BIOTECHNOLOGICAL METHOD

TO PREVENT EROSION

From

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ABSTRAK

Kaedah Bioteknikal merupakan satu pendekatan baru dalam kestabilan cerun dan mencegah hakisan permukaan dalam kejuruteraan geoteknik. Kaedah ini menggunakan elemen-elemen mekanikal dalam kombinasi bersama elemen-elemen biologi terutamanya tumbuhan hidup, untuk menstabilkan kegagalan cerun dan pencegahan hakisan permukaan. Kaedah yang diselidik disini penggunaan fiber kelapa dan kelapa sawit di samping bersama tumbuhan. Penyelidikan dijalankan untuk mengkaji setakat mana efektifnya kaedah ini. Setelah ujian rich terus dijalankan, didapati kaedah menggunakan fiber kelapa dan tumbuhan lalang adalah sangat efektif berbanding dengan kaedah lain. Fiber kelapa mempunyai ikatan yang kuat diantaranya dan apabila digunakan bersama tumbuhan lalang yang mempunyai akar tunjang dan serabut menambahkan ikatan fiber dengan tumbuhan dan juga sekaligus menambahkan kekuatan tanah dan menggurangkan kegagalan cerun berbanding keadaan tidak menggunakan fiber.

ABSTRACT

Biotechnology method is one of the applications in engineering methods where it was using the mechanical element and combination with biological element, mainly live staking plant for the reason of slope stability, soil stability and erosion control. The methods for research using here were coconut fiber and oil palm fiber with live staking plant. Research for study how effective these methods were done. The direct shear test give the results where coconut fiber is more effective compare with oil palm fiber. It has the highest fastening with the long coarse grass compare with grass where long coarse grass have strand root and straight root. The root will go through the fiber and inside the soil so the soil become more stabilize than before.

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CHAPTER 1

INTRODUCTION

1.1 PREFACE

Biotechnology method is one of the applications in engineering methods with live staking plant for the reason of slope stability, soil stability and erosion control. Using the plant as a method for erosion protection is a common phenomena and it was applied everywhere. Actually planting can be said is the best available method for erosion controls however we need something more effective, low budget and environmental friendly.

There is a rapid growth in the use of bioengineered soil erosion and sedimentation control designs especially in environmentally sensitive areas. Most of these designs incorporate coir (coconut fiber and palm fruit fiber) products to provide the required initial structural stability until the establishment of sustainable vegetation. Design criteria in these designs assume a certain rate of degradation in the coir products [1].

Coir (coconut fiber) and also palm fruit fiber usage has become very common among professionals in various industries due to its versatility [1]. In the horticultural industry, agricultural industry, or erosion control industry, coir has established a remarkable reputation for its superiority to other available natural materials. As for the palm fruit fiber, it is newly innovated and researches are still conducted on its implementation. Compared to the horticultural and agricultural industries, palm fruit fiber is relatively new to the erosion control industry and it may take some time for this industry to learn and understand about coir. Recognition of fiber in the erosion control industry has come from the fact that it is an abundant, renewable natural resource with an extremely low decomposition rate and a high strength compared to other natural fibers.

In traditional erosion control blanket applications, fiber blankets are well known for superior performance compared to other organic blankets. In most of these applications, long-term tensile strength in the blankets is not a critical design criterion. The rapid growth of environmentally concerned designers with their innovative bioengineering designs has increased coir use in the erosion control industry. These designs incorporate fiber products as structural components in the construction [1].

1.1.1 HISTORY OF THE BIOTECHNOLOGY METHOD

Biotechnology method was used since the 12 century in China. It is a 'brush layering' where they used to stabilize the slope. In early of 20 century, China uses the same method to prevent flood and erosion at along 'Yellow River' (Huanghe). In Europe, mostly in German the biotechnology method was used more than 150 years ago. They use it to prevent erosion along the river side, water channel and road side [2].

After the World War II there is a revolution in biotechnology method in Europe. This revolution had cause to replace the biotechnical method to the one which uses concrete and steel. A Lot problem arise by the implementation of the new method, such as the price for the material very high and a very high cost in the construction of the engineering structure had made lot make the biotechnology method return to use plant as a major source to prevent the erosion. Now after lot of research had been conducted, biotechnology is widely used in conjunction with engineering structure. This new method becomes one of the main solutions to prevent the erosion.

1.2 OBJECTIVE

In this thesis, I have set up few objectives so that I can present a good paper regarding the research that I conducted. The objectives of the project are:

- To study the biotechnology methods in soil erosion
- To study the effect of the fiber in soil
- To study and compare the magnitude of soil erosion before and after the implementation of fiber
- To compare the effectiveness of coconut fiber and palm fiber in soil

CHAPTER 2

LITERATURE REVIEW

2.1 SOIL EROSION

Soil erosion is one form of soil degradation along with soil compaction, low organic matter, and loss of soil structure, poor internal drainage, salinisation, and soil acidity problems. These other forms of soil degradation, serious in themselves, usually contribute to accelerated soil erosion.

Soil erosion is a naturally occurring process on all land. The agents of soil erosion are water and wind, each contributing a significant amount of soil loss each year in Ontario.

Soil erosion may be a slow process that continues relatively unnoticed, or it may occur at an alarming rate causing serious loss of topsoil. The loss of soil from farmland may be reflected in reduced crop production potential, lower surface water quality and damaged drainage networks [4].

2.2 TYPES OF SOIL EROSION AND EFFECTS

Basically wind and water are the main agents of soil erosion. The amount of soil they can carry away is influenced by two related factors, speed and plants cover [4].

2.2.1 EROSION BY WATER

The rate and magnitude of soil erosion by water is controlled by the following factors:

- **Rainfall Intensity and Runoff**

  Both rainfall and runoff factors must be considered in assessing a water erosion problem. The impact of raindrops on the soil surface can break down soil aggregates and disperse the aggregate material. Lighter aggregate materials such as very fine sand, silt, clay and organic matter can be easily removed by the raindrop splash and runoff water; greater raindrop energy or runoff amounts might be required to move the larger sand and gravel particles. Soil movement by rainfall (raindrop splash) is usually greatest and most noticeable during short-duration, high-intensity thunderstorms.

- **Soil Erodibility**

  Soil erodibility is an estimate of the ability of soils to resist erosion, based on the physical characteristics of each soil. Generally, soils with faster infiltration rates, higher levels of organic matter and improved soil structure have a greater resistance to erosion. Sand, sandy loam and loam textured soils tend to be less erodible than silt, very fine sand, and certain clay textured soils. Tillage and cropping practices which lower soil organic matter levels, cause poor soil structure, and result of compacted contribute to increases in soil erodibility. Many exposed subsurface soils on eroded sites tend to be more erodible than the original soils were, because of their poorer structure and lower organic matter.

- **Slope Gradient and Length**

Naturally, the steeper the slope of a field, the greater the amount of soil loss from e erosion by water. Soil erosion by water also increases as the slope length increases due to the greater accumulation of runoff. Consolidation of small fields into larger ones often results in longer slope lengths with increased erosion potential, due to increased velocity of water which permits a greater degree of scouring (carrying capacity for sediment).

- **Vegetation**

Soil erosion potential is increased if the soil has no or very little vegetative cover of plants and/or crop residues. Plant and residue cover protects the soil from raindrop impact and splash, tends to slow down the movement of surface runoff and allows excess surface water to infiltrate. The effectiveness of any crop, management system or protective cover also depends on how much protection is available at various periods during the year, relative to the amount of erosive rainfall that falls during these periods.

2.2.2 EFFECTS OF WATER EROSION [4]

- **Sheet and Rill Erosion**

Sheet erosion is soil movement from raindrop splash resulting in the breakdown of soil surface structure and surface runoff; it occurs rather uniformly over the slope and may go unnoticed until most of the productive topsoil has been lost. Rill erosion results when surface runoff concentrates forming small yet well-defined channels (Figure 2.1). These channels are called rills when they are small enough to not interfere with field machinery operations. The same eroded channels are known as gullies when they become a nuisance factor in normal tillage.

Figure 2.1: Both sheet and rill erosion

- **Gully Erosion**

There are farms in Ontario that are losing large quantities of topsoil and subsoil each year due to fully erosion (Figure 2.2). Surface runoff, causing gull formation or the enlarging of existing gullies, is usually the result of improper outlet design for local surface and subsurface drainage systems. The soil instability of fully banks, usually associated with seepage of ground water, leads to sloughing and slumping (caving-in) of bank slopes.

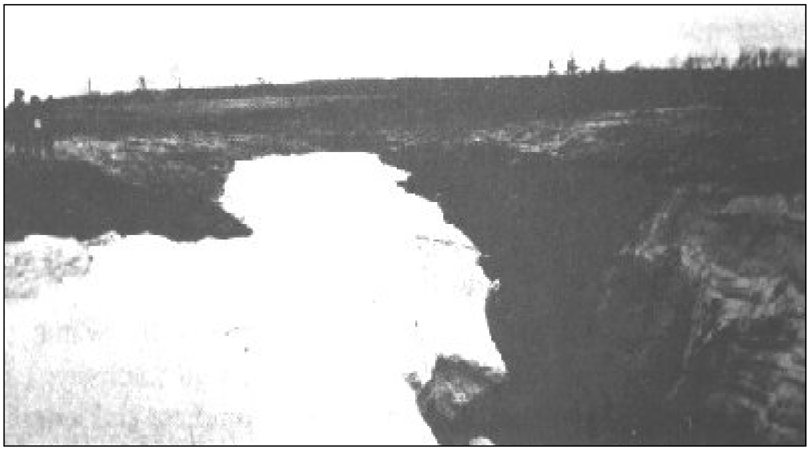

Figure 2.2: Gullying erosion

- **Stream and Ditch Bank Erosion**

Poor construction, or inadequate maintenance, of surface drainage systems, uncontrolled livestock access, and cropping too close to both stream banks has led to bank erosion problems.

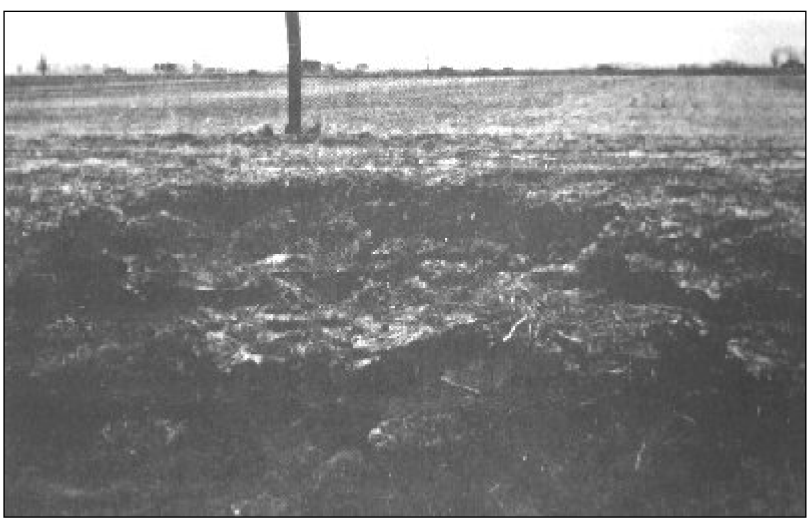

Figure 2.3: Stream and Ditch Bank erosion

- **On-Site Effects**

The implications of soil erosion extend beyond the removal of valuable topsoil. Crop emergence, growth and yield are directly affected through the loss of natural nutrients and applied fertilizers with the soil. Seeds and plants can be disturbed or completely removed from the eroded site. Organic matter from the soil, residues and any applied manure is relatively light-weight and can be readily transported off the field, particularly during spring thaw conditions. Pesticides may also be carried off the site with the eroded soil. Soil quality, structure, stability and texture can be affected by the loss of soil. The breakdown of aggregates and the removal of smaller particles or entire layers of soil or organic matter can weaken the structure and even change the texture. Textural changes can in turn affect the water-holding capacity of the soil, making it more susceptible to extreme condition such a drought.

- **Off-Site Effects**

Off-site impacts of soil erosion are not always as apparent as the on-site effects. Eroded soil, deposited down slope can inhibit or delay the emergence of seeds, bury small seedling and necessitate replanting in the affected areas. Sediment can be deposited on down slope properties and can contribute to road damage. Sediment which reaches streams or watercourses can accelerate ban erosion, clog drainage ditches and stream channels, silt in reservoirs, cover fish spawning grounds and reduce downstream water quality. Pesticides and fertilizers, frequently transported along with the eroding soil can contaminate or pollute downstream water sources and recreational areas.

2.2.3 EROSION BY WIND

The rate and magnitude of soil erosion by wind is controlled by the following factors:

- **Erodibility of Soil**

Very fine particles can be suspended by the wind and then transported great can be blown along the surface (commonly known as the saltation effect). The abrasion that results can reduce soil particle size and further increase the soil erodibility.

- **Soil Surface Roughness**

Soil surfaces that are not rough or ridged offer little resistance to the wind. However, over time, ridges can be filled in and the roughness broken down by abrasion to produce a smoother surface susceptible to the wind. Excess tillage can contribute to soil structure breakdown and increased erosion.

- **Climate**

The speed and duration of the wind have direct relationship to the extent of soil erosion. Soil moisture levels can be very low at the surface of excessively drained soils or during periods of drought, thus releasing the particles for transport by wind. This effect also occurs in freeze drying of the surface during winter months.

- **Vegetative Cover**

The lack of permanent vegetation cover in certain locations has resulted in extensive erosion by wind. Loose, dry, bare soil is the most susceptible, however, crops that produce low levels of residue also may not provide enough resistance. As well, crops that produce a lot of residue also may not protect the soil in severe cases. The most effective vegetative cover for protection should include an adequate network of living windbreaks combined with good tillage, residue management, and crop selection.

2.2.4 EFFECTS OF WIND EROSION

Wind erosion may create adverse operating conditions in the field. Crops can be totally ruined so that costly delay and reseeding is necessary - or the plants may be sandblasted and set back with a resulting decrease in yield, loss of quality, and market value (Figure 4).

2.3 THE IMPORTANCE OF PLANTS ON SOIL

Plants provide protective cover on the land and prevent soil erosion for the following reasons [3]:

- Plants slow down water as it flows over the land (runoff) and this allows much of the rain to soak into the ground;
- Plant roots hold the soil in position and prevent it from being washed away;
- Plants break the impact of a raindrop before it hits the soil, thus reducing its ability to erode;
- Plants in wetlands and on the banks of rivers are of particular importance as they slow down the flow of the water and their roots bind the soil, thus preventing erosion.

The loss of protective vegetation through deforestation, over-grazing, and fire make soil vulnerable to being swept away by wind and water. In addition, over-cultivation and compaction cause the soil to lose its structure and cohesion and it becomes more easily eroded. Erosion will remove the top-soil first. Once this nutrient-rich layer of soil is gone, few plants will grow in the soil again. Without soil and plants the land becomes desert-like and unable to support life - this process is called desertification. It is very difficult and often impossible to restore decertified land.

2.4 PREVENTION OF SOIL EROSION

Preventing soil erosion requires political, economic and technical changes. Political and economic changes need to address the distribution of land in South Africa as well as the possibility of incentives to encourage farmers to manage their land sustainable. Aspects of technical changes include [3]:

- The use of contour plugging and wind breaks;
- Leaving unplugged grass strips between ploughed land;
- Making sure that there are always plants growing on the soil, and that the soil is rich in humus (decaying plant and animal remains). This organic matter is the "glue" that binds the soil particles together and plays an important part in preventing erosion;
- Avoiding overgrazing and the over-use of crop lands
- Allowing indigenous plants to grow along the river banks instead of plugging and planting crops right up to the water's edge

- Encouraging biological diversity by planting several different types of plants together.
- Apply biotechnical method in which uses plants and fiber together

The biotechnical method is widely implemented on erosion control regarding its effectiveness in control of soil erosion and also economic compared to the other methods that available.

2.5 BIOTECHNICAL METHOD FOR EROSION CONTROL

Erosion and slope failure are the two phenomenons which occur simultaneously. Normally, lose or soil movement on the surface of the slope will lead to the increment in erosion rate and also slope failure. This clearly shows the close relationship between erosion and slope failure. Thus, erosion deterrent method and slope stabilization are very much in needed. [2]

Basically, biotechnical method consists of two main functions, first is erosion control and the second is slope stabilization. This method involves in the cultivation of plants together with the engineering structure on the surface of particular slope area. This shows that plants are playing important role in the process of erosion control while the engineering structure contribute to the slope stabilization. Theoretically, this clearly shows the effectiveness of this biotechnical method as a good erosion control method.

This method is suitable to use because, we can cultivate different type of plant on different soil surface slope according to the suitability. There are different kinds of soil available and soil is the most suitable medium for the plant cultivation. Moreover it can supply and provide the basic needs such as water, nutrient and air to for the growth of plants. Thus, it encourages the usage of this biotechnical method.[8]

Nowadays there are lots of biotechnical methods have been developed successfully. This of biotechnical method can be categorized according to its implementation. There are three major categories.

i. Biotechnical method using plants with light stiff material
ii. Biotechnical method using plants with engineering structure
iii. Biotechnical method using soil cover

Each category posses different characteristics and functions but in overall, all these methods serve as an erosion and soil stability (slope) control methods.

2.6 ADVANTAGES OF BIOTECHNICAL METHOD

The implementation of the biotechnical method will provide us with lots of advantages. Mean while, the performance of this biotechnical method very much depends upon on the characteristics of the plants because plants are playing important role in this method. The advantages of this methods are [2] :

i. Plants are used as major soil cover

ii. The strong bond between the root of plants and soil

iii. More efficient and economic

iv. Easy to implement and conduct

2.7 TYPES OF BIOTECHNICAL METHOD [2]

2.7.1 BIOTECHNICAL METHOD USING LIGHT STIFF MATERIAL

This method involves plants with light dead material also known as bio-engineering method. This method usually use light dead material such as geosynthectic with plants. The purpose of this method is to stabilize the soil in terms of slope stabilization and soil erosion. It can control the erosion on shallow soil surface effectively mean while it also serves as detention structure on the slope. The plants are cultivated in particular design of arrangements. The techniques available for this biotechnical method are:

i. *Live Staking*

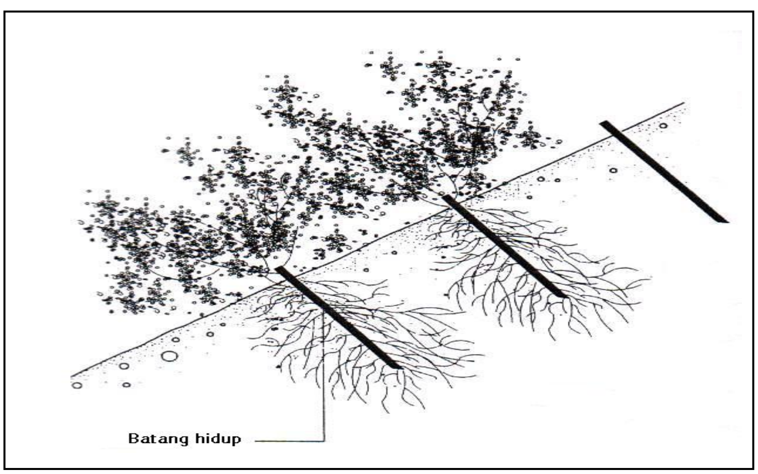

Figure 2.4: Diagram '*Live Staking*' (Gray, 1990)

ii. Live Fascine

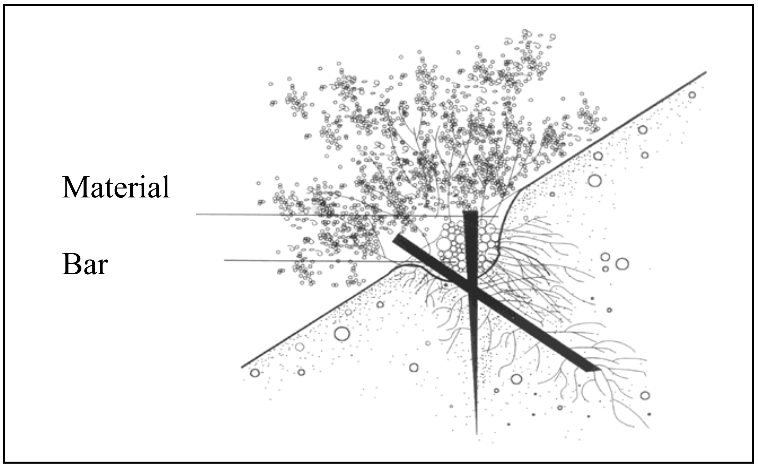

Figure 2.5: Diagram '*Live Fascine*' (Gray, 1990)

iii. Brushlayering

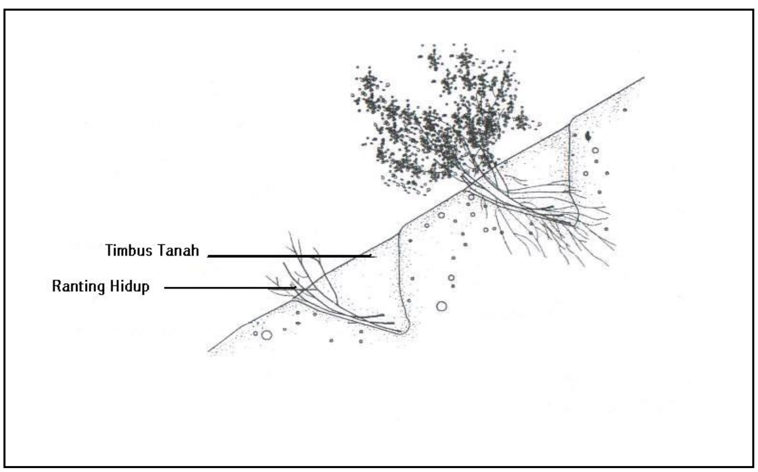

Figure 2.6: Diagram '*brushlayering*' (Gray, 1990)

iv. Vegetated Geogrids

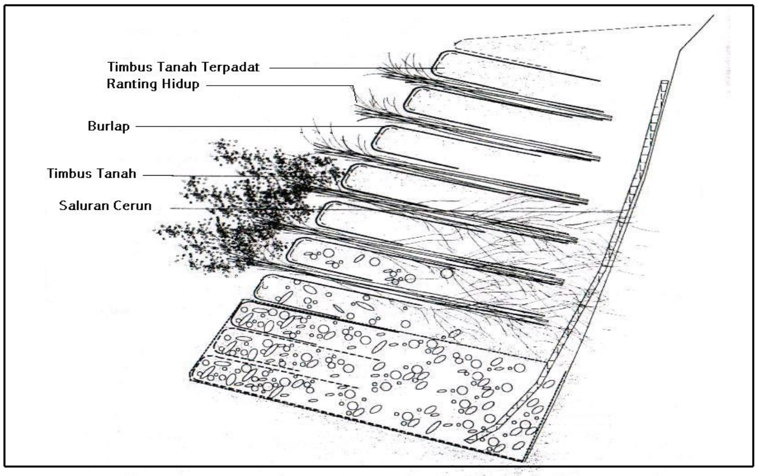

Figure 2.7: Diagram '*Vegetated Geogrids*' (Gray, 1990)

vi. Branchpacking

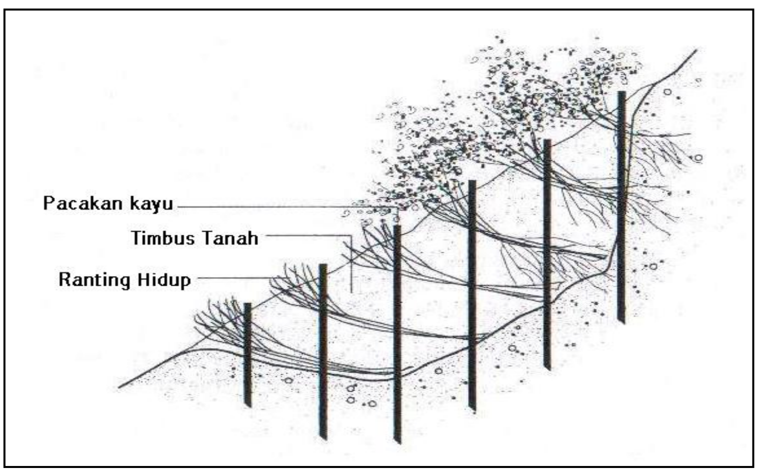

Figure 2.8: Diagram '*branchpacking*' (Gray, 1990)

v. Live Slope Grating

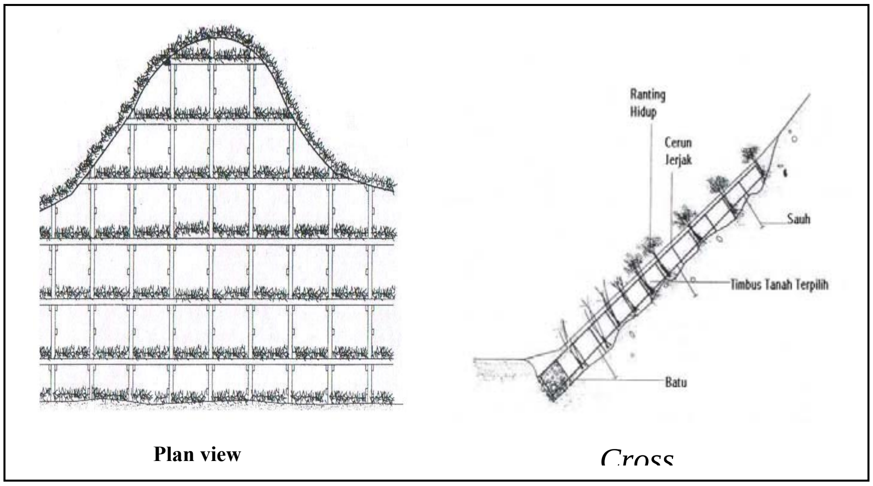

Figure 2.9: Diagram '*Live Slope Grating*' (Gray, 1990)

2.7.2 BIOTECHNICAL SOIL COVER

This method is the best effective method to control the soil erosion. Normally soil surface at slope easily expose to the soil erosion compared to the flatten soil. In this method, escarpment of hill is cuts into storey of terrace and the soil is covered with the soil cover material. Normally channel for water is provided through the escarpment.

Cement and concrete, and plants can be used as soil cover material. Other than that dead substance such as geosynthetic material also used in conjunction with plants are also used as a soil cover in escarpment. Soil cover with the plants can effectively control the erosion compared to the semen and concrete because the concrete easily affected by the corrosion process. Figure 2.10 below show the use of plants as a soil cover material in escarpments.

Figure 2.10: Usage of plants as a soil cover material on the surface of escarpments

Grass and herbs is the most suitable plants that can be used as soil cover material. This because the growths of those plants are much faster compared to the plants such as tree.

The soil cover can protect the soil particle surface from the bash of rain falls and also reduce the velocity of the water flow on the surface. More over the roots of plant can make a strong bonding with the soil so that it does prevent the movements of soil particle. The strong bonding can prevent the soil particle movements even thought if there is water flow in the soil. Other than preventing water erosion, this method also can be implemented to control the wind erosion. With plantation the layer of plants, it can reduce the wind velocity, thus can control the wind erosion.

2.7.3 BIOTECHNICAL SOIL WITH COCONUT AND OIL PALM FIBER

The idea of using coconut fibers as reinforcement in composite materials is not a new or recent one. Man had used this idea for a long time, since the beginning of our civilization when grass and straw were used to reinforce mud bricks. In the past, composites, such as cellulose fibers, were extensively used by the automotive industry. However, during the seventies and eighties, coconut fibers were gradually substituted by newly developed synthetic fibers because of better performance. Since then, the use of coconut fibers has been limited to the production of rope, string, clothing, carpets and other decorative products. Over the past few years, there has been a renewed interest in using these fibers as reinforcement materials.

Oil palm fiber is a non-hazardous biodegradable material extracted from oil palm's vascular bundles in the empty fruit bunch (EFB) through a patented decortation process. The fibers are clean, non-carcinogenic, free from pesticides and almost free from soft parenchyma cells. It conforms to the Malaysian MS 1408:1997 (P) specifications for EFB fiber. Palm fibers are versatile and stable; it can be processed into various dimensional grades to suit specific applications such as mattress and cushion production, erosion control, soil stabilization/compaction, landscaping and horticulture, ceramic and brick manufacturing, thermoplastic filler, flat board manufacturing, paper production, acoustics control, livestock care, compost, fertilizer, animal feed, and many others [5].

Even though oil palm fibers playing an important role in erosion control but it is still undergo some research to proof the true quality in erosion control and also for slope stability. Figure 2.11and 2.12 shows the oil palm fiber and also coconut fiber

Figure 2.11: Oil palm fiber

Figure 2.12: Coconut Fiber

In this method, the plantation of grass is done on top of the fiber which is layered on the soil. The method can strengthen the bonding between the plant and soil. The implementation of the layer of fiber in between the plant and soil can improve the soil cover structure thus the wind erosion and also water erosion could be minimize to a very low level.

Out of all the biotechnical methods, biotechnical soil cover with fiber method shows a very good result in controlling the erosion.

2.8 TYPE OF PLANTS [6]

According from Malaysia Latex Research Institute, there are 185 type of grass found in Malaysia were recorded and where most of the type are used as soil cover for erosion control and stability. It is because of the weather in our country where there are only two season only compare to the other country where there are four season. Its make most of the grass type are suitable for soil cover. The most used type of grass for soil cover

- *Axonopus compressus*
- *Brachiaria mutica*
- *Chrysopogon aciculatus*
- *Coix lacryma*
- *Cynodon dactylon*
- *Dactyloctenium aegyptium*
- *Dichanthium annulatum*
- *Echinochloa crus*
- *Eleusine indica*
- *Imperata cylindrica*
- *Ischaemum indicum*
- *Ischaemum magnum*
- *Leersia hexandra*
- *Panicum repens*
- *Pennisetum purpureum*
- *Phragmites karka*
- *Saccharum spontaneum*
- *Tripsacum laxum*
- *Vetiveria zizanioides*

In this study, I'm using *Agropyron cristatum* (roadside grass) and also Bromus inermis (long coarse grass) as soil cover plants. [7]

CHAPTER 3

METHODOLOGY

3.1 THEORY

The barricade for shear soil causes from friction between the items and the hold and handle condition. The shear strength **s** is the shear stress which needed to cause the gliding up to a surface of soil, or

$$s = \sigma \tan \text{Ø}, \quad (3.1)$$

$$\textit{Normal stress} = \text{Ø} \quad (3.2)$$

$$\textit{Shear barricade angle} = \sigma \quad (3.3)$$

In this direct shear test, soil imposes a stress until the soil is fail with moving a part of former soil link with another part of soil. When a shear force with an enough magnitude which had impose, the below part of the box move with upper part and it will cause the soil shear happen in a long a horizontal way which can detach both of the box.

Direct shear test is simple and faster to operate. As thinner specimens are used in shear box, they facilitate drainage of pore water from a saturated sample in less time. This test is also useful to study friction between two materials – one material in lower half of box and another material in the upper half of box.

The angle of shearing resistance of sands depends on state of compaction, coarseness of grains, particle shape and roughness of grain surface and grading. It varies between 28^o (uniformly graded sands with round grains in very loose state) to 46^o (well graded sand with angular grains in dense state). The volume change in sandy soil is a complex phenomenon depending on gradation, particle shape, state and type of packing, orientation of principal planes, principal stress ratio, stress history, magnitude of minor principal stress, type of apparatus, test procedure, method of preparing specimen etc.

In general loose sands expand and dense sands contract in volume on shearing. There is a void ratio at which either expansion contraction in volume takes place. This void ratio is called critical void ratio. Expansion or contraction can be inferred from the movement of vertical dial gauge during shearing. The friction between sand particles is due to sliding and rolling friction and interlocking action.

The ultimate values of shear parameter for both loose sand and dense sand approximately attain the same value so, if angle of friction value is calculated at ultimate stage, slight disturbance in density during sampling and preparation of test specimens will not have much effect.