The Application of Hydro Mulching Material for Ecological Rehabilitation of Rockfill Slope in Hong Kong

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Abstract

Rockfill material has been used by many practicing engineers for the design of slope to minimize the risk of landslides in Hong Kong. The use of rockfill slope such as gabion wall will not only affect the aesthetic appearance of the environment but also limit the growth of natural vegetation as well as the survival of the surrounding habitants.

In recent years, ecological rehabilitation of man made slope has become a major concern in Hong Kong due to the implementation of government's green policies since 1990s. Hydro mulching is one of the most common methods for establishing green covers on non-soil surface slope. The construction method provides environmental friendly visual appearance for the slope, improve air quality, minimize sunlight reflection, serve as noise and moist absorbing agent and reduce the temperature around the slope area.

The objective of this paper is to evaluate the merits of Hydro Mulching techniques for the sustainability of rockfill slope in Hong Kong. The concept of Hydro Mulching is discussed in details with special references made to the construction industry. A case study on the application of hydro-mulching technique for the restoration of rockfill slope is highlighted.

Keywords

Rockfill slope, slope greening, ecological rehabilitation, hydro-mulching, environment friendly, Hong Kong

1. Introduction

Hong Kong is situated in an area with hilly terrain and the majority of the land is derived from the excavation of slope for the construction of residential and economical building. As much of the developed land is situated in slope area subject to large amount of rainfall in the summer, the stability of these slopes is a major concern.

The establishment of rock fill slope can enhance the stability of slope and at the same time reduce the risk of landslides. Although the construction of rockfill slope is a viable method of slope construction to minimize the slope failure, vegetation however cannot be grown on this type of surface due to insufficient nutrients within the geological materials. Environmental and ecological problems created by these types of slopes have become a great concern. Greening on man-made slopes not only will enhance the aesthetics of our environment, but also can serve the purpose of erosion control and slope stabilization. Technical guidelines were developed (GEO, 1984) by the government for the use of vegetations for slope surface protection.

The enhancement of aesthetics and ecological rehabilitation of man-made slopes has become a public concern and one of the key elements of Hong Kong government's policies since late 1990s. Under the Landslip Preventive Measures Programme, the appearances of 470 government-owned slopes have been improved by covering with green vegetation in the past three years (HKSAR, 2002).

As the nature of rockfill slope is limited on the growth of vegetation, this paper intends to introduce Hydro Mulching Material for rehabilitation of rockfill slope in Hong Kong. The study will include a case study to illustrate its advantages and the performance of Hydro Mulching techniques.

2. Merits of Green Sloping

The use of convention rockfill slope will not only affect the aesthetic appearance of the environment but also limit the growth of vegetation as well as the survival of the surrounding habitants. However, the application of green vegetation for slope coverage provides an environmental pleasing visual appearance, improve air quality, minimize sunlight reflection, serve as noise absorbing agent, and reduce the temperature around the area. A set of guideline was stipulated in the GEO government publication (Wong et. al., 1999) for the application of vegetation for cut slope. The greening of the slope provides a nice outlook and improves the environment with harmonious atmosphere. The improvement is the environment that helps to soothe the emotion of the residents and enhance the recovery pace during therapy.

A site with green vegetation can improve air quality during the process of photosynthesis, as vegetation will absorb toxic gas like carbon dioxide, and release oxygen. This greatly increases the air quality of the surrounding. If the slope is located

near the residential buildings, the improvement in air quality provides a healthy living and therapy environment for the residents.

Furthermore, a site with green slope has the capability of minimizing the Sunlight Reflection and can improve the scenery of nearby residential areas. It is believed that green color can help to release the emotion of people, thus, by having green slope scene, the tension (or pressure) of the residents facing slope can be eased.

In order to optimize the land use and minimize the disturbance caused to the adjacent area, the traditional methods such as hydro-seeding or hydro-seeding with erosion control mat has its problems in establishing healthy and full vegetation covers on steeper slopes. For example, slope gradient greater than 60°, Geotechnical Engineering Office (GEO) of the Civil Engineering Department HKSAR suggested proprietary products to be used for slope greening (Chan, 2002).

Organic hydro-mulching technique is a newly designed vegetation system with innovative construction concept to take account of different kinds of shrub species on the slope. The time of construction is only a few months and then vegetation can be successfully applied on slope. Other merits include the noise and moist absorbing and reduction of temperature around the area, and most important this technique may applied to steeper slope.

3. The Mechanism of Geological Material and Vegetation Interaction

The removal of slope vegetation can often increase the rate of soil erosion and reduces the factor of safety of a slope. Bioengineering which incorporates geotechnical engineering and ecology offers a viable solution for the protection of water and soil resources against losses and erosion in slope area (Sotir and Christopher, 2003). An integrated hydrology and slope stability model can be used to evaluate the stability of a slope. If vegetation in a slope is well established, then it can provide a canopy to intercept the rainfall so as to prevent slope detachment and movement. Furthermore, substantial lowering of water table by the suction of root uptake through evaporation-transpiration could also reduce the risk of slope failure.

The Richards' equation has been adopted by scientist and engineer as an algorithm to solve infiltration and soil water transport problems for unsaturated zone. This equation is used to predict the water movement based on unsaturated geological material behavior. This equation is actually a combination of the Darcy's law and the continuity equation:

$$\frac{\partial \theta}{\partial t} = \frac{\partial}{\partial z} K(h)\left[\frac{\partial h}{\partial z} + 1\right]$$

where

K = the hydraulic conductivity (m/day)
h = the pressure (matric) potential (m)
θ = the volumetric water content (m^3/m^3)
z = the gravitational potential in (m)
t = time (day)

By considering precipitation and potential evapo-transpiration rate as the upper boundary condition, actual transpiration is limited by the rate of water uptake by plant root. Plants are main carriers of water incorporating root uptake capability in regulating the moisture-root-plant-air system. The vegetation parameters included plant height, rooting depth and leaf area index. The parameters are permeability, suction characteristic of geological material and others.

4. Climatic & Vegetation Boundary Conditions for Unsaturated zone Modeling

Effective precipitation is defined as the difference between the measured rainfall and the computed interception. As surface runoff increases in low permeability soils during high intensity rainstorms in summer monsoon season, water will stay on the ground surface when rainfall intensity is greater than the capacity of the soil for absorbing water.

Potential evapo-transpiration is the upper boundary condition in the simulation of water content redistribution in soils. Although the rainfall data show much variability, the use of the average daily rainfall can usually be used in the simulation.

Vegetation also plays an important role in affecting the Leaf area index which is a parameter to evaluate the potential soil evaporation and potential transpiration. Many simulation model such as SWATRE (Belmans et. al. 1983) up to recent developed CHASM (Wilkinson et. al. 2000) model have been used successfully to simulate the water movement within geological materials through the plant roots.

The modeling of the plant characteristics can be performed through the input of vegetation coefficients including plant height and root depth. Others include leaf area index value which is function of the soil surface covered by plants. Generally, a polynomial equation can adequately predict the leaf area index of the vegetation based on soil cover as variable.

5. The Application of Organic Hydro-mulching Technique in Hong Kong

In Hong Kong, natural topsoil on man-made slopes is usually inadequate or their qualities of nutrient and humus contents are not suitable for root development of plant.

Therefore, application of mulch/soil mix is necessary for establishing healthy vegetation covers. The major difference between these mulching systems and the other proprietary products is the qualities of soil/mulch mix. Organic Hydro-mulching technique is used to apply organic mortar called Fiber Soil which contains approximate 50% of imported organic compost by volume. The material consists of organic compost, peatmoss, chemical fertilizers, planting seeds and tackifier.

The major components of this technique are (1) installation of 3-dimension PVC coated wire mesh for reinforcing the fiber soil. (2) spraying of minimum of 50 mm thick of fiber soil and (3) installation of bio-degradable erosion control mat for protecting the finished surface of the Fiber Soil.

In addition, slow release fertilizer strip would be included for slope with gradient more than 45°. The fertilizer strip would be installed horizontally at 500mm c/c. Seeds of 15gm/sq m of recommended vegetation seed of Bermuda grass, Bahia grass or Wedelia can be mixed into the Fiber soil. Eco-bag filled with Fiber Soil can be installed for the pit planting work of woody shrub species according to the landscape design.

The main advantage of using Fiber Soil is its ability to sustain vegetation on man-made slopes of soil or non-soil surface conditions by providing a growth medium for root anchoring and nutrients for plant. The decomposed material of organic matter includes nitrogen (N), phosphorus (P) and potassium (K) compounds, which are the macronutrients for plant development (Rieley & Page, 1999). In addition, it helps to retain soil moisture, reduce irrigation requirements, and enhance the soil structure over time (Caltrans, 2004). Even after adverse weathers like heavy rainstorms and tropical cyclones, Fiber Soil can be self-sustained on steep slopes and prevent in-situ earth materials from erosion.

6. Performance Review of Organic Hydro-mulching Technique in Hong Kong

Organic hydro-mulching is an innovative method of vegetation system which makes use of natural vegetation to grow on slope surface including soil, rock fill, jointed rock and concrete slopes. The technique was first introduced to Hong Kong in 1999. Since its inception the performance of the system has been proven to be sound and excellent for growing vegetation on steep slope. The organic hydro-mulching system was developed aiming at tackling difficulties of vegetating on steep slopes and to suit the local climate and slope conditions in Hong Kong.

In the performance review study of organic hydro-mulching technique conducted by the GEO and the Geotechnical Section, Campus Development Office of the Chinese University of Hong Kong, satisfactory vegetation coverings (84.1%±25.2% SD; 87.6%±14.4% SD) were observed on man-made slopes which have applied the organic

Hydromulching technique (Lui & Shiu 2004 and Geotechnical Section 2002, respectively). As the vegetation surveys in both studies were conducted during the plant growing season, whether the vegetation tolerance of drought after dry winter was also studied including year 2003 and 2004 when the records of annual total rainfall were 12.3% and 21.5% below average (HK Observatory, 2005).

In view of the above, the performance review of Fiber Soil at fifteen man-made slopes was carried out where the organic Hydromulching technique was applied on different types of slope such as shotcrete, rock-filled, chunam and bed rock, and the slope with the soil surface including complete decomposed granite (SDG) in different time periods and examination on vegetation performance and nutrient concentration was found to be acceptable.

The study also revealed that the levels of macronutrients in the Fiber soil were stabilized in the first year and would not be reduced thereafter. Furthermore, hydro-mulching technique can be applied on different site condition regarding slope gradient surface condition and the design of planting species.

7. Case Study of Hydro Mulching on Rockfill Slope

In 2000, an agreement has been established between the government and the Disney International to build Hong Kong Disneyland at a site near Penny's bay in Lantau Island. The project site is at Yam O Tuk Fresh Water Services Reservoir, Lantau Island where a service reservoir with access and pipeline was constructed within the site of the country park in the Southern part of the Island. As the slopes was designed to be covered by rockfill that will cause bad visual impact to visitors in day one opening of the Hong Kong Disneyland. Toyo Greenland Ltd. has been assigned to green up the slope in order to provide excellent visual appearance for visitors and the rehabilitate the ecosystem of the site area. The hydro-mulching company was undertaking to restore the ecology of the slope around the area as shown in Figure 1. The existing rockfill slope was treated with organic hydro-mulching which serves to maintain the slope integrity as well as providing an environmental friendly greening effect. The mulching system comprises of a double layer of non-woven fertilizer strip which is installed inside the three dimensioned PVC coated wire mesh and fixed on rock slope with galvanized mild steel anchor and sub-anchor to firm support beneath the rock surface to provide full vegetation cover to the slope.

Figure 1 – Project Site located at Yam O of Lantau Island, Hong Kong

The project was the first of its kind in Hong Kong that adopted organic hydro-mulching system in rock slope area in such large scale. The project site is located near the wild life area of Yam O so that people can easily walk around the area for recreation and picnic. The objective of the project is to rehabilitate a man-made rockfill slope so that new habitats can be established and nutrients can be recycled. The average gradient of the slope is about 45° with slope height of 24 meter and slope length of 34 meter.

The restoration work was started in November 2003 and was completed in May 2004. Few months after hydro-mulching installation, the slope was changed to freshly green and some of the pioneer species of grass seeds germinated which demonstrated the first step of greening up the slope. After half year, the vegetation assessment results revealed that the slopes had satisfactory performance with the healthy vegetation cover of *Melastoma sanguineum, Gordonia axillaries, Rhododendron simsii and Mallotus paniculatus* flowers. As these are native flowering and an evergreen species in Hong Kong which requires very low maintenance and is green all year around. Moreover, other flowers can also be grown from February to October every year.

Figure 2 – The view of the Project Site before and 4 years after green slope construction

8. Application Procedures

The construction of the rockfill green slope involved the installation of wire mesh with anchor and sub-anchor followed by fertilizer strip installation. Turf reinforcement Mat is fixed with fabricated fertilizer strip in order to strength the planting material to prevent leakage and washout between the rocks. Spacers are fixed under the Turf Reinforcement Mat in order to indicate the thickness of fiber soil sprayed on the top. The fiber soil, which consists with peatmoss, compost, slow release fertilizer and bonding agent and then mixed with grass seeds. A unique wet spraying machinery is used to spray the mortar to cover the whole slope. The fiber soil is a good planting media and its high air permeability will encourage development of the rooting system. It could also retain moisture and nutrients for roots to improve bioengineering strength of vegetation so as to hold soil particles to prevent erosion. A biodegradable erosion control mat, Geomat, is laid to provide the temporary surface erosion control until the successful establishment of vegetation.

The spraying of the unique fiber soil called Soil-Factor Mix which consists of more than 60% of organic matter such that 50 mm thickness of the layer is good enough to support the selected vegetation of climber and grass species. The high permeability of the Soil-Factor allows roots of vegetation to penetrate into the planting medium which is the most important factor in promoting fast vegetation growth with the chosen seed mix. Besides, the Soil Factor Mix is the self-sustained material being proved to be non-washed out under the heavy rainstorm on step slope in Hong Kong. It is light in weight compared to traditional topsoil and has cohesive ability to provide surface erosion

control functions. On the other hand, distinctive Eco-Bay has been used for plantation of scrubs and small trees.

The vegetation can be self-sustained on the steep slope of rockfill slope and sand, clay or mud was included for Hydro-mulching with the fiber soil consists of high content of natural fiber. This material is light and has been used to minimize the surcharge load to the existing slope.

8.1 Environmental & Public Concern

The slope is situated in a hill slope of Yam O in Lantau Island which can be viewed even at a long distance from the Yam O MTR station. Before the application of the system, the slope was unattractive and grey in color covered with rock fill. After the application, it has become green and attractive to the sight of the people even far away. The slope totally blended in with the surrounding natural vegetation and the greening effect has been achieved.

8.2 Achievement

The project has received numerous professional attentions both locally and internationally after the completion of project due to its innovative idea. Upon completion of the project, the slope has been green throughout all seasons for the past three years. The slope is covered with the perennial vegetation such as *Melastoma sanguineum, Gordonia axillaries, Rhododendron simsii and Mallotus paniculatus* flowers, not only green color is found but also beautiful flowers of different colors from various vegetations can be seen throughout the year. Now, the organic hydro-mulching system is adopted by the engineer and architect to be used as a cost effective methodology to enable vegetation to grow on difficult rockfill slope. Besides it was found that local native species of shrub and flower can be adopted into such system which would enhance the ecology of vegetation in Hong Kong.

9. Conclusion

The application of organic hydro-mulching has been proven to be an effective measure in preventing slope surface erosion and the restoration of a rock fill slope with natural vegetation. The organic hydro-mulching method enables natural vegetation to grow for the establishment of natural coverage to replace the traditional soil filled rock slope.

Apart from providing erosion control function, the important objective of the hydro-mulching technique was to establish a greening system on the slope. An ecosystem consists of a dynamic set of living organisms to interact among them, and interact with the environment in which they live (soil, climate, water and light). Under the ecosystem,

the vegetation on the slope can provide self-sustained nutrients cycle and supplement to each other after the full establishment. The greening slope not only could improve the visual impact to the human being or provide the surface erosion control, it could also provide and support the habitats to the rare wild life of the surrounding area. Finally, Hydro-mulching system has been proven to be successful in the application of rockfill slope rehabilitation.

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