Paper

Application of Biotechnology and Cost Effective Eco Friendly Solutions to Prevent Unwarranted Slope Failures by Using Vetiver Grass, Geosynthetic Cover and Plate Piles

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Abstract

The use of biotechnology in slope engineering has been long forgotten. In early days of slope engineering tree planting were part of slope protection and stability enhancement works. However, over the last decade close turfing, hydroseeding and geosynthethic erosion control cover were used for slope protection works without emphasising the need of tree planting. These surface cover only perform well under short term condition but fails under long term condition due to (a) continuous saturation of surface cover; (b) over grown bushes prevents or minimize surface runoff and increases the infiltration into soil, by reducing surface runoff coefficient; (c) inadequate root anchorage into slope; (d) lost of soil matrix suction due to reduce surface runoff and (e) irregular geological formation and relic joints during slope cutting works. Listed above are some of potential causes of unwarranted slope failure. In many cases the unwarranted slope failures cause thousands of Ringgit to rectify. This paper discusses few simplified approach using biotechnology and 'do it yourself' methods to prevent and repair unwarranted slope failure.

Keywords

Vetiver grass, Plate piles, Relic joints, Unwarranted slope failure, Matrix suction.

1.0 Introduction

Slope engineering construction and works related to long term maintenance and slopes requires to take into consideration various factors to prevent unwarranted failures which will be expensive to repair. Unwarranted slope failures occurs mainly due to poor maintenance, lack of surface cover, infiltration of rainfall, geological features such as daylighting effects, geological relict joints, poorly engineered slope such as planning, maintenance, design and construction works.

The listed potential causes can be prevented with minor enhancement to quality control works and maintenance program which can be implemented periodically. There are many reasons for landslide to occur, some of major factors that causes landslides and slope failures are due to heavy prolong rainfall with uncontrolled surface runoff, geomorphological factors such as seepage and poor drainage system, geological and geotechnical factors, hydrological factors, climatic factors, human activity and vegetation cover. Other landslide trigerring and contributory factors are as reported by Kwong et al. (2004) as described in Table 1.

The following are the slope design stages and fundamental factors that required to be reconsidered;

- Development and planning stage
- Design stage
- Construction stage
- Maintenance stage

a) Planning stage
Slope designation in any construction project should consider the development planning as listed below in Figure 1. The development planning stages comprises of primary and secondary feasibility consideration to be approved. Primary consideration shall be the possible lost of life, building and facilities damage, losses of properties and economically and environmental protection. The secondary consideration required minimum F.O.S. (factors of safety), verified design practice, geological evaluation of natural terrain and maximum cut, fill height and angle of the slope. When both consideration is feasible, the approval committee should restrict the cutting slope within development lot which could affect the neighboring lot stability. This is also considering the monitor of ground water flow to identify the natural artesian and consider the impact of social, economy and lost of life factors as well.

Table 1: Landslide triggering and contributory factor, modified from Kwong et al (2004).

Landslide trigerring factors
- Rainfall intensity and rise in groundwater level - Adverse construction and human activity - Deterioration and erosion of surface - Bursting and leakage of buried water services - River erosion and flooding contributory factors - Adverse geological conditions -Substandard and inadequate site investigation works -Inadequate design practise -Poor constrruction works -Adverse topogrpahy condition -Inadequate maintenance works

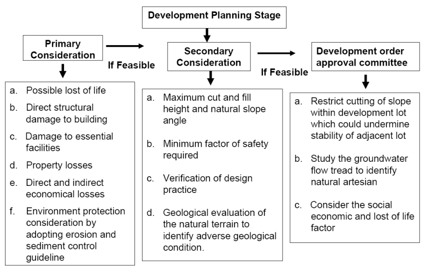


Figure 1: Factor to be considered for slope design during development planning stage

b) Design stage
Any designation should highlighted slope stabilization works, estimate the total risk and loss framework, able to perform and improved along with codes practise, experiences and findings. The design should implement the site investigation works with quality and reliable laboratory works. The design should be able to sustain triggering and contributory factors of landslides such as high rainfall intensity, rise in groundwater level, adverse construction, human activity, surface erosion, adverse geological conditions, inadequate design practice and poor construction works. Rainfall intensity must no be taken lightly since this can highly contribute to the failure of the slope. The primary warning system based on rainfall intensity to be incorporate during design stage by identifying areas with heavy rainfall, population density and number of hazardous slope. The key consideration factors for design are simplified in Figure 2.

c) Construction stage
During construction stage, primary identification on the subsurface condition includes the soil type, ground water level, geological formations and boundaries, soil weathering profile and additional site investigation works. The quality record

keeping must be on site modification by quality control exercise, manufactures quality control records and site photography archive. The filling must be done according to specified density inspection. Open cut or fill slopes need to be protected against the erosion. This activity must perform quality ground stabilization works to suit site condition. The environment protection must be implement for bare slope formation by prepare sufficient silt traps, following the guide on development environmental protection regulations and MASMA guideline as shown in Figure 3.

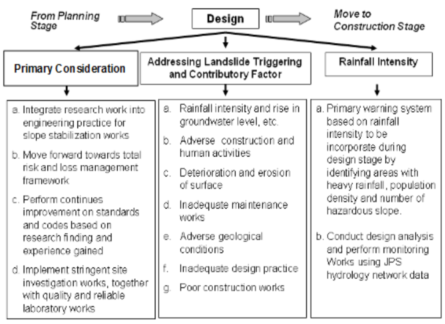


Figure 2: Factors to be considered during design stage

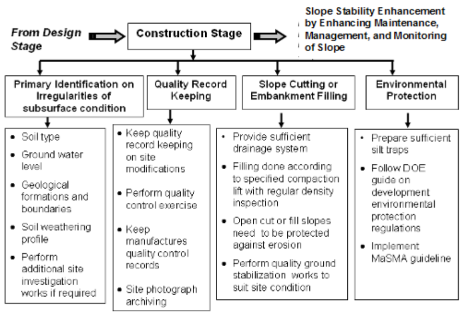


Figure 3: Factors to be considered during construction stage

d) Maintenance stage

The additional slope stability maintenance and enhancement aspect (Figure 4) should be consider are registration of the slopes, establish the landslide early warning system, create slope management solutions, providing education to the residents regarding proper registration, maintenance of slopes reporting potential landslides and creates a feed back center from the residents on deteriorating slope for the local authorities to take immediate action.

2.1 Application of vetiver grass in slope stabilization

The use of conventional technique to retain the slope has been an interest for engineers for many years. The application of engineering in tandem with bio-engineering is proven to be more cost effective and effective approach. Root reinforced soil has a greater shear strength compared to soil only (Nordin et al., 2011). However, not all vegtation can be used for slope engineering. The vegetation required to have deep penetration roots with high root tensile strength. Among the plants vetiver grass proven to be much reliale and durable.

The vetiver grass is low cost, biotechnology employing vetiver plant for soil and water conservation and environment protection works. The system is very practical, low maintenance, and effective to control soil erosion, sediment mobilization, water conservation, land stabilization and rehabilition which are environmentally friendly. Root properties of vetiver grass can help to reduce soil erosion and strengthen slope stability when planted effectively. Grimshaw (1994) and Yoon (1994) have emphasis the early developing deeply penetrating (sometimes up to 3.5m fibrous root system of vetiver and its capability of anchoring themselves firmly into slope soil profiles).

The physical properties of vetiver grass is made of massive, finely strutured taproot system with fast growing capability up to 2-4m deep.Vetiver has stiff and upright stem, high tolerance of relatively deep water and can grow into dense hedges. The new shoots of vetiver can emerge from base while the new roots of vetiver will develop from nodes. The top growth of vetiver can grow up to 95cm to 160 cm(37"-63") after six months per tillering rate of 18-30 tillers per plant. Vetiver grass has a high tolerance to extreme climate variation, range from prolonged drought, flood, submergence to extreme temperatures (-15° C to 60° C). The effective vetiver hedges have been established with annual precipitation levels as low as 300mm and with up to 6 month drought. Truong and Baker (1998) has mentioned the high tolerance of heavy metal bearing soil (As, Cd, Cr, Ni, Pb, Hg, Se and Zn). Regarding to Figure 5, vetiver hegdegrows strengthen the surficial layer of 1-4m which is prone to slippage. The root itself strengthen the upper weak soil layer. The new composite of soil-root will creates higher properties of soil. The taproot of vetiver grass acts as a 'living soil nail'.

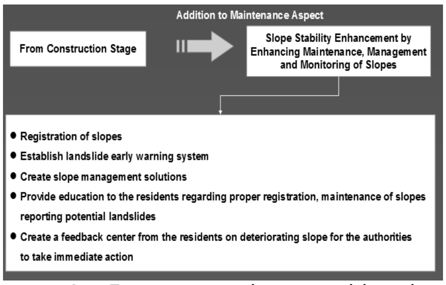


Figure 4: Factors to be considered during maintenance stage

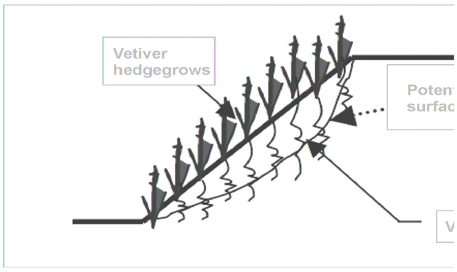


Figure 5: Vetiver grass for slope stabilization mechanism

3.0 Application of plate piles in slope stabilization

Relict joint is a result of expansion in soil due to weathering cycle of hot and cool condition. The pressure is relief when overlying rocks are removed by excavation or slope formation (Figure 6). This will form a free space for water to enter, thus reducing the interface cohesion and friction within joint set. Hence, the shear strength along the relic joint will reduce with the time as well.

The relict joint will facilitate the rainfall infiltration and accelerate the lost of matric suction due to the development of positive pore water pressure. Thus, the slope with relict joint will have a rapidly reduced F.O.S. (factor of safety) as compared to a stabilized slope. Failure could occur through the weak plane of relict joint which are adversely oriented with respect to the topography of the slope in order to reduce or prevent failures related to relict joints. The relict joint zones will are proposed to be strengthen using plate piles. The pile plate forms a barrier where the soil arches between the plates and limits downslope movement. The plate itself are driven into the slope by using small vibratory hammer to a depth about 24 inches below the slope surface to ensure the plate pile is not visible when the installation is completed (Figure 7).

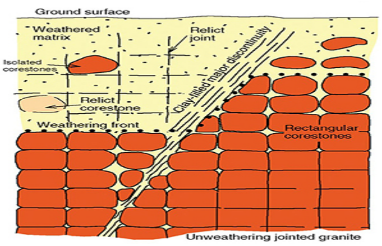
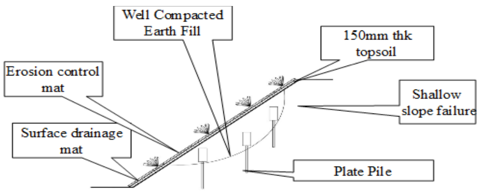


Figure 6:



Schematic of relict joint feature in the slope

Figure 7: The application of erosion control mat and surface drainage mat together (optional) with plate piles installation

4.0 Conclusion

The use of biotechnology and solve environmental friendly solutions can be used to slove unwarranted slope failures. The adoption of these ecofriendly method requires awareness among engineers and developers. The cost of repair for unwarranted slope failures can be reduced. However it is best to work on failure prevention from early stages of development or construction works.

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