted in bioengineering is the diligent efforts by the Vetiver Network (TVN) including its regional allied networks, the Royal Development Projects Board (RDPB), 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 this miracle grass for the bioengineering aspects.

4. WHERE CAN VGT BE APPLIED IN BIOENGINEERING

The scope of applications are varied and many: the foremost of which is the erosion control and stabilisation 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 substituted by vetiver at much lower costs. Property boundaries or filled-up lands with or without structures can be stabilised with vetiver to keep their sitting structures, physical shapes and real-estate values intact. Rivers, levees and reservoir banks can be strengthened and stabilised 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, mattresses to strengthen all these structures/revetments to make them function even better.

5. PHYTOREMEDIATION

Phytoremediation (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 it also costs around one-tenth to one-third of conventional remediation technologies. It is expected that in the U.S. the use of phytoremediation techniques will increase more than 10 fold 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 phytoremediation 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.

6. VGT AS A PHYTOREMEDIATION 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 those conducted by Truong (Ref. 10), shows that vetiver is an ideal plant for such purpose. His findings showed that it is highly tolerant of toxicity of 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.

Significant amount of work have been done in Australia and South Africa to rehabilitate gold, platinum, coal and other mines using vetiver and found to be effective (Ref. 11).

For landfills and other contaminated sites some works have been done in a 20-year-old landfill in Australia and found it to be able to suck up the leachate substantially. In China, a 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 odour as well (Ref. 12). Recent Chinese study also revealed the successful use of vetiver as a wetland plant to remediate animal waste from a piggery (Ref. 13).

In Thailand, it was reported that vetiver could decontaminate agrochemicals, especially pesticides and prevented them from accumulating in crops, polluting streams and other ecosystems (Ref. 14). 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 amount of N, P,K,Ca,Mg,Pb,Cd and Hg.(Ref. 15). Laboratory results also showed the ability of vetiver in absorbing heavy metals (Ref. 16).

At a major landfill at Kamphaengsaen, 90 km northwest of Bangkok, where 5000 tons of garbage is being dumped daily, a test section has been earmarked for the planting of vetiver. Planting was carried out in July in 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 techniques and conventional techniques to assess its performance. As the experiments are still ongoing, part of the results will be displayed in poster presentations at the Second International Vetiver Conference (ICV-2), Ref. 17. 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.

7. CONCLUSIONS

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 1980s, mainly in the agricultural sector. Later as the unique characteristics of vetiver became better known through scientific researches, vetiver has emerged as an ideal plant for bioenginering and phytoremediation. The last years of the last millennium were the years of R & D (Research and Development)-- the Test and Try period. From now onwards it should be the era of large-scale and practical implementation. With its low-tech simplicity, low cost, effectiveness, and sustainability, VGT-Vetiver Grass Technology- should be the technology of choice in the New Millennium, whether by means of bioengineering or phytoremediation, for the conservation and protection of the environment, especially for the cash-strapped developing countries.

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