Slope surface treatment using a bio-soil approach

Jooyoung Im, Yeong-Man Kwon & Gye-Chun Cho

Department of Civil and Environmental Engineering, Korea Advanced Institute of Science and Technology (KAIST), Korea

Ilhan Chang

School of Engineering and Information Technology (SEIT), University of New South Wales (UNSW), Australia

ABSTRACT: In recent years, studies on the biopolymer effects on soil stabilization and improvement have been studied as a possible sustainable alternative. Previous studies have shown that the effects of biopolymer on soils have a substantial increase in both strength and reduction in surface erosion. However, all previous studies have been performed in the laboratory scale, and its performance on the field scale has yet to be verified. In this study, biopolymers were applied on a slope surface around the area of Seosan in the Rep. of Korea. The effects of biopolymers on the slope stability and erosion resistance were observed over a period of 4 months. In addition, the effects of the construction process and equipment were analyzed. The results from this field applications showed that the effects of biopolymers on the slope surface were beneficial, however, a more optimized construction process is necessary for better performance and reliability.

Keywords: Biopolymer, Soil Improvement, Slope stabilization

1 INTRODUCTION

In recent years, sustainable engineering methods have been in development. In the field of geotechnical engineering, the use of bio-based materials is one of the most promising materials for sustainable construction. Among such bio-based materials, one material called biopolymers has shown quite significant promise. Biopolymers are polymers that are derived for biological organisms, most commonly from micro-organisms (Endres et al. 2013). The various properties of biopolymers has allowed for its use in numerous fields of industry. Biopolymers have been widely used in food production, agriculture, cosmetics, medical treatment, and pharmaceuticals (Lorenzo et al. 2012; Saha and Bhattacharya 2010; Van de Velde and Kiekens 2002). Biopolymers have been generally accepted as sustainable materials that have zero or close to zero carbon footprint.

Various studies on the geotechnical engineering properties of biopolymers have been investigated in the past. Chang and Cho (2015) has shown that small quantities of biopolymers are capable of producing significant improvements in strength. In this study 0.5% Xanthan gum biopolymer was shown to have strength nearly double that of 10% cement treated soils (Chang et al. 2015a). In addition to Xanthan gum, other biopolymers (such as Gellan gum, Agar gum, Guar gum, B-glucan, etc.) have shown various properties that enhance the characteristic of soils (Dove et al. 2016; Etemadi et al. 2003; Gupta et al. 2009; Khachatoorian et al. 2003). However, most test and experiments on biopolymer use in geotechnical engineering has been performed at the laboratory scale, and as many would know, the properties of soils may greatly vary based on the scale.

For this study the use of biopolymers for a large scale site application was performed. The biopolymers were mixed and added into the surface of a slope located around the area of Seosan in the Rep. of Korea. The effect of the biopolymers were monitored over a period of 4 months and the effects of natural rainfall and environment on the surface erosion, vane shear strength, and vegetation were observed.

2 SITE EQUIPMENT AND PROCEDURE

2.1 *Equipment*

For this study, the method of biopolymer application was tested using a dry mixing spray using an air compressor. The air compressor was connected to a soil supply system where in situ soil was used as the target soil of this study. The particle size distribution of the soil is shown in Fig. 1.

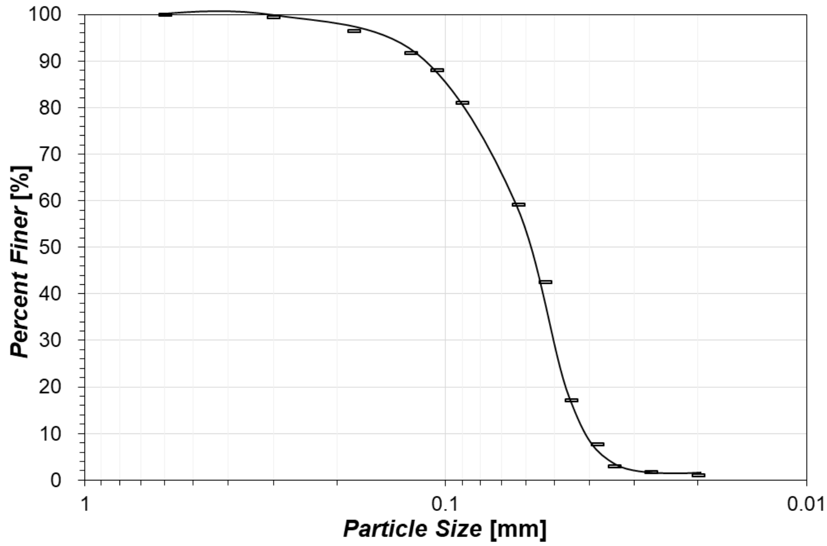
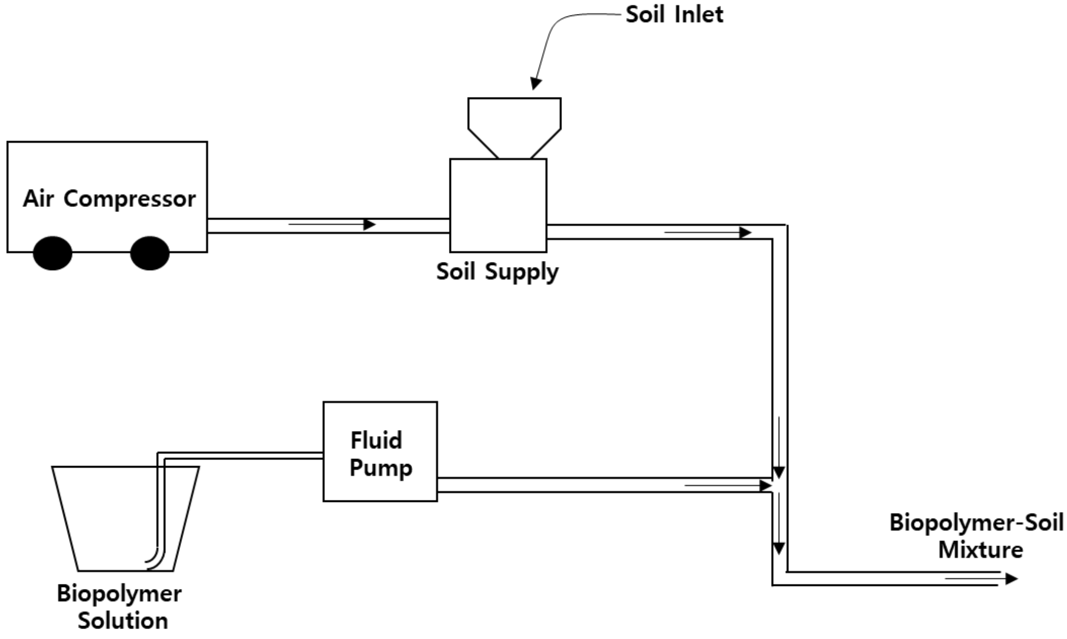
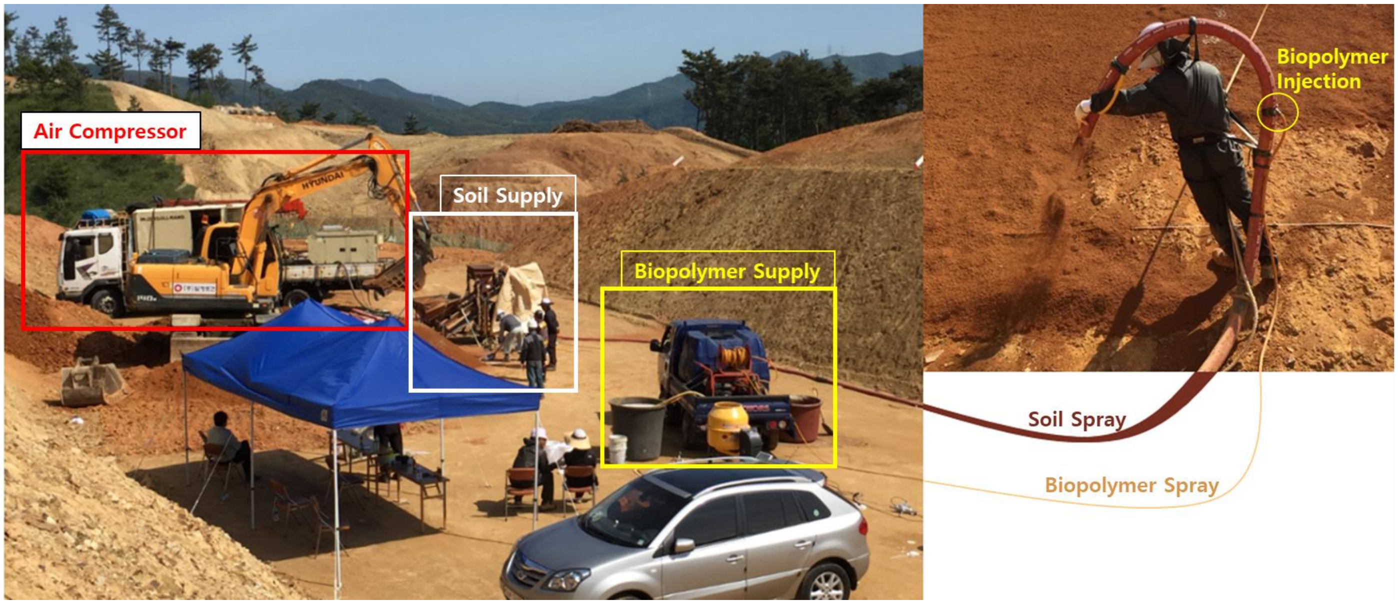


Figure 1. Particle size distribution of target soil

The air compressor and soil supply was used to supply the soil through the hose and a small opening at the end of the nozzle was used to spray the target biopolymer solution into the soil. The biopolymer was pumped using a fluid pump. The schematic of the equipment layout is shown in Fig. 2a and the overall picture of the site is shown in Fig. 2b.



(a)



(b)

Figure 2. (a) Equipment layout and (b) On site setup

2.2 *Procedure*

In order to remove large stones from clogging the pipes of the equipment, a 25 mm sieve was used to sieve the in situ soil once before construction, and the target vegetation seeds (perineal lye grass, Kentucky blue grass, thatched grass, and tall fescue) were mixed into the soil. The soil was then put in the soil supply hopper through a simple conveyer belt system, which allowed for a steady input of soil without allowing for clogging effects within the soil supply device or the pipes. The soil was then carried by the air flow provided by the air compressor, and the biopolymer were injected into the soil pipe near the nozzle. The biopolymer solution was injected into the soil pipe through the use of a fluid pump at approximately 2 m behind the outlet of the pipe. This would allow for the biopolymer solution to mix with the soil within the pipes without much worry on clogging in the pipes due to the coagulation of soils and biopolymers.

Three types of biopolymers were tested at this site. The first (biopolymer A) was designed for soil strengthening while allowing for vegetation growth along the surface of the slopes. The second (biopolymer B) was designed for soil strengthening and also an anti-weed polymer that inhibited the growth of vegetation. Lastly biopolymer C was designed mainly for high strengthening of the soil. Each section was set at 5m x 5m, and these sections were set next to an untreated section of soil for comparison. The sectional diagram is shown in Fig. 3.

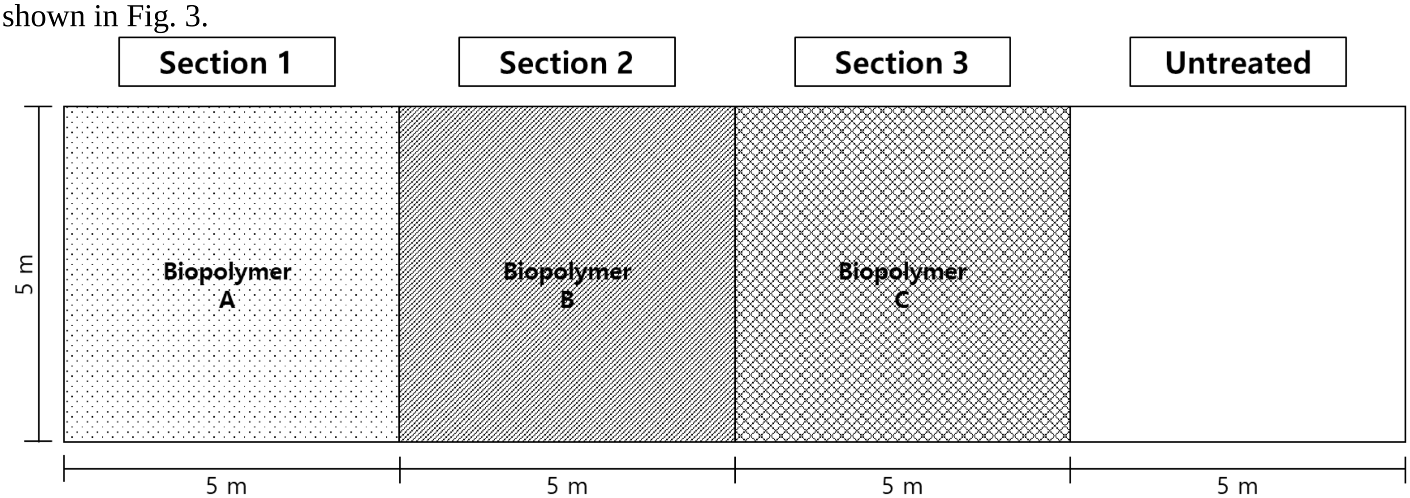


Figure. 3 Site testing sectional layout

3 MONITORING RESULTS

Monitoring of the site was performed every 2 weeks. The site was monitored visually for any signs of notable surface erosion alongside torvane tests and a rough estimate of the number of sprouts. Results are shown in Table 1 and Fig. 4.

Table 1. Torvane and Vegetation Monitoring Data

	Section 1		**Section 2**		**Section 3**		**Untreated**	
	Vane (kPa)	**Sprouts (#/m^2)**	**Vane (kPa)**	**Sprouts (#)**	**Vane (kPa)**	**Sprouts (#)**	**Vane (kPa)**	**Sprouts (#)**
2 weeks	164.2	≈2000	153.6	0	187.1	≈800	56.4	-
4 weeks	149.5	≈2000	144.6	0	208.4	≈1200	49.0	-
6 weeks	146.7	≈2200	127.7	0	196.1	≈1200	40.2	-
8 weeks	156.9	≈2200	135.7	0	171.6	≈1500	51.3	-
10 weeks	157.5	≈2200	118.3	0	165.9	≈1500	6.6	-
12 weeks	154.2	≈2200	131.6	0	174.0	≈1500	4.5	-
14 weeks	127.5	≈2200	112.4	0	147.1	≈1500	43.1	-
16 weeks	122.3	≈2200	114.4	0	150.3	≈1500	41.6	-

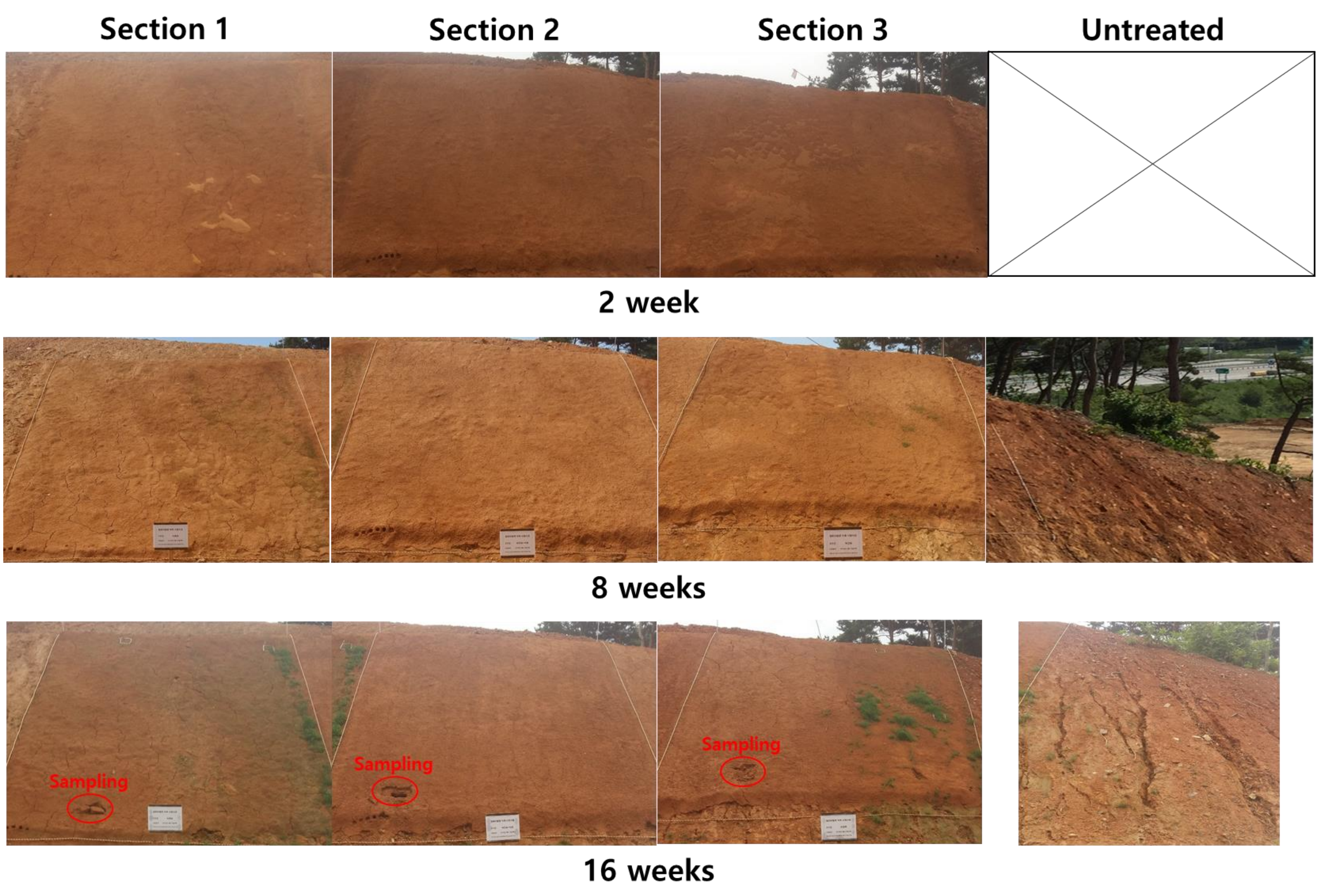


Figure 4. Monitoring Pictures (from left to right: Section 1, Section 2, Section 3, and Untreated)

When we observe the vane shear strengths of the soils, it was seen that section 3 had the overall highest strength followed by section 1 then section 2. However, in comparison with the untreated soil strength, large increases in strength were observed. Before the 10 week mark section 1, 2, and 3 had an average vane strength around 150 kPa, 140 kPa, and 190 kPa respectively. However, after the 10 week mark slight reductions in strength were observed for all cases, which was the result of heavy rainfall which was experienced at the site during weeks 10-12. Additionally, visual observations of the site after weeks 10-12 showed large amounts of erosion on the untreated soils, however, all biopolymer treated sections showed none or negligible amounts of erosion.

In the case of vegetation growth, as expected section 2 exhibited no vegetation throughout the 4 months of monitoring. As for sections 1 and 3, section 1 showed the largest amount of seed germination at around 2200 sprouts/m^2 while section 3 shows low amounts of seed germination at around 1800 sprouts/m^2. However, it was observed that there was a limit to the growth of the vegetation and the average height of the sprouts did not exceed 2 cm. This is believed to be a result of the high density of the soil resulting from the dry mixing method used in this study along with the soil used (large amounts of fine soils). Due to the high density, the root penetration of the vegetation seems highly limited resulting in a stagnation in the growth of the plants.

4 CONCLUSIONS

In this study a dry mixing method using an air compressor and fluid pump was performed, and the effects of the biopolymer treated soils on the slope were monitored over a period of 4 months. From the results it was observed that the use of all 3 types of biopolymer allowed for a significant increase in the soil strength, which also helped in the erosion resistance of the soils. Additionally, unlike conventional methods such as cement, the growth of vegetation can be controlled through the use of the type of biopolymer. However, from this test it was observed that a systematic method of construction is required for biopolymer use. Due to the high viscosity and surface tension of the biopolymer solution, the mixing of the soil and biopolymer did not seem very homogeneous and several sections of varying biopolymer concentration were observed. Moreover, for uses requiring large degrees of vegetation growth, the method of application may need to be varied in order to allow for optimal conditions of vegetation without drastic increases in the dry density of the soils with limit the growth of vegetation.

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