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Building a layer of continuous fiber soil
(Manual type: sandy soil at left and continuous fiber at right)

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The Geofiber method – Protecting slopes with environment-conscious continuous fiber reinforced soil

1. Introduction

The Geofiber method is one of the methods for protecting natural slopes and/or cut slopes. In Japan, where terrains are very often steep or confined, it is vital to ensure inhabitants safe and secure living environment by preventing collapses of natural slopes and protecting cut slopes. Traditionally, concrete structures or steel bars have been used to protect those slopes, but, in recent years, a new method called "Geofiber Method" has been introduced and installed at lots of sites that utilizes continuous fiber reinforced soil that consists of sandy soil and fiber.

This article presents the Geofiber method registered as a quasi-recommended technology in 2016 on the New Technology Information System (NETIS) operated by Ministry of Land, Infrastructure, Transport, and Tourism of Japan.

2. Overview of the Geofiber Method

2.1 Applications

Geofiber method offers protecting of natural/cut slopes as well as covering existing concrete surfaces or structures, etc. with a layer of continuous fiber reinforced soil, and thereby enable those slopes to be vegetated in parallel. Conventional methods for shotcrete, mortar spraying and free-frame work, had a drawback of difficultly allowing vegetation to grow over those surfaces and leaving non-vegetation surfaces. Another problem was that as the concrete deteriorates over the years, repairing and reinforcement work becomes necessary. Meanwhile, the Geofiber method allows vegetation to grow all over the layer of continuous fiber reinforced soil and eventually creates a natural green landscape. This makes it ideal for slope protection works aimed at creating or preserving natural landscapes, such as slopes in national and quasi-national parks, slopes in historic sites and cultural properties, roadside and park slopes desired to be in harmony with surrounding scenery, protection of wooded hillsides, etc. This is why the Geofiber method has been adopted in a wide variety of slope protection works, including cut or filled slope work, landslide prevention work on steep slopes, road improvement work, erosion control work, forest conservation work, etc.

2.2 Continuous fiber reinforcement soil for slope protection

Continuous fiber reinforcement soil is a homogeneous mixture of sandy soil and a certain amount of fibers (Table 1). Mixing sandy soil with continuous fibers gives the material pseudo-cohesion from the mutual friction and constraint of the fibers and sandy soil and increases the shear strength of the soil. The Geofiber method consists in spraying this material over the hillside or slope to build up a layer of continuous fiber reinforced soil that protects the slope (Photo 1). This soil was granted a civil engineering material technology review certificate in 1992 as "continuous fiber reinforced soil for the protection of retaining walls and slopes," which attests that mixed fibers increase the strength of the soil, give it sufficient erosion resistance for practical purposes, and make greening of slopes possible. Further, the method was granted mechanized construction technology review certification in 2000, which attests the effects of various methods for building layers of continuous fiber reinforced soil.

Table 1 Standard mix of materials for continued fiber reinforced soil (per 1 m^3)

Material	Specifications	Amount	Remarks
Sandy soil		1 m^3	Result
Continuous fibers	Polyester multi-filaments 167±6T	3.3 kg	Weight per 10,000 m of T fibers 167T=167 g per 10,000 m (3.3 kg/m^3=197.6 km/m^3)
Water and fertilizer retention agents	Organic blocks	1 to 2 pcs/m^2	Per 1 m^2
Additives			As necessary

Photo 1 Building a layer of continuous fiber soil (Manual type: sandy soil at left and continuous fiber at right)

2.3 Design and execution of work

As shown in Figure 1, the Geofiber method consists in stabilizing and protecting slopes and creating environment for green vegetation by combining three processes. The first process is anchoring work with plates practiced on stable grounds that aim at integrating the layer of continuous fiber reinforced soil with the natural ground. If the natural ground is unstable, the ground is first reinforced (by rock bolt work, ground anchor work, etc.) to stabilize the slope before the layer of continuous fiber reinforced soil is built over it. The second process is building up a layer of continuous fiber reinforced soil over the natural ground. After providing drainage over and at the toe of the slope, a layer of continuous fiber reinforced soil is sprayed and built up all the way from the toe to the top of the slope. Sandy soil is sprayed onto the slope with pneumatic sprayers. A special machine with fiber bobbins sprays the mixture of water and continuous fibers from four jet nozzles designed for the purpose (Photo 2). These ejector nozzles oscillate so that fibers are discharged in a homogeneous mixture in desired directions. The sandy soil and continuous fibers from these two systems are discharged in such a way that fibers fall on top of another at the target area to build up a layer of the soil (Figure 2). At the same time, the amount of discharge of the sandy soil and continuous fibers is continuously controlled by a dedicated control device.

The standard working area for the manual operation type in which workers hold and operate nozzles is 45 m in slope height and 150 m in pneumatic transportation distance. Roughly classified, there are two ways the slope is built, as shown in Figure 3: one is the slope protection type that builds a same thickness of layer of 20 cm or more and the other is the retention wall type. Either way, the surface angle is kept to 50% or less (1:0.5) to allow vegetation to take root and grow. The third process is vegetation work. The standard method consists in spraying a vegetation base material of 3 cm in thickness. The surface of the continuous fiber reinforced soil is covered with diamond wire netting that serves as greening foundation and then sprayed with a

vegetation base material to build up the vegetation layer. The vegetation base material is a mixture of greening seeds, fertilizers, and anti-erosion agents selected designed to meet a greening objective set forth in advance in view of the surrounding environment.

Reflecting the increasing number of cases where the Geofiber method was adopted, information on the design and execution of the continuous fiber reinforced soil method is compiled and published by the Public Works Research Center in April 2009 under the title of *Design and Execution of Slope Protection*

Work by Geofiber Method with Continuous Fiber Reinforced Soil.

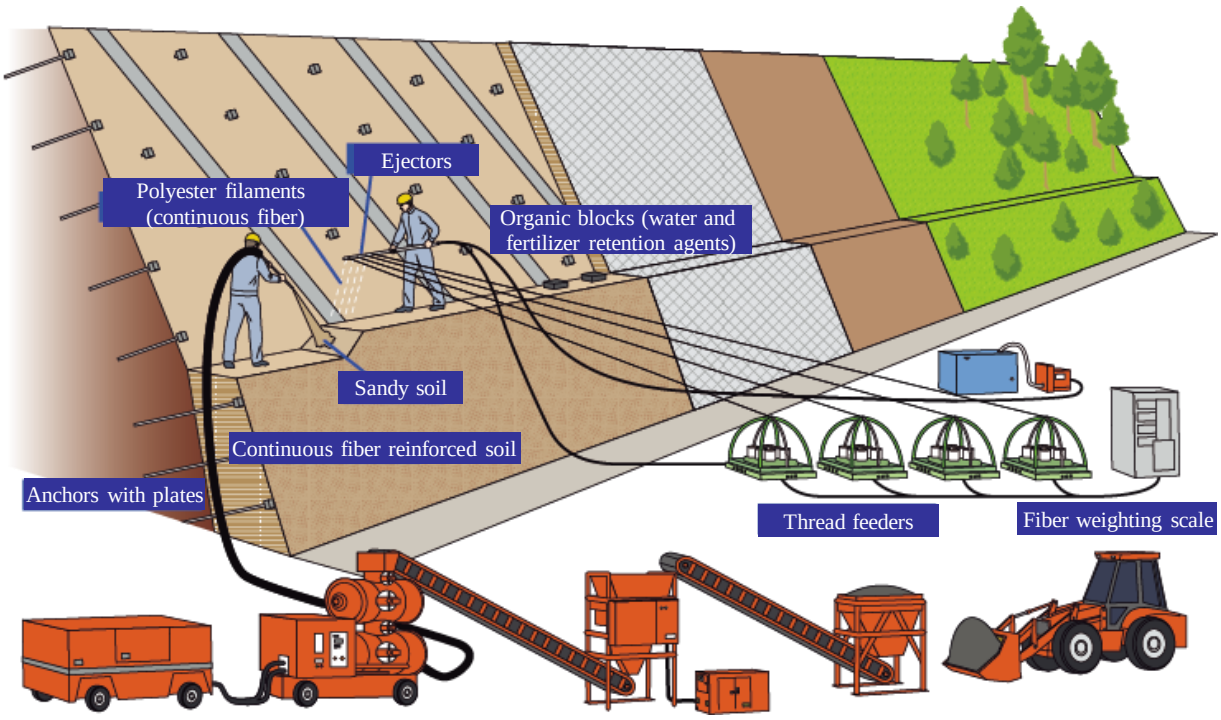


Figure 1 Overview: Execution of slope protection work by the Geofiber method

Photo 2 Ejector nozzles

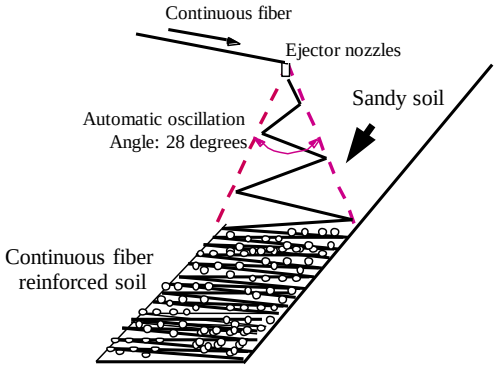
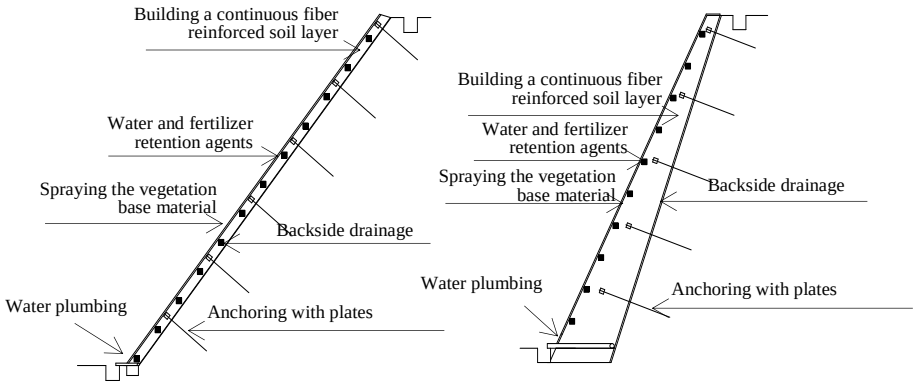


Figure 2 Building up a mixed layer of continuous fiber and sandy soil



(Slope protection type) (Retention wall type)

Figure 3. Cross section of structures

3. Examples of application

3.1 Landslip prevention work on steep slopes, preserving existing trees

In the example illustrated by Photos 3 to 6, the slope between a residential district and a promenade had significantly eroded over time, with existing trees exposing roots at bases. Conventional methods of slope protection would have meant cutting down the trees and using a lot of concrete, but we used the Geofiber method as a solution that allowed us to protect the slope without cutting down the existing trees. Photo 3 shows how the slope was being covered with the layer of continuous fiber reinforced soil and Photo 4 shows the slope completely covered with the layer of continuous fiber reinforced soil. The layer was then sprayed with a vegetation base material, which grew to cover all over the slope with green grass within one month (Photo 5). During twenty-one years following the protection work, the vegetation on the slope succeeded from initially dominant herbaceous plants to invading plants and to current thickets of trees (Photo 6).

Photo 3 Building a layer of continuous fiber reinforced soil

Photo 4 Completed layer of continuous fiber reinforced soil

Photo 5 One month after the work

Photo 6　21 years after the work

3.3 Maintaining landscapes on historic sites and cultural properties

In 2013, Typhoon Wipha hit the city of Kashima, Ibaraki Prefecture, and a slope across from Mitarashi Pond of Kashima Jingu Shrine crumbled. Till then, the Geofiber method had been adopted on various historical and cultural property sites to preserve historical landscapes, including the restoration of a slope in the compounds of Kiyomizudera Temple in Kyoto and burial mounds in Yoshinogari Historical Park, Saga Prefecture. In the same manner, the crumbled slope in Kashima Shrine was restored by soil nailing (with rock bolts) and by the Geofiber method, i.e., protecting and greening the slope with a layer of continued fiber reinforced soil and that of a vegetation base material that matched the surrounding vegetation (Figure 4 and Photos 7 to 9).

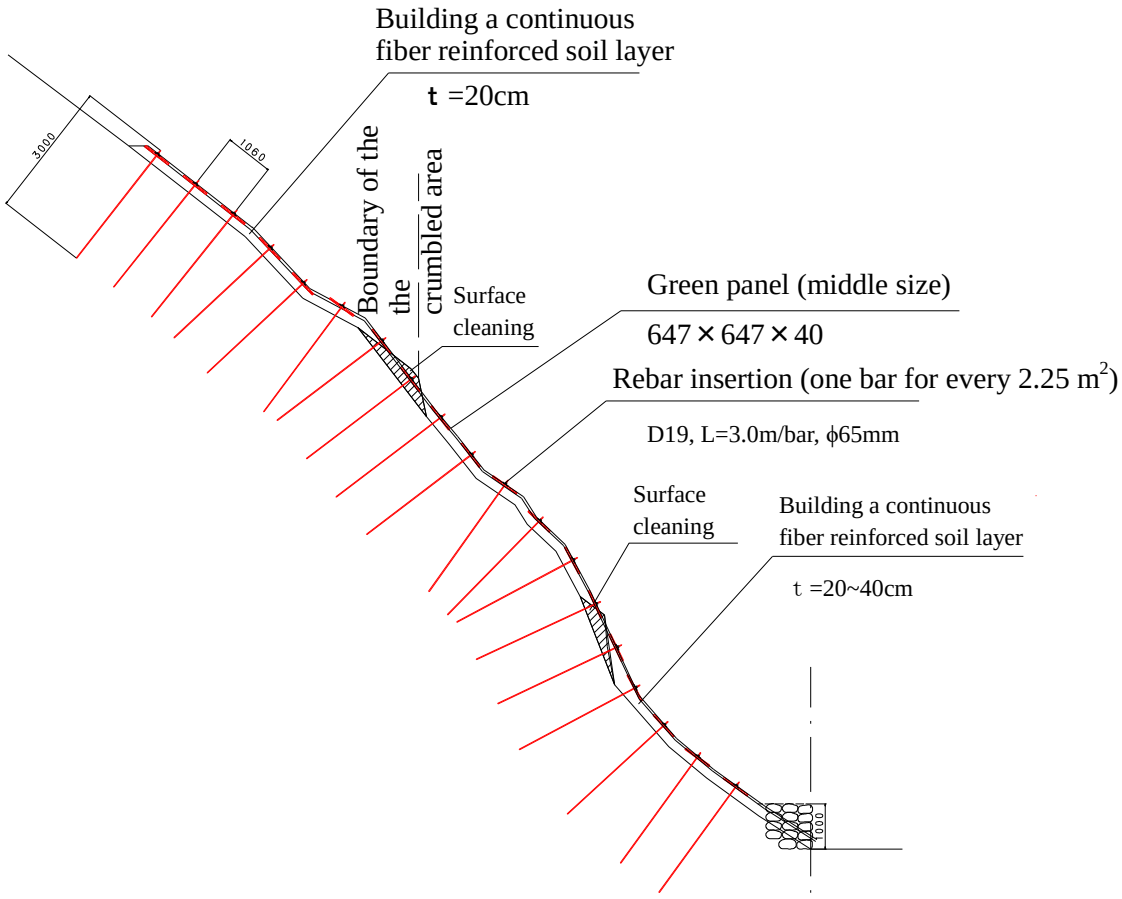


Figure 4. Image of slope protection applied with soil nailing work

Photo 7 After collapse

Photo 8 Completion of soil nailing and the continuous fiber reinforced soil layer

Photo 9 Preservation of historic landscape

4. Track record and characteristics of the Geofiber method

So far, the Geofiber method has been adopted on more than 3,200 sites in Japan as well as an increasing number of sites in South Korea and Hong Kong. The characteristics of the Geofiber method that spurred its adoption on many sites are summarized as follows:

① Highly erosion-resistant, the method prevents the weathering and erosion of the natural ground.
② Pseudo-cohesive, the soil offers an excellent shear strength.
③ Offering a great freedom of formative design, the method is effectively applicable also to uneven and wooded terrains.
④ The method allows the successive transit of vegetation from herbaceous plants to woody plants over time.

5. Conclusion

As time goes by, slope protection work is required to be more and more environmentally-friendly. In addition to landscape considerations, it is becoming increasingly vital to take account of such issues as global warming prevention, absorption and fixation of carbon dioxides, symbiosis of humans and nature, etc.

We hope that the Geofiber method will be used more and more widely in the years to come as an ideal solution for protecting hillsides and slopes without exposing concrete structure.

References:

(1) Public Works Research Center, Civil Engineering Material Technology Review Certificate, May 1992.
(2) Construction Machinery Research Institute, Construction Mechanization Technology Review Certificate, March 2003.
(3) Public Works Research Center, Design and Execution of Slope Protection Work by Geofiber Method with Continuous Fiber Reinforced Soil, April 2012.
(4) The Geofiber Society, Photo Book Celebrating the 20 years of Geofiber Soil Reinforcement Practice

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