Advances in sprayed fibre soil application for the sustainable landscaping of cut slopes in Japan and Hong Kong

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Synopsis

Sprayed fibre soil technology has been extensively used in Japan for over ten years and has been recently applied in Hong Kong. Three methods will be presented which can be used for retaining, erosion control and successful landscaping for both slope remediation and major site formation works. A sustainable approach to raw materials supply is described. Construction flow can be modified to include re-cycled materials produced either during the site works or by integrating by-products from exiting industrial processes. The authors will outline a prescriptive approach to design which can be used to assess required thickness using empirical design criteria of soil strength, rainfall and slope angle.

Keywords: fibre soil, spray installation, vegetation base, slope greening, landscaping

1. Introduction

Slope greening technology based on the spray installation system in Japan was developed during the time of high economic growth in 1960's and 70's in response to the increased environmental awareness of the Japanese community. In Hong Kong, during the last 3 years, the local government has also sought to provide an improved balance between the growing urbanisation and the local environment. Technical Guidelines have been published by the Government[1] and a number of techniques have undergone trials[2]. In this paper, we aim to introduce well-established slope greening techniques to Hong Kong which are based on spray installation technology developed and improved in Japan for over 2 decades. The systems are applicable to a variety of situations including steep slopes, rock and concrete environments.

2. Applicable slope greening methods

2.1 Development history of spray installation system

The vegetation base installation technique using a mortar spray gun was first developed in the mid 70's in Japan to improve landscaping and environmental conservation. The materials consisted primarily of bark compost and peat moss which are installed using pressurized air to create a compacted vegetation base with a high water retention capability and erosion resistance. The

vegetation base spray installation technology became rapidly and widely applied across Japan, and established itself as a standard method in steep slope greening works.

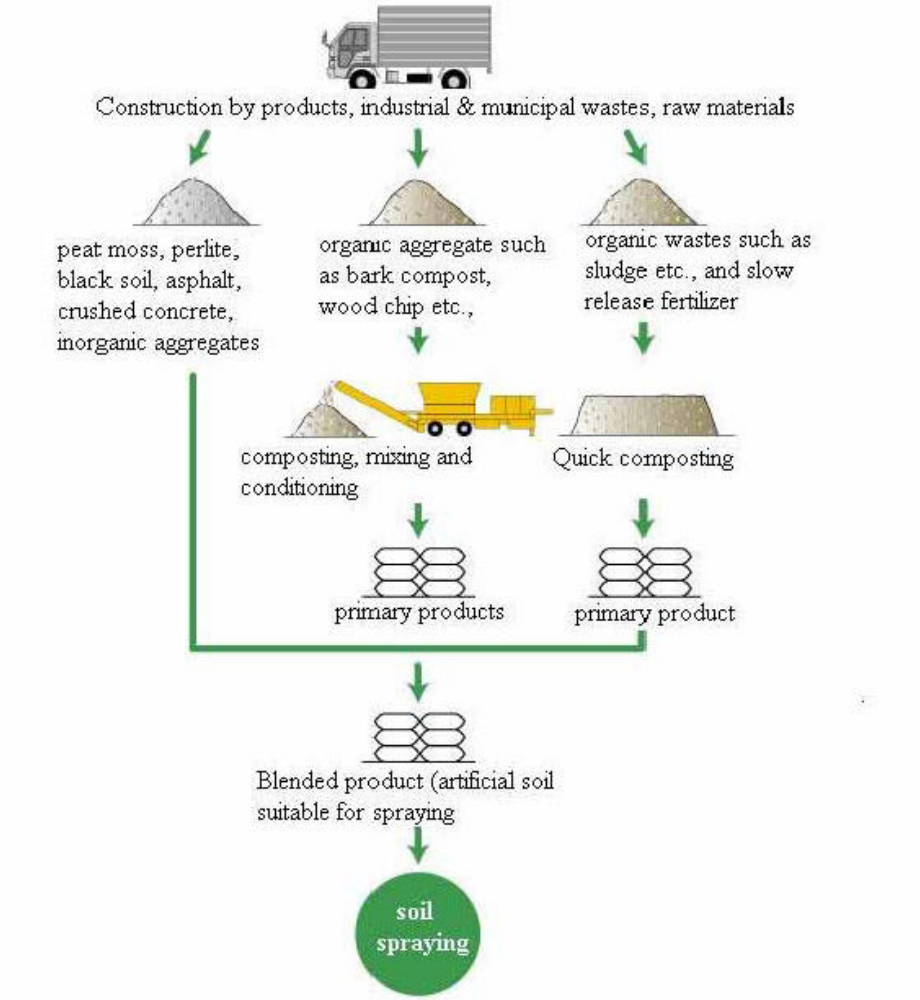


Figure 1: The ECOCYCLE Process

In the early 1990's, a new method was developed to promote the recycling and reuse of construction wastes produced in site formation works as a replacement of the vegetation base materials supplied on the market. Cut trees and shrubs are crushed and composted, then sprayed back to the surface where these materials are originated (see Fig.1 The "Ecocycle process"). This recycling process led to a number of other cottage industries emerging providing organic additives and fertilizers which in turn solved problems of disposal of by-products from other industries.

Also in the early 1990's, a new function was added to installation system to develop a new form of reinforced spray soil. The soil structure was reinforced with a continuous synthetic fibre installed on slope surface to protect from shallow slip failure (see Figure3 "Roving Wall"). The vegetation base containing grass seeds is applied on top of this fibre soil layer to produce a variable thick layer system which is capable of providing a media for root development of larger shrubs. Care should be taken however installing these isolated systems against typhoon damage where the tree height exceeds the stability provided by the root system and plant base.

Recently developed is a new type of short fibre technique currently being introduced to Hong Kong (The All Greening Method see Figure 2 and 3). The hybrid system combines the recycling advantages of the Ecocycle with the reinforcement advantages of the continuous fibre reinforced soil system. Additionally, a simple one layer system provides a significant improvement in production rates of spraying with increased sustainable value.

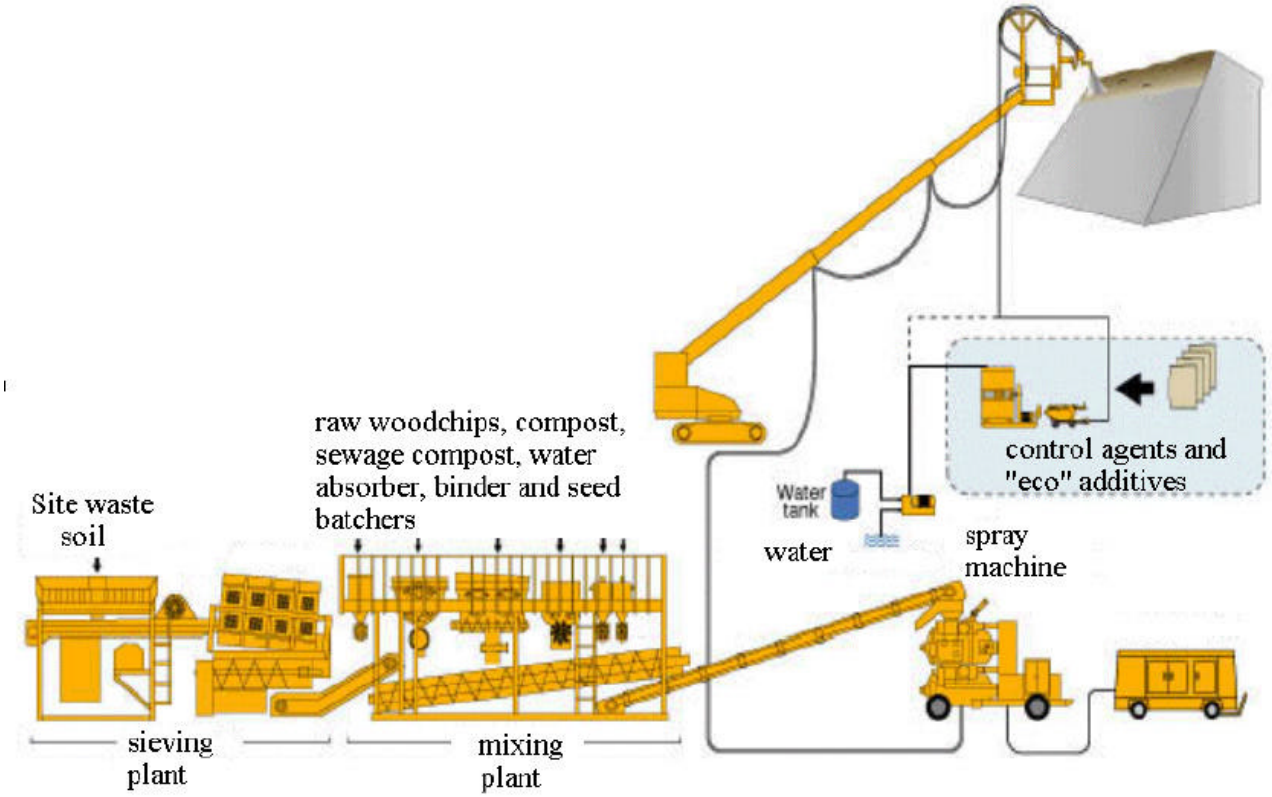
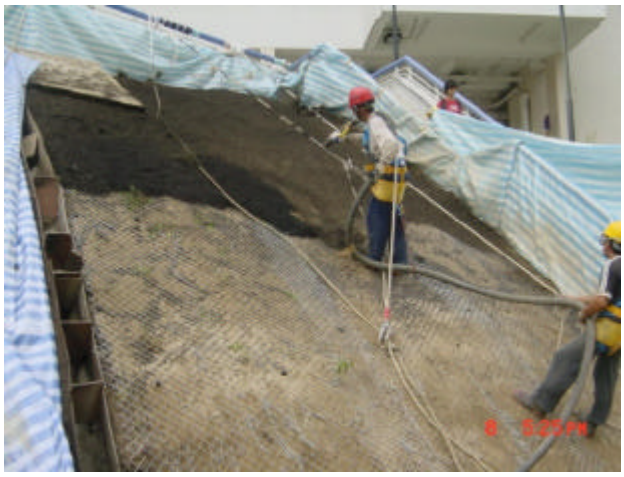


Figure 2: Fully automatic spray system for short fibre “All Greening System”

2.2 Discussion on applicability of these systems in Hong Kong

The local slope conditions in Hong Kong make fibre reinforced soil an effective product to use due to its high erosion resistance and capability to be installed in thick layers when required. The main technical benefits of continuous fibre reinforced soil (Roving Wall) are:

1. Continuous synthetic fibre (lightweight polypropylene) is mixed with sand by pressurized air to increase the shear strength of the sprayed surface layer. Prescriptively shear strengths are cohesion 40-45 kPa (design range 40-100 kPa) and a friction angle of 42 ° (43-51 °) giving the designer flexibility to provide the optimum strength per site.
2. Efficient bonding and compaction of the sprayed soil layer to the underlying surface alleviates water erosion behind the applied layer which may often occur in undular slopes.
3. The natural hydrological cycle and existing vegetation is minimally disturbed.

All Greening 20 cm	Roving Wall 20 cm
	
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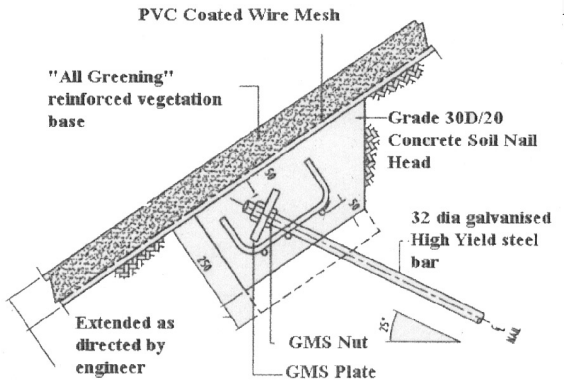
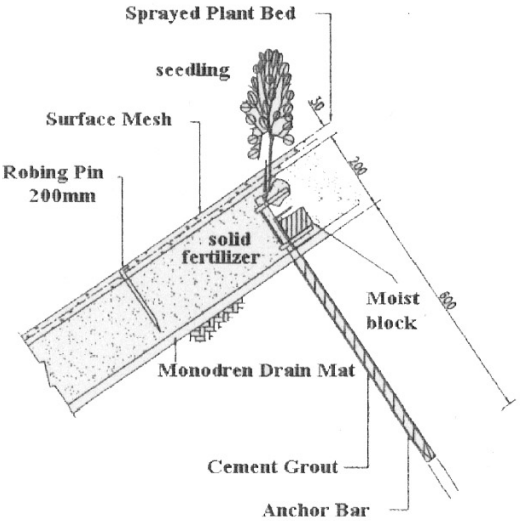
1 year after	1 year after
	
Schematic Cross Section	Schematic Cross Section

Figure 3: Standard structural detail of the fibre reinforced soil.

In addition, the All Greening Method (Single layer system see Figure 3) allows incorporation of the Ecocycle process enabling the reuse of construction and industrial by-products, enhancing a sustainable approach to slope landscaping within the community.

3. Application Examples in Hong Kong

Trial panels for both techniques, “All Greening” and “Roving Wall”, were installed at the Chinese University in 2002 by the authors on shotcrete covered slopes. The first year’s performance is illustrated in Figure 3. Additional work includes the installation of continuous fibre reinforced soil in Sai Kung for a private development and work undertaken for a roadside slopes on Hong Kong Island. The former example in Sai Kung is one of the first slopes in Hong Kong where the reinforced soil was designed over a decomposed soil nailed slope without the use of any interceding shotcrete.

4.1 Determination of required thickness of spray installed vegetation base layer

A prescriptive design criteria for the required thickness of installed vegetation base layer (applicable to short fibre methods) is well established. In this criteria, sustainable vegetation growth is regarded, from extensive installation and trials, to be controlled by 3 major parameters; 1) precipitation, 2) slope gradient and, 3) surface conditions which determine how deep roots can penetrate (see Figure 4 below).

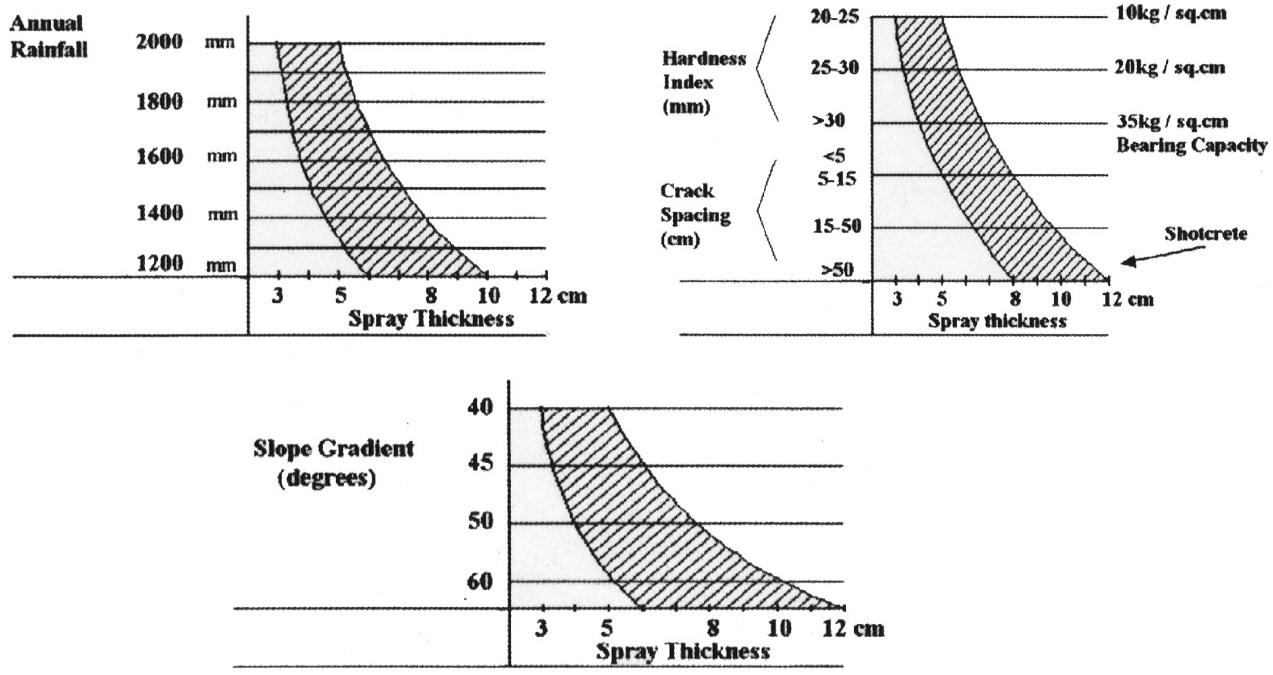


Figure 4: Rainfall, hardness and surface condition vs thickness of sprayed vegetation bed.
Hardness index taken from portable tester by YAMANAKA.

In Hong Kong, the authors have adopted these criteria with good results to date. However it is an ongoing process to develop and refine similar criteria specific to Hong Kong conditions based on local experience and long term observation.

5. Conclusion

The use of the fibre reinforced sand and vegetation base spray systems is proving an effective method for sustainable landscaping of a variety of slope surfaces including rock, soil and artificial covers such as shotcrete or mass concrete surfaces. The major disadvantage of these techniques lie principally in their perceived high cost.

In making a cost comparison with other methods however we should be careful to take full account of the sustainable value of bioengineering methods. Especially those which offer to replace a number of key cost centres such as structural performance, landscaping and aesthetic value, environmental purpose, cost of re-current maintenance, social value and promotion of a recycling.

Further research on the long-term of performance of sprayed vegetation bases for the effective landscaping and erosion control of slopes in Hong Kong is ongoing. The development of a prescriptive design approach is presented and is currently under review for application to local slope engineering and landscaping projects in Hong Kong.

5. Acknowledgements

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Reference.

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