Review of biodegradable geosynthetics in eco-friendly engineering application

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ABSTRACT: Biodegradable geosynthetics as a biodegradable geosynthetics was introduced in terms of biodegradability. Development of biodegradable geosynthetics, its background and technical concerns were discussed through some research results of PLA (polylactic acid) specimens. Test method for biodegradability of PLA as a biodegradable geosynthetics were considered and suggested based on composting method. Finally, the rest result shows that the concept of biodegradability for biodegradable geosynthetics is available in the environmental application. PLA 4032D/PBAT (80/20) blend shows improvement of environmental performance as a biodegradable geosynthetics application than PLA 4032D only used.

Keywords: Biodegradable geosynthetics, biodegradability, PLA (polylactic acid), composting method, environmental performance

1 INTRODUCTION

Although durability of geosynthetics should be emphasized for long-term service period, durability controlled mechanism could be required to fulfil the short-term degradability purpose for biodegradable geosynthetics. Biodegradable geosynthetics are made of eco-environmental biodegradable polymeric resins or natural materials and they must maintain their needed performance such as durability, design strength, hydraulic property etc. during service period in the application field. Then, after service period they should be degraded no harmful state in the soil structures. Key performance of biodegradable geosynthetics is biodegradability with required service period namely; the control mechanism of biodegradability between initial and later stage of installation in the field.

Therefore, control technique of maintenance and degradability of biodegradable geosynthetics is dependent on the material properties. Also, it is very important to select what kind of raw resin, additives and plasticizer to control the biodegradability of biodegradable geosynthetics. Therefore, more detailed design technique should be needed to approach and setup the reasonable condition and recipe to manufacture biodegradable geosynthetics. Besides this, the most optimum installation technology is needed to realize and match the performance of biodegradable geosynthetics.

Still now, there is no international test method to evaluate the biodegradability of biodegradable geosynthetics performance and only the geosynthetics performance test methods of ISO and ASTM International are applied for this purpose.

In this paper, biodegradability test tool of biodegradable geosynthetics using PLA materials was suggested in eco-friendly engineering application and importance of environmental performance of biodegradable geosynthetics was reviewed to be related to the quantitative analysis of biodegradability of biodegradable geosynthetics by conceptual consideration.

2 EXPERIMENTAL

Tensile properties were evaluated with universal testing machine (Hounsfield, H1000KS). To investigate the degradation behavior, strength retention was measured the PLA 4032D and its blend. Degradation behavior in 0.01 M phosphate buffered saline solution of pH 7.4 was monitored by incubation in a shaking water bath at 45.0±0.5℃ for up to 10 weeks. Tensile strength of incubated specimens was measured every 2 weeks using a tensile tester. The strength retention was determined by strength retention before and after degradation. 63.6mg/150ml enzyme solution for bio-degradable resistance was made by 17 unit/mg of Esterase contained enzyme solution (Aldrich Co.) in pH 8.0 phosphate buffered saline solution. PLA specimen was immersed in this solution for 4 weeks and and strength retention was determined before and after testing. UV resistance was done in accordance with ASTM D4355-07 (Standard Test Method for Deterioration of Geotextiles by Exposure to Light, Moisture and Heat in a Xenon Arc Type Apparatus). Exposure time to UV is 500 hoursand strength retention was determind by strength comparison before and after UV exposure condition. For testing of interface friction property between PLA 4032D and PLA4032D/PBAT (80/20) blend sheet (;5×15×0.2cm size), ASTM D5321-08(Standard Test Method for Determining the Coefficient of Soil and Geosynthetic or Geosynthetic and Geosynthetic Friction by the Direct Shear Method) was applied and standard sand was used as test soil.

3 RESULTS AND DISCUSSION

3.1 *Mechanical properties of PLA blend*

In Figure 1, tensile strength of PLA 4032D/PBAT blends decreased with increase of PBAT content. Especially, strength retention over PBAT content 40 wt% was less than that of 100% PBAT and this is due to compatibility decrease between PLA 4032D and PBAT by compounding.

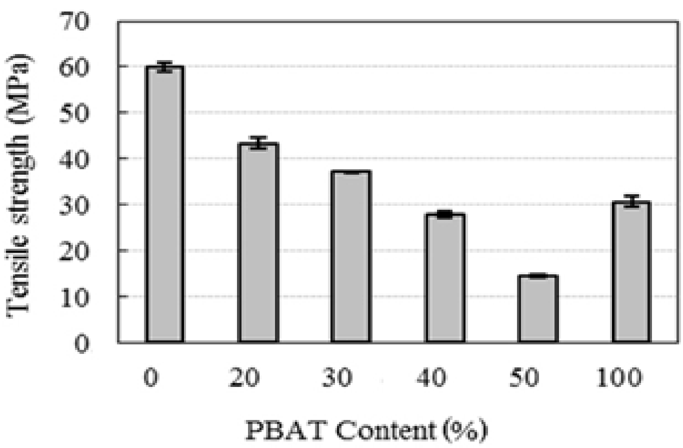

Figure 2. Tensile strength PLA 4032D/PBAT blends with blending ratio

Figure 2 shows the breaking strength of PLA 4032D with exposure temperature. In here, PLA 4032D blends were made to add PBAT which is a kind of biodegradable resin to improve flexibility of green geosynthetics and strength decrease tendency is seen with PBAT blend ratio and temperature. From the slope of strength decay is very important because degradability control mechanism is determined through the half-life of strength analysis.

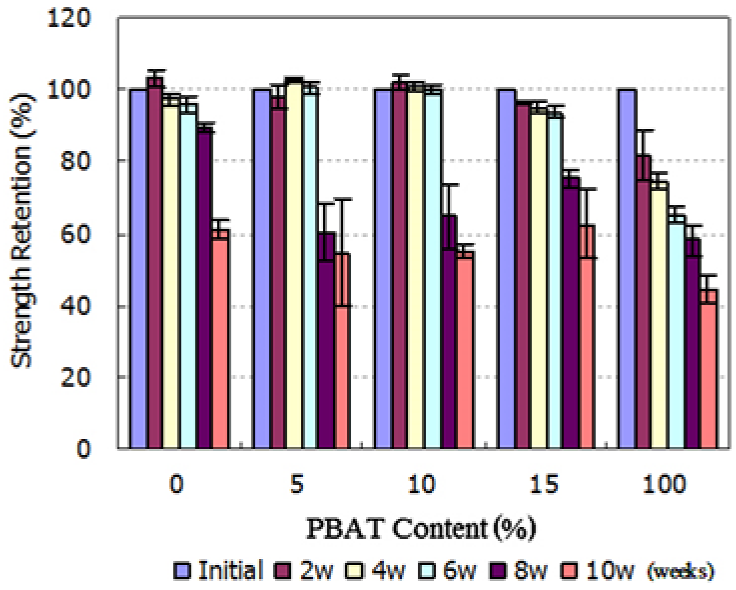

Figure 2. Breaking strength of PLA 4032D with PBAT content for burial times at 45℃

3.2 *Environmental properties of PLA blend*

Figure 3 shows the PLA 4032D specimen burial in soil and this shows strength retention of PLA 4032D under exposure condition and especially under activated sludge burial condition we can find the very rapid strength decay within 30 days. However, PLA shows almost 50% strength retention in soil burial condition within one year and this means green geosynthetics of PLA can be available for one year if the strength decay slope could be controlled. To control biodegradability of PLA used green geosynthetics, more restricted design technology must be adopted in the quality control and assurance of manufacturing and construction procedure in the installation field. Figure 4 shows the excellent UV resistance of PLA 4032D and PLA 4032D/PBAT (80/20) blend through tensile strength comparison before and after UV exposure. For this case, it is seen that PLA 4032D/PBAT (80/20) blend shows the less decrease of tensile strength retention than PLA 4032D used only and this means the improvement of UV stability. Table 1 shows interface frictional coefficient between PLA specimen and soil by direct shear test for environmental application as geosynthetics. In here, PLA 4032D/PBAT (80/20) shows improvement of interface frictional performance than PLA 4032D only used and this is an example of performance improvement by PBAT blending.

Table 1. Interface frictional coefficient between PLA specimen and soil

Normal stress (kPa)	Frictional coefficient	
	PLA 4032D	PLA 4032D/PBAT(80/20)
50	0.665	0.718
100	0.642	0.703
150	0.613	0.692

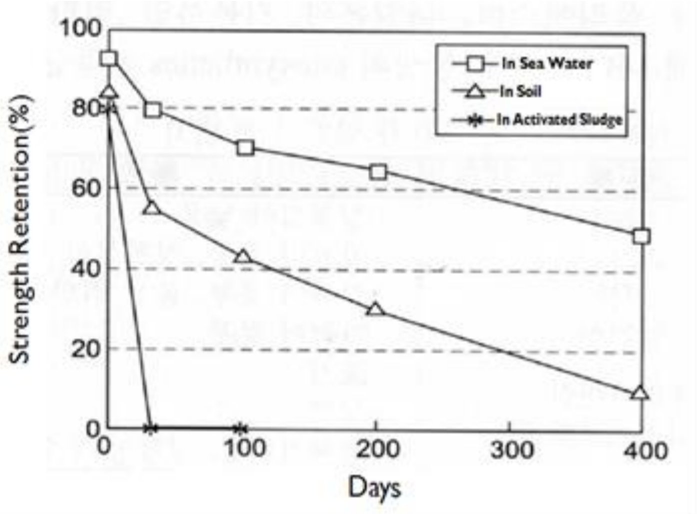

Figure 3. Strength retention of PLA 4032D under environmental exposure condition

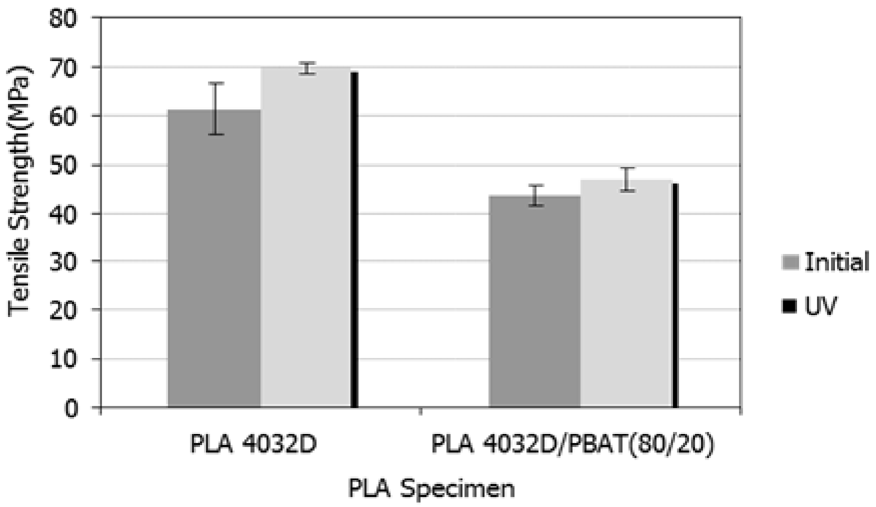

Figure 4. UV resistance of PLA 4032D and PLA 4032D/PBAT (80/20) blend with tensile strength

3.3 *Proposal of biodegradability evaluation*

The influence parameters of biodegradability of PLA and the most reasonable biodegradable mechanism should be determined by experimental data with exposure conditions such as atmosphere, water and soil etc. Still now, there is no international test method to evaluate the biodegradability of green geosynthetics performance and only the geosynthetics performance test methods of ISO and ASTM International are applied for this purpose. However, it is not reasonable for green geosynthetics to adopt these test methods directly and new test methods should be introduced for green geosynthetics performance testing. Figure 5 shows the quantitative concept of biodegradability evaluation of green geosynthetics and the best evaluation items should be selected in accordance with influence parameters which determine the long-term performance under real field installation conditions. Figure 6 shows the test procedure of biodegradability of PLA specimen for green geosynthetics and finally, property analysis could be obtained to consider and refer the exposure conditions in the real installation field. In here, we can suggest a kind of hydrolysis method procedure of Figure 7 and this shows the evaluation procedure of degradability of PLA. ASTM D5338-98 (Standard Test Method for Determining Aerobic Biodegradation of Plastic Materials under Controlled Composting Conditions) is introduced to simulate the real installation condition. Through the experimental data analysis, we can suggest the degradability test method with temperature as shown in here. By using Arrhenius plot of accelerated experimental data, we can predict the long-term biodegradable behaviors with temperature and induce this to designing the green geosynthetics. Figure 8 shows the regulation proposal of evaluation method of biodegradability for green geosynthetics to overall the above review and analysis of correlation between index and field tests could be the connection key factor to confirm the biodegradable behaviors for green geosynthetics.

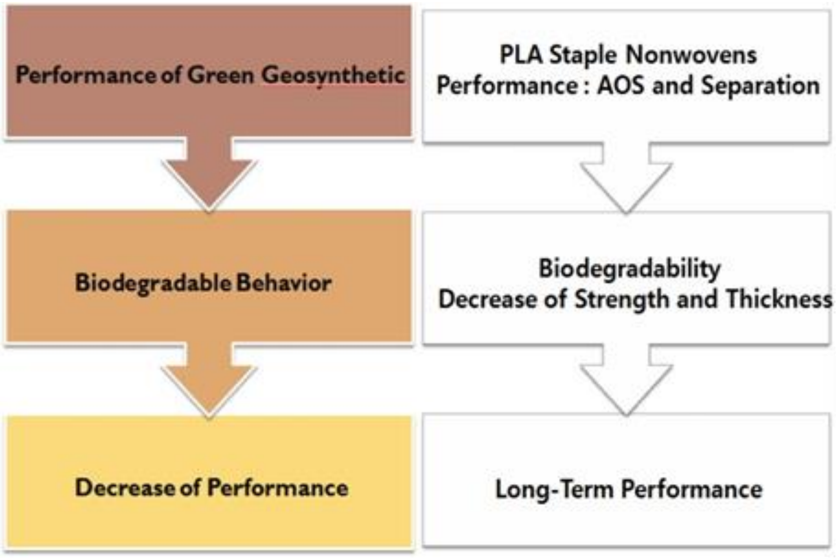

Figure 5. Quantitative concept for biodegradability evaluation of green geosynthetics

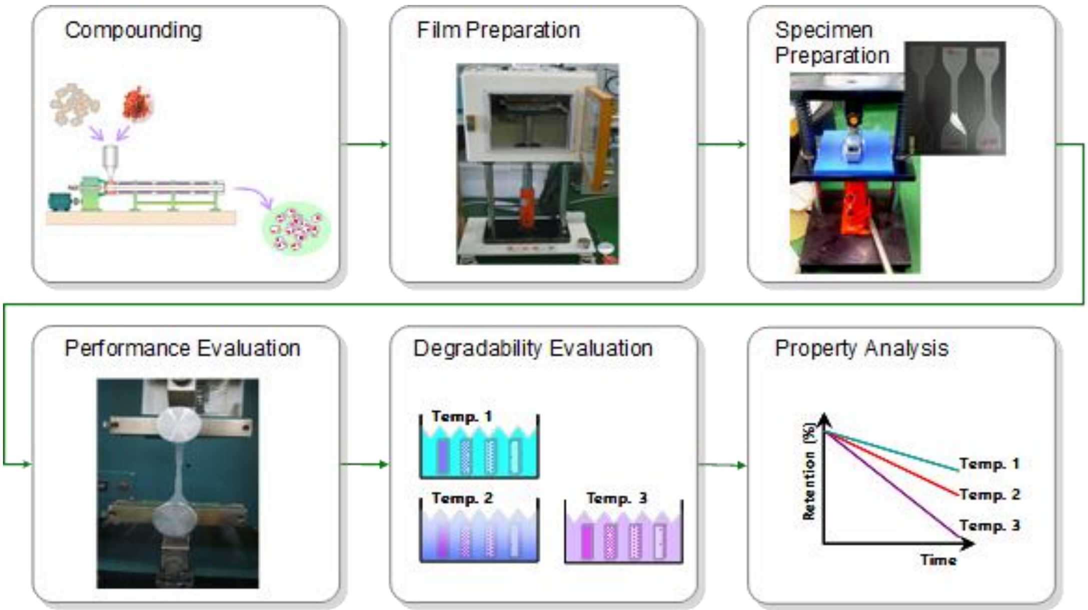

Figure 6. Test procesure of PLA for green geosynthetics

4 CONCLUSION

PLA 4032D/PBAT (80/20) blend shows improvement of environmental performance as a green geosynthetics application than PLA 4032D only used. However, more restricted design technology must be adopted for this and more specific composition and selection of optimum additives of PLA blending should be determined for the quality control of PLA related geo-synthetics. To evaluate the biodegradability of green geosynthetics performance, new test methods should be introduced and the needed evaluation items should be selected by considering influence parameters on the long-term performance under real field installation conditions.

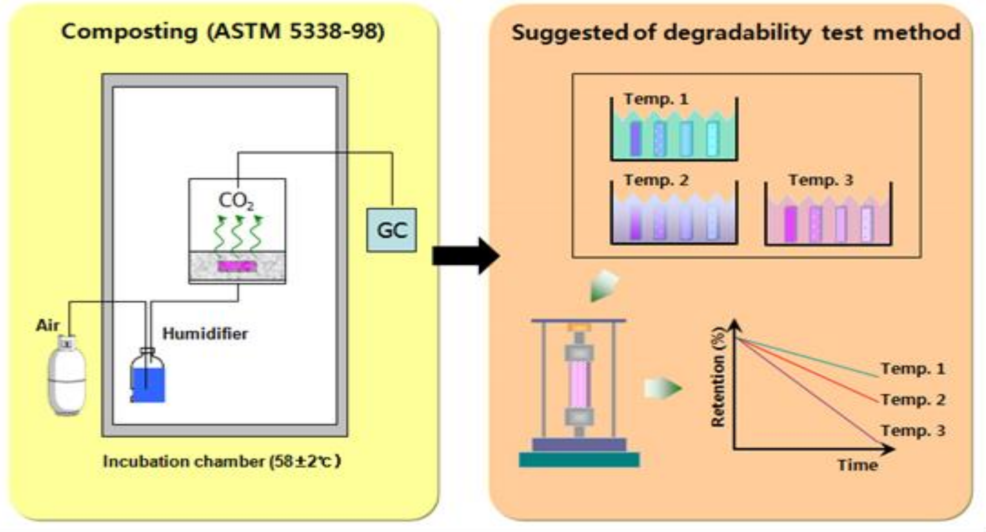

Figure 7. Suggested evaluation procedure of degradability of PLA.

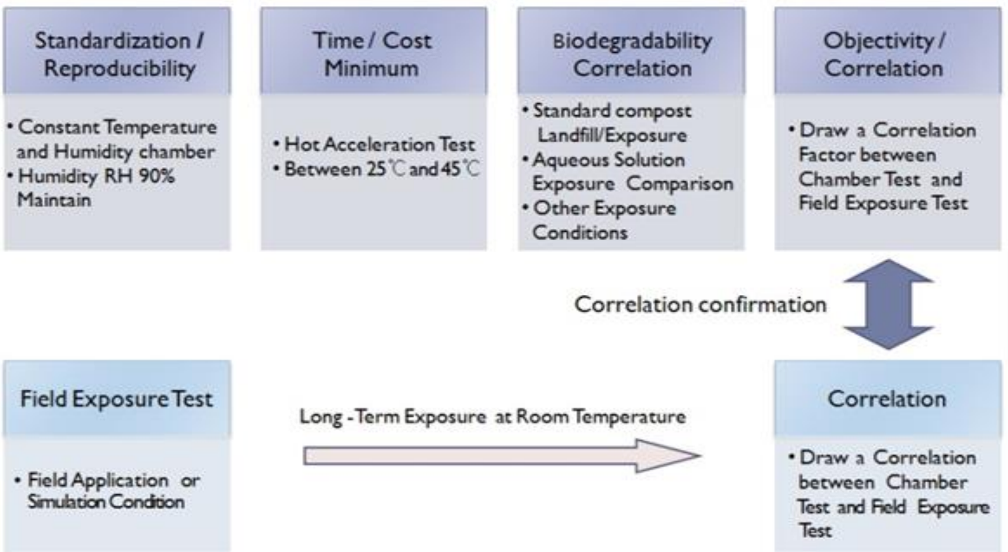

Figure 8. Proposal of standardization guide of biodegradability for green geosynthetics

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