Vetiver Grass: Application for Stabilization of Structures

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The unique characteristics of vetiver grass, *Vetiveria zizanioides,* and its potential use for stabilizing structures, particularly those relating to earth embankments and cuts associated with roads, waterways, and building sites, are described. The paper refers to past research on the generic characteristics of vetiver grass and its application as a means of a vegetative response for the control of erosion and sedimentation problems. Case studies in Asia, Africa, and Latin America are evaluated demonstrating the effectiveness of vetiver using a series of on-site photographs. It is concluded that the engineering community should take a close look at the use of vetiver because of its proven ability to stabilize soil and earth structures more effectively and at a lower cost than any other known technology.

In 1993 the National Research Council published a review of vetiver (*1*) that verified the importance of this grass for soil and water conservation and for the stabilization of embankments and other earth structures. This paper is devoted to the use of vetiver for the stabilization of structures, particularly earth fill embankments, cuts, and drainage ways. The paper will show how vetiver can be used for the structural strengthening and protection of earthworks, as an interface between earth and concrete and earth and water, and in the dissipation of hydraulic forces. Laboratory experiments are just starting to yield results. Large demonstrations from various parts of the world now show the usefulness of vetiver. In this case the user is the experimenter, and this study attempts to document that use.

Vetiver Technology

Why vetiver grass? Vetiver (Figure 1), the most common and effective species of which is *Vetiveria zizanioides,* is unique. This quality, together with its wide geographic and ecological area of adoption, makes it an attractive plant for structural stabilization.

Vetiveria zizanioides belongs to the subtribe Sorghinae and has close links with *Chrysopogon. V. zizanioides* (L.) Nash. is densely tufted, awnless, wiry, glaborous perennial grass. The plant grows in large clumps from a multibranch root stock with erect culms 0.5 to 1.5 m high. The leaf blades are relatively stiff, long, and narrow—up to 75 cm long and 8 mm or less in width—glaborous but downward rough along the edges. Panicles are 15 to 30 cm long, narrow acute, appressed, awnless, one sessile and hermaphroditic, somewhat flattened laterally, with short sharp spines, three stamens, and two plumose stigmas; the other spikelet is pedicilled and staminate. Some cultivated forms rarely flower.

Two of the 13 species of vetiver are found in India, *V. zizanioides* and *V. lawsonii. V. zizanioides,* cultivated for the aromatic oils in its roots, appears to differ from

FIGURE 1 Closeup of vetiver crown showing dense root system and strong, dense, erect leaves and stems. This clump, along with a whole field of vetiver being used for mine land reclamation, had been burnt but in 4 weeks had fully recovered (photograph courtesy P. K. Yoon).

north India to south India. The northern cultivars flower and produce viable seeds; the southern cultivars seldom flower, and when they do, the seeds are generally sterile. Anatomical studies carried out at the University of Bangalore make the following points (*2*):

> Even though the stem shows the anatomical features of a normal grass, morphologically it is different from other grass in having swollen nodes, long internodes which are to some extent covered by the unfurled bundles of leaves except at the apical portions. The roots are very long and fibrous [Figure 2] and are unique in having aerenchyma in the outer cortical region (Scitaminae groups). In this respect the plant differs from other normal grass. Anatomically the plant is a hydrophyte, yet due to its deep and extensive root system an established plant functions under xerophytic conditions. Thus the plant exhibits unique features.

Vetiver has been used for thousands of years as mulch, thatch grass, and fodder and for brooms and paper pulp. The roots of vetiver grass have been used to weave mats, screens, or fans; for medicinal purposes; and as insect repellents. Its major commercial use has been the extraction of a complex volatile oil from its roots. The grass offers some unique qualities, as discussed in the following paragraphs.

The grass is a C4, is drought tolerant, and has deep, strong roots. It is resistant to most pests and diseases. A few, such as Fusarium wilt, have been identified, but none appear to be serious. It will grow in soils from less than pH 3 to over pH 11 (*3,4*). It has tolerance to high levels of soil toxicity caused by manganese, aluminum, and other metals. It grows under rainfall conditions of

FIGURE 2 Vetiver in Malaysia with 2-m root at 12 months. Root length differs between cultivars, but generally those originating from south India and then further selected and bred for high oil content have the longest and strongest roots (photograph courtesy P. K. Yoon).

less than 600 mm per year in Andhra Pradesh, India, to 6000 mm per year in Sri Lanka. It grows well in China at 30 degrees north latitude and on slopes of more than 50 percent in Malaysia, Thailand, and South Africa. It grows on red latosols, black cracking vertisols, roadside rubble (Figure 3), C-horizon gravels, laterites, sodic, and saline on soils.

Based on years of observations, the grass is not known to be invasive. At Msamfu Research Station in Zambia (J. C. Greenfield, personal communication, 1986), vetiver planted in 1923 grew in the same rows as those it was planted in. In Fiji, St. Vincent, and south India (Gundalpet), the vetiver hedge *zizanioides*, originating probably from south India, has shown little ev-

FIGURE 3 Vetiver on roadside rubble in Malaysia. Public Works Department in Trinidad and Tobago has used vetiver for decades to stabilize road shoulders (photograph courtesy P. K. Yoon).

idence of setting viable seed. In some instances, cultivars, particularly those from north India, do set viable seed. Even so, the removal of escapes is easily effected by cultivation methods.

Farmers have said that vetiver repels rats and snakes, and there is strong evidence that vetiver hedges exclude rhizomatous weeds. Vetiver's repellency to rats is a useful characteristic in relation to rodent damage to embankments.

Compared with other systems such as grass buffer strips and contour earth bunds, vetiver hedges take up minimal space. Depending on soil type, rainfall, and fertility, it will take from 9 months to 4 years to establish a fully functioning hedge. During 1990 an effective hedge in Fujian (China) was established on a 20 percent slope in 12 weeks (Provincial Government of Fujian, personal communication, 1990). At a USDA Soil Conservation Workshop in November 1990, it was reported that in Louisiana, effective hedges were established on degraded soils of an army tank training area in 10 weeks. Full and effective hedges on 60 percent slopes have been established in Thailand in less than a year. The key to accelerated hedge development is the use of quality planting material (vetiver is propagated through culm division) and close planting within the row (about 10 to 15 cm apart). The distance between hedgerows can vary according to site but normally they are located at a vertical interval of 1 to 2 m. Pruning the hedgerow encourages tillering and helps establish a denser hedge and a better sediment trap more quickly. Compared with structural techniques that deteriorate in effectiveness from the day of construction, vetiver hedges improve from year to year as their filtering action improves with the increased density of the hedge.

Vetiver (*Vetiveria nigratana*) hedges have been used for decades as wind breaks in the semiarid states of northern Nigeria, Kano and Sokoto. Many have observed its ability to stop the larger fraction of windborne soil. In colder climates, vetiver hedges are good windbreaks against cold winter winds. Vetiver leaves die back during the winter, but because of the structural strength of the leaves and stem, the barrier is maintained until new growth occurs. However, vetiver will not survive prolonged subzero temperatures typical of continental areas of the Northern Hemisphere.

Mature vetiver is less palatable than popular fodder grasses. However, during periods of extended dry seasons of more than 6 months and during times of extreme fodder shortages, it will be eaten. If managed properly and harvested fairly frequently for cut-and-carry feeding, the palatability and digestibility improve considerably. In Mali the floodplain vetiver areas are regularly burnt by livestock owners to ensure a young and palatable flush (C. de Haan, personal communication, 1990). However, the plant cannot be destroyed because its crown is below the soil surface. Goats frequently eat vetiver down to about 15 cm above the ground; thereafter, the plant material is too coarse even for goats. Vetiver is also fire tolerant and cannot be destroyed. It regenerates very quickly after a fire. Hence, it is effective as a soil conservation measure in sugarcane plantations, where cane is often burnt before being harvested.

Research at the International Crops Research Institute for Semi-Arid Tropics (*5*), India, compared vetiver with stone barriers, lemongrass, and bare ground (the control) under natural (total rainfall 689 mm) and artificial rainfall conditions. In all cases, vetiver was the most effective technology for reducing soil and water loss. Vetiver reduced rainfall runoff by 57 percent and soil loss by more than 80 percent. The results from the experimental hydrographs showed the enhanced delay in release of runoff from the vetiver plots, an interesting feature that could be effective if applied widely as an upper catchment flood control measure. The same research team (*6*) confirmed that in the following year vetiver performed even better. Vetiver shows a distinct improvement in efficiency as the hedges become older and more dense. At the International Center for Tropical Agriculture in Colombia (*7*), vetiver was compared with other vegetative systems grown in conjunction with cassava. At 11 months (rainfall 1240 mm), vetiver hedge reduced soil loss from 142 ton/ha for bare fallow to 1.3 tons/ha for cropped cassava between vetiver hedges. Rainfall runoff was reduced from 11.6 to 3.6 percent. Other researchers have reported similar results. Evidence (*8*) shows strong positive correlation between soil loss and water runoff reduction when vetiver is grown on black vertisols in western India. Vetiver is shown to be significantly superior to other hedge-type barriers. In Louisiana (*9*), demonstrations conclusively show the impact of vetiver hedges on sediment retention. In Malaysia (*10*) large-scale experiments have demonstrated substantial sediment deposits behind vetiver hedges, in one case of about 1 m in 1 year (Figure 4).

Farmers have generally reported favorably on the use of vetiver. A farmer (*11*) has used vetiver on the family sugarcane farm in Natal, South Africa, for more than 70 years as a means of stabilizing roadsides. This farmer has extended the use of vetiver to stabilize his farm drainage lines, embankments of dams, and so forth. Vetiver users in Central America, including those from Honduras (K. Hendriksen, personal communication, 1993) confirm that vetiver hedges are the most cost-effective method of soil conservation, as do users in Ethiopia (A. Mekonnen, personal communication, 1993) and other African countries. Vetiver can regenerate from stem nodes. As the sediment builds up behind and within the vetiver hedge to form a terrace, the grass grows up with the rising terrace. In Fiji, terraces with risers as high as 3 m have been formed naturally (*12*) under such conditions.

There is considerable evidence to support the use of vetiver for embankment stabilization (*11,13–16*). Vetiver has been used successfully in Malaysia, India, South Africa, West Indies, and Brazil to stabilize roadsides. Vetiver has been used in conjunction with geotechnical applications for embankment stabilization in Nepal. It has been tested successfully (*15*) to stabilize goldmine slag heaps in South Africa. It has also been used (J. Embrechts, personal communication, 1993; *17*) (though mainly unrecognized and unknown to engineers and others) to stabilize flood and canal embankments and riverbanks in Bangladesh.

Because of its great strength and capacity to absorb and dissipate hydraulic energy, vetiver has the potential to stabilize canal banks against the force and shock of boat wash. Therefore, the Panama Canal Commission is showing interest in the application of vetiver to the canal. The Vetiver Network has received positive reports of the use of vetiver to reduce erosion in small dam spillways in Zimbabwe (*18*), gullies in Fiji (J.C. Greenfield, personal communication, 1986), China, India, and South Africa; and drainage ways in Guatemala, South Africa, Malaysia, and Nepal (*10,11,16,19*). More recently, reports have been received of its use for the protection of building sites located on sloping land (*15*). Vetiver has not been used on railroad embankments, but it could be highly effective on the normally very steep slopes of embankment fill areas.

Vetiver can be used effectively to stabilize irrigation channels (*20*). Experiments using irrigation channels with vertical side slopes compared vetiver on unlined slopes and polyethylene-lined slopes. The side slopes planted with vetiver in the polyethylene-lined channels remained vertical; unlined slopes remained nearly vertical. The results indicate the high ability of vetiver to bind the soil (a sandy loam), as well as the potential for designing channels with much steeper slopes to save land.

Vetiver has been used in many countries as an effective means of stabilizing gullies often associated with roads. Because of its strength, vetiver can withstand high-velocity water flows that are normally associated with gullies. It can also grow through deep deposits of

FIGURE 4 Cross section of vetiver hedge row in Malaysia showing buildup of sediment behind hedge 2 years after planting (photograph courtesy P. K. Yoon).

FIGURE 5 Malaysia test planting using containerized raised plants on highway cut 8 months after planting vetiver hedges. Note unprotected area continues to erode; where protected, other grass species are now able to become established. Alternative to vetiver is to continue applying costly and often ineffective hydroseeding techniques (photograph courtesy P. K. Yoon).

sediment that are formed behind vetiver hedges established in gullies. As a result, natural steps are formed in the gullies. Where gabbions are used to stabilize gullies and waterways, vetiver, if planted in association with the structures, will help stabilize them. When high water velocities are expected, vetiver may best be planted from polybagged planting material to ensure quick establishment. In the first year, this requires protection by sandbags and pegging with bamboo stakes.

Case Studies

Road Embankment and Cut Stabilization

In Brazil, road shoulders have been stabilized with vetiver for at least 30 years, as have roads in many of the

FIGURE 7 Vetiver hedges used in Guatemala for more than 20 years to protect cut slopes of coffee estate roads (photograph by R. G. Grimshaw).

Caribbean Islands. In Natal, South Africa, the shoulders of sugar estate roads have been stabilized with vetiver. More recently, vetiver has been used to stabilize steep roadside cuts and fills in Malaysia and Thailand using advanced planting techniques pioneered by P. K. Yoon of Malaysia. It is also reported that road cuts on mountain roads in Nepal and Guangdong Province of China (*21*) have been stabilized with vetiver (Figures 5–11).

Waterway and Drainage Stabilization

Vetiver plays an important role in stabilizing the interface between water and earth and water, concrete, and earth. Vetiver has both hydrophytic and xerophytic characteristics as well as great physical strength, and is an ideal plant for stabilization where these media interface. Vetiver will survive months submerged in water. It

FIGURE 6 Vetiver hedge rows protecting sides of farm access roads in South Africa (photograph courtesy J. C. Greenfield).

FIGURE 8 Two rows of vetiver hedges interplanted with leguminous cover effectively protect road cut in Thailand. Note sediment-free drain (photograph by R. G. Grimshaw).

FIGURE 9 **Steep, high road cut in Doi Tung Royal Development Project, Thailand, is being stabilized with vetiver hedges (1 year old). On closer inspection one sees volunteer natural species being established behind hedges where there is more moisture. Note that vetiver hedges spread out runoff, dissipate concentrated hydraulic forces, and allow runoff to move slowly and evenly down face of cut (photograph by R. G. Grimshaw).**

FIGURE 11 **Newly planted vetiver on downstream slope of earth dam in Zimbabwe. Vetiver rows have actually been planted too close together and are therefore more costly than necessary. Lines should have been planted about 1 m apart (photograph courtesy J. C. Greenfield).**

can be used, in its traditional embankment stabilization role, to stabilize banks of earth dams on the downstream side (Figure 11) and to replace rip-rap and protect the wall from wave-induced erosion on the upstream side.

Vetiver can also be effective for stabilizing bridge abutments, drainage lines, culvert inlets and outlets, and earth spillways and overflows (Figures 12 and 13).

Vetiver has been used to stabilize natural and artificial riverbanks. In Bangladesh, vetiver has been used for decades for this purpose. The United Nations Development Program is currently performing tests on vetiver to determine if it can stabilize embankments that interface with brackish water in delta areas. In China vetiver has been found to stabilize river training banks and reclaim riverbeds (*21*). There is considerable potential for this type of use, and it is soon to be tested in Indonesia. Vetiver could also be used to stabilize waterways in the lower reaches of the Mississippi in Louisiana. The Panama Canal Commission is expected to test vetiver as a way of stabilizing the banks of the canal against the wash of the large vessels that pass through it. On a smaller scale vetiver might be very effective against the current destruction of Thailand's *klongs*, which have

FIGURE 10 **Vetiver used to protect edge of road drain from sedimentation and small rock fill in Doi Tun, Thailand. Note clean drain, which saves annual maintenance costs and ensures that drain functions when needed (photograph by R. G. Grimshaw).**

FIGURE 12 **Vetiver trapped in waterway, Natal, South Africa. Over 1 m of silt (from neighboring and unprotected farm) was retained over a 3-day, 250-mm storm event. Note that vetiver remains standing and growing through sediment (photograph courtesy J. C. Greenfield).**

FIGURE 13 Vetiver stabilizing concrete-earth interface and protecting sides of downstream drainage way, Natal, South Africa (photograph courtesy J. C. Greenfield).

been badly eroded due to the use of high-powered water taxis.

Economics of Vetiver

Using vetiver is a relatively inexpensive technology. Vetiver must be propagated vegetatively; therefore, the cost of production of planting material depends on the cost of labor. At the Doi Tung Royal Development Project in Thailand, 20 million vetiver slips have been produced and planted over the past 2 years. In 6 months, 1 ha of nursery will produce a minimum of 1.25 million bare-rooted vetiver slips, enough for about 42 km of hedge (three slips per planting station, with each station 10 cm apart). The farmer earns $2,600 (U.S.) per hectare on the sale of quality vetiver slips. The hedge cost for planting material is equivalent to about $6/100 m. If slips are planted in containers (polybags), the cost of plant material is $60/100 m (*21*). Where the sites are difficult and hedge development must be accelerated, the use of containerized plants is probably the most effective method. On most embankments vetiver planted at about 1 m between lines would provide very effective protection. Vetiver has a relatively low cost, is inert, and once established requires minimal maintenance. This makes it a potentially effective means of stabilizing earthen structures using vegetative methods.

Conclusions

The engineering profession should expand the use of vetiver to stabilize structures and other areas (such as land slumps) that warrant the use of a vegetative system. From our observation and analysis of worldwide vetiver use, we have determined that there are no negative results of using this grass. We are certain the grass will be successful if it is planted according to the correct technical specifications. It is simple and cost-effective. The technology has been proven and it works.

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