APPLICATION OF VETIVER GRASS TECHNOLOGY TO THE STABILIZATION OF ROAD INFRASTRUCTURE IN THE WET TROPICAL REGION OF AUSTRALIA

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Abstract

New road construction works along improved horizontal and vertical alignments require substantial clearing of the natural vegetation and the earthwork required very often involves major cut and fill embankments. Construction of associated bridges and culverts also results in disturbance of the existing vegetation. Resulting from these construction activities, extensive areas of disturbed land are placed at risk of erosion. This risk is exacerbated in areas of Australia which are subject to high-intensity rainfall. The wet tropical regions of Australia extend over vast areas with a diversity of soil types, including highly dispersive soils containing little if any nutrients.

In the wet tropics of Far North Queensland, vetiver contour hedges have recently been established as a rapid and effective method of stabilizing new road embankments and other disturbed areas. Other trials undertaken with substitution of vetiver contour hedges to control storm water runoff, in lieu of the traditional and expensive methods of constructing rock check dams in table drains and culvert outlets, concrete shoulder dykes and treatment of areas subject to piping are encouraging in terms of effectiveness and attractive cost benefits.

Introduction

The wet tropics of Australia extend over a vast area of the Northern Australian continent and are subjected to well-defined wet and dry seasons. The wet season, which generally extends from December to April, is subject to high-intensity rains whereas the dry season is dry and dusty, with little if any rain. The region also contains a diversity of soil types with sound materials suitable for road construction purposes and often difficult to find. For example, the soil on which the road described below was built is very poor in plant nutrients (Table 1), which makes stabilization by plants very difficult. Therefore it is highly erodible under high rainfall conditions.

This lack of suitable materials often results in road batters and table drains being subject to deterioration by erosion and, if left untreated, this would result in failure of the embankments and place the road itself in jeopardy. In addition, when erosion occurs, this would cause the unwanted transportation of sediment along natural watercourses.

The realignment of creek beds for bridge and culvert construction works involves disturbance of natural vegetation, leaving these areas at risk of erosion. Traditional protection of these disturbed areas with hard rock riprap, rock mattresses and gabions are expensive solutions. In some areas, suitable naturally occurring hard rock is scarce or does not exist, resulting in substantial cost penalties on account of the haul distances involved in transporting materials to the work site.

The high-intensity seasonal rains and the diversity of soil types in the wet tropical regions of Australia pose particular problems to road and bridge construction engineers. Whilst you may well say that engineers should program their construction activities to take account of the wet and dry seasons, financial and political pressures invariably dictate otherwise and some construction activities, with the exception of major earthworks, often extend through the wet season.

This paper describes some of the road construction problems encountered and the trials undertaken using various applications of vetiver grass technology (VGT). Results of these trials have been

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Table 1. Chemical analysis of a typical wet tropical region of Australia

Analysis	Unit	Level
PH		7.3
EC	mS/cm	0.01
Cl	mg/kg	BQ
N03-N	mg/kg	BQ
P	mg/kg	4.0
Ca	meq/100g	1.4
Mg	meq/100g	2.2
Na	meq/100g	0.04
K	meq/100g	0.11

BQ = below quantification

encouraging and further work has been undertaken using vetiver hedges to protect recent road infrastructure projects in Far North Queensland with considerable success. Various applications of VGT will be discussed and this paper also provides a cost-benefit summary by comparing costs of VGT with those of traditional protection using concrete and rock structures.

Typical Road Embankment and Drainage Problems

Erosion of Cut Batters

Without protection the cut batters constructed in highly erodible soils would be easily eroded by high-intensity rainfall during the wet season. In many cases these soils are also deficient in nutrients, which makes stabilization by vegetative means very slow and difficult. The common method of stabilization by hydro-mulch treatment to these cut batters has not provided sufficient cover or root structure to protect the batters from erosion.

Erosion of Fill Batters

Steep (1:1) batters: If unprotected, fill batters are prone to erosion by high-intensity rainfall and runoff water from the road surface. This will eventually lead to damage to the road shoulders. The conventional concrete shoulder dykes are very costly and provide insufficient protection to the shoulders of the road built on this highly erodible soil. Attempts to stabilize the fill batters with hard rock protection have not been successful due to the undermining of the rock structure.

Steep batters at culverts: The steep slope above culverts is easily eroded. This often results in the road shoulder, culvert wing walls and culvert apron being undermined. Attempts to protect fill batters, batter chutes and culverts with traditional methods such as hard rock riprap are expensive and often fail due to undermining.

Gully Erosion Threatening Adjoining Road Works

Gully erosion on this road is very severe and if left unchecked, gully erosion will recess upstream and eventually undermine the adjoining road pavement.

Underground Piping

Any movement of water beneath the road pavement on this highly sodic soil will wash out fine soil particles, leaving voids which eventually collapse and cause the road to fail.

Results of Preliminary Trials

Cut and Fill Batter Protection

The initial planting of vetiver hedges on cut and fill batters was carried out in December 1998. Very good establishment of vetiver hedges was achieved five weeks after planting.

Vetiver hedges were almost 1 m high three months after planting and 1.5 m high five months after planting. The batters were successfully stabilized by vetiver hedges in April 1999, five months after planting. This is in sharp contrast to the control areas and those protected with hydro-mulching, which were badly eroded by the high-intensity storms during the wet season. In addition it was also noted that a single vetiver hedge planted on the edge of the road shoulder encouraged the establishment of natural vegetation down the steep fill batter.

Gully Erosion Control

In the gullies, establishment of vetiver contour hedges encouraged sheet flow with reduced velocity and the re-establishment of natural vegetation between the hedges.

Replacement and Substitution of Road Concrete Shoulder Dykes with Vetiver Hedges

The establishment of vetiver hedges on the edge of the road shoulder has also successfully replaced the traditional concrete road shoulder dykes. This allows controlled low-velocity flows down the batter to support natural batter re-vegetation but also directs large flows to concrete batter chutes. In addition, the dense hedges also trapped gravel moving from the new road surface, thus strengthening the road shoulders.

Application of Vetiver Contour Hedges in Wide Table Drains

When planting in short rows on contour lines along the table drains, vetiver hedges encourage low-velocity sheet flow, trap sediment and promote the re-establishment of natural vegetation between the hedges, which further reduces the risk of erosion. The conventional practice of constructing rock check dams in these table drains provides no protection against erosion in this highly erodible soil.

Vetiver Grass Used in Combination with Riprap Rock Protection and a Rock Check Dam

When planting around rock structures, vetiver hedges with their deep roots prevent these structures from being undermined. Vetiver was very effective in protecting riprap rock structures and a rock check dam in a narrow table drain.

Recent Road Construction Work

The success of the preliminary trial has led to further applications of VGT in erosion and sediment control on a new road in the same region.

On this new road, vetiver hedges were used for the stabilization of fill batters, including steep fill batters at culverts, and to protect culvert inlets. When planted at culvert inlets, vetiver hedges encourage sheet flow and reduce stream velocity to prevent erosion. When gabions were used to protect the upstream bank of culvert inlets, vetiver contour hedges were planted in the gabion backfill to prevent it from undercutting.

Vetiver hedges were also used to protect culvert outlets, which are often severely damaged by high-velocity flows. Vetiver contour hedges were also planted in the backfill to prevent undermining of the downstream gabions.

Cost Comparisons

Unit Rates

The unit rates given in this paper are expressed in Australian dollars (AUD). Also the unit rates are for road construction projects in remote areas of Northern Queensland some 300 to 400 km from the nearest main centre and therefore include significant transport costs.

Cut Batters

Vetiver contour hedges: Earth cut batters are generally constructed at a slope of 1:1. Cut batters are generally hard and require preparation in the form of 300-mm wide contour benches to facilitate the planting of vetiver and retention of water and fertilizer. These benches are machine-cut at an extra cost of AUD3.00 per metre, making the total cost of vetiver hedges on cut batters AUD18.40 per linear metre, which is equivalent to AUD21.40/m^2

Hay mulch treatment to cut batters: The alternative use of hay mulch at AUD1.60 per square metre on 1:1 or steeper batters rarely provides suitable cover for protecting these batters against erosion. For hay mulch to provide effective protection against erosion, it is necessary to flatten the batters to 1:2 or even flatter, depending on the nature of the soil. Flatter batters attract substantially increased earthwork costs, which negate any cost savings achieved.

Vetiver grass treatment *Note that all rates are given per linear meter on the basis of seven plants per linear meter*	Unit	AUD
Supply of vetiver planting material in tubes from main centre nurseries	m	8.50
Transport to site, plant, water and fertilize	m	7.00
Total for supply and planting vetiver hedges	m	15.50
Hay mulch treatment		
Supply mulch, spray and water	m^2	1.60
Hard rock treatment		
Dump rock	m^3	21.00
Selected riprap	m^3	65.00
Grouted rock pitching	m^2	66.00
Steel wire rock mattress	m^2	43.00
Rock check dam	m	42.00
Concrete structures		
Road shoulder dyke	m	38.00
Batter chute	m^2	70.00

Fill Batters

Vetiver contour hedges: Earth fill batters are generally constructed at 1:1 slopes and steeper over culverts. Machine benching of fill batters is not required and the cost of protecting fill batters does not exceed AUD 15.50 per linear metre**,** which is equivalent to AUD18.20/m^2.

Hay mulch treatment to fill batters: The alternative use of hay mulch treatment on fill batters does not provide adequate treatment unless the batters are constructed to 1-on-4 or flatter slopes.

Cost Summary

Road batter protection	AUD per linear metre	AUD/m^2 of batter face
Vetiver hedges on cut batters	18.40	21.40
Vetiver hedges on fill batters	15.50	18.20
Culvert protection		
Vetiver hedges	18.20	
Grouted rock pitching	65.75	
	Saving 73%	
Road shoulder protection		
Vetiver hedges	15.50	
Traditional concrete shoulder dykes	38.00	
	Saving 60%	
Table drain scour protection		
Vetiver contour hedges	15.50	
Traditional hard rock check dams	42.00	
	Saving 64%	
Miscellaneous protection work		
Vetiver hedges generally	15.50	
Steel wire rock mattress	43.00	
	Saving 64%	

Conclusion

The advantages of using vetiver hedges to protect road infrastructure works are summarized as follows:

- Vetiver hedges can be rapidly established in arid conditions and poor soils with little if any nutrients.
- Once established vetiver hedges are maintenance free and withstand arid and dry-season conditions, including bush fires.
- Provides protection to steep cuts and fill batters resulting in substantial savings in earthwork costs.
- Encourages sheet flow and reduced water runoff velocity resulting in natural vegetation re-growth and prevention of erosion.
- Eliminates undermining of hard rock structures.
- Effective alternative to hard rock check dams.
- Effective prevention of gully erosion.
- Very cost effective, with savings ranging from 73 % for culvert protection to 64 % for table drain and miscellaneous protection works and 60 % for road shoulder protection.
- In highly erodible soils, the most important advantage of vetiver technology over conventional structures is that rock structures themselves are not stable and constant maintenance is required to protect the road works, which will add to the overall operating costs of infrastructure in the long term.