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Review of Sustainable Geosynthetics by Eco-Friendly Environmental Concept and Degradation Related Test for Field Application

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ABSTRACT
In this study, eco-friendly environmental concept in PLA (poly lactic acid) geosynthetics application was reviewed and concept of green geosynthetics as a sustainable material was introduced in terms of biodegradability. Development of green 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 green geosynthetics were considered and suggested based on composting method. Finally, the rest result shows that the concept of biodegradability for green geosynthetics is available in the environmental application. PLA 4032D/PBAT (80/20) blend shows improvement of environmental performance as a green geosynthetics application than PLA 4032D only used.

1. INTRODUCTION

Green revolution by sustainable geosynthetics is rapidly increasing in every construction sites e.g., green structure, green installation, green industry etc. especially on the eco-environmental point of view. Biodegradable geosynthetics as a green material could be made from eco-environmental polymeric resins and they must maintain their needed performance during service period in the real field application. (Koerner. 2005 and Dixson et al. 2003)The important concept of biodegradable geosynthetics is focused on their degradable behaviors of used resins and needed performance for engineering qualification with evaluated technical data. Therefore, it is very important to select what kind of raw resin, additives and plasticizer to control the biodegradability. (Bastioli. 2005 and Tsuji. 2008) In this study, to consider this, environmental availability of biodegradable geosynthetics by PLA was introduced and reviewed to be related to the quantitative analysis of degradability as long as biodegradable geosynthetics are installed in soil structure. And technical availability of biodegradable geosynthetics was introduced as green geosynthetics and reviewed to be related to analysis of degradability by conceptual consideration. Through the overall review of degradability of biodegradable geosynthetics, it is seen that biodegradable mechanism could be controlled theoretically and more restricted design technology must be adopted in the quality control and assurance of manufacturing procedure in the installation field. Finally, to evaluate the degradable performance of biodegradable geosynthetics, new test concept and the needed evaluation items should be selected by considering influence parameters on the long-term performance under real field installation conditions.

2. EXPERIMENTAL

2.1 Physical Properties

The molecular distribution of PLA resins (NatureWorks Co. Ltd.) was investigated with gel permeation chromatography (Waters GPC system, 515 pump, 2410 RI detector, Styragel column, PS standard). Tensile properties were evaluated with universal testing machine (Hounsfield, H1000KS).

2.2 Hydrolysis Properties

To investigate the degradation behavior, strength retention was measured with PLA 4032D and 6201D. 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.

2.3 Enzymatic Degradation and UV Stability

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 film specimen was immersed in this solution for 4 weeks and and strength retention was determined. 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 hours and strength retention was determined by strength comparison before and after UV exposure condition.

2.4 Interface Frictional Property

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 Physical Properties of PLA

As shown in Table 1, PLA 6201D and 4032D showed similar polydispersity index (PDI), but PLA 4032D had a slightly higher molecular weight.

Table 1. Mechanical properties of PLA resins.

Grade	PDI***	Tensile strength (MPa)	Elongation at break (%)	Young's modulus (GPa)
PLA 6201D	1.5	61.1 ± 5.2	2.10±0.10	3.65±0.09
PLA 4032D	1.6	64.1 ± 2.3	2.23±0.00	3.38±0.21

***PDI means polydispersity index.

Tensile properties were measured with film specimens. There was no significant difference in tensile properties between two PLA resins, the maximum tensile strength was about 60 MPa and elongation was near 2.2%. As shown in Figure 1, PLA 6201D showed faster degradation than PLA 4032D which may be caused by the lower molecular weight.

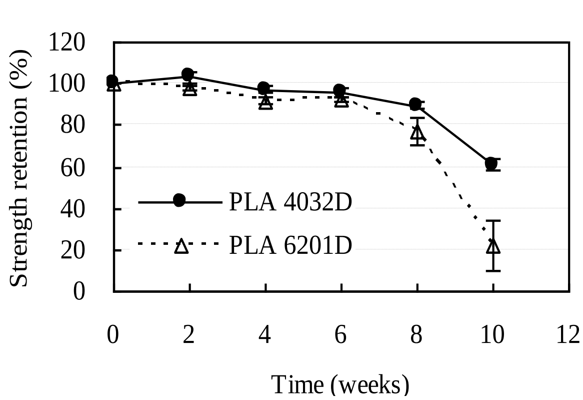

Figure 1. Strength retention of PLA at 45℃.

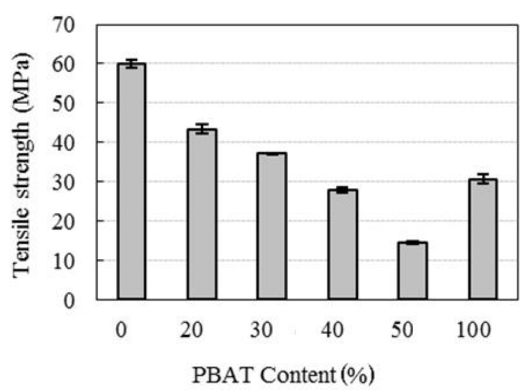

Figure 2. Tensile strength PLA 4032D/PBAT blends with blending ratio.

3.2 Mechanical Properties of PLA Bend

In Figure 2, 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 3 shows Young's modulus of PLA 4032D/PBAT blends and Young's modulus decreased with PBAT content increase. From this, it is seen that brittleness of PLA 4032D could be improved by blending with PBAT. Figure 4 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.

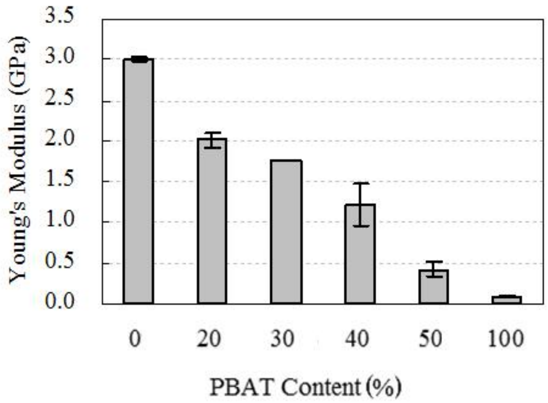

Figure 3. Young's modulus PLA 4032D/PBAT blends with blending ratio.

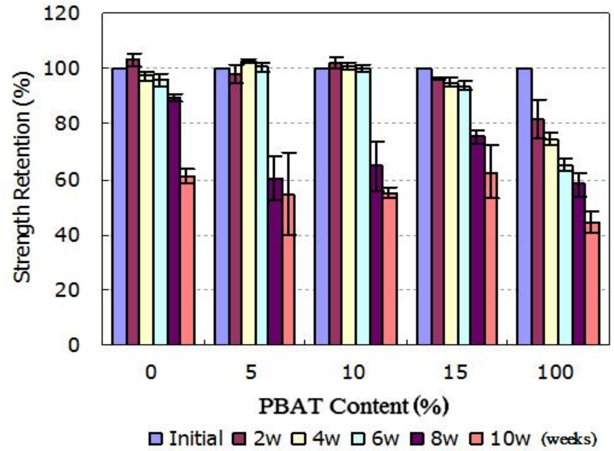

Figure 4. Breaking strength of PLA 4032D with PBAT content for burial times at 45℃.

3.3 Environmental Properties of PLA Blend

Figure 5 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. Also, Figure 5 shows tensile strength of PLA 4032D specimen which is blended with PBAT content and it is seen that tensile strength decreased with PBAT content. For blending case of 50/50 PLA 4032D/PBAT, tensile strength decreased about 30% of 100 PLA 4032D used. This means the additive content is a kind of important factor to affect and control the bio-degradability of green geosnthetics. Figure 6 shows strength retention after 4 weeks enzyme solution treatment and it is seen that strength decrease was occurred in enzyme solution. However, it is not easy to control degradation rate and test circumstance and therefore, this test method is very limited tool for prediction of PLA service time.

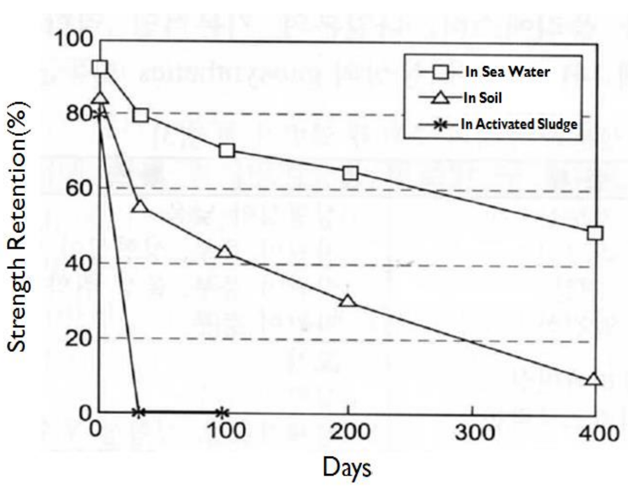

Figure 5. Strength retention of PLA 4032D under environmental exposure condition.

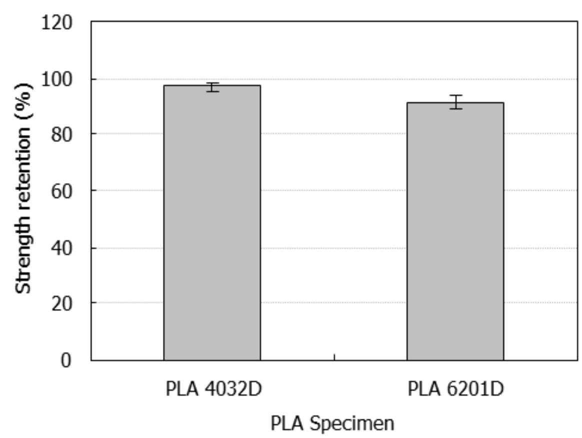

Figure 6. Strength retention of PLA after 4 weeks treatment in enzyme solution.

Figure 7 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.

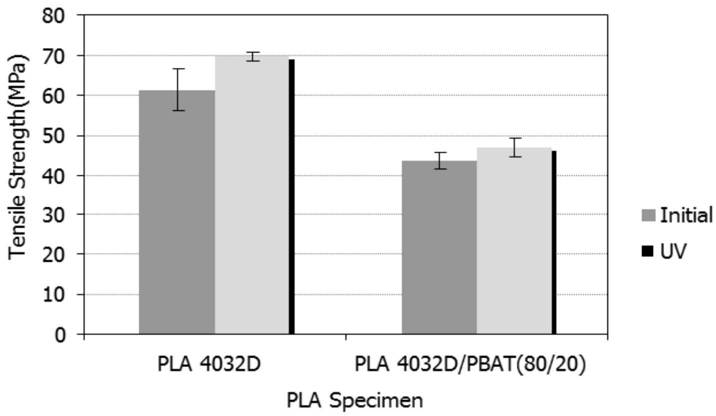

Figure 7. UV resistance of PLA 4032D and PLA 4032D/PBAT (80/20) blend with tensile strength.

Table 2 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 2. 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

3.4 Proposal of Biodegradability Evaluation

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 9 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.

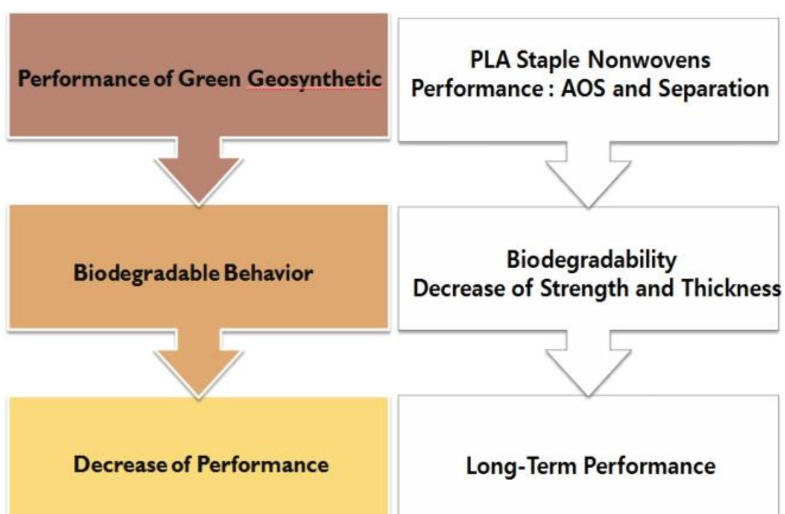

Figure 9. Quantitative concept for biodegradability evaluation of green geosynthetics.

Figure 10 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 11 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 behaviours with temperature and induce this to designing the green geosynthetics.

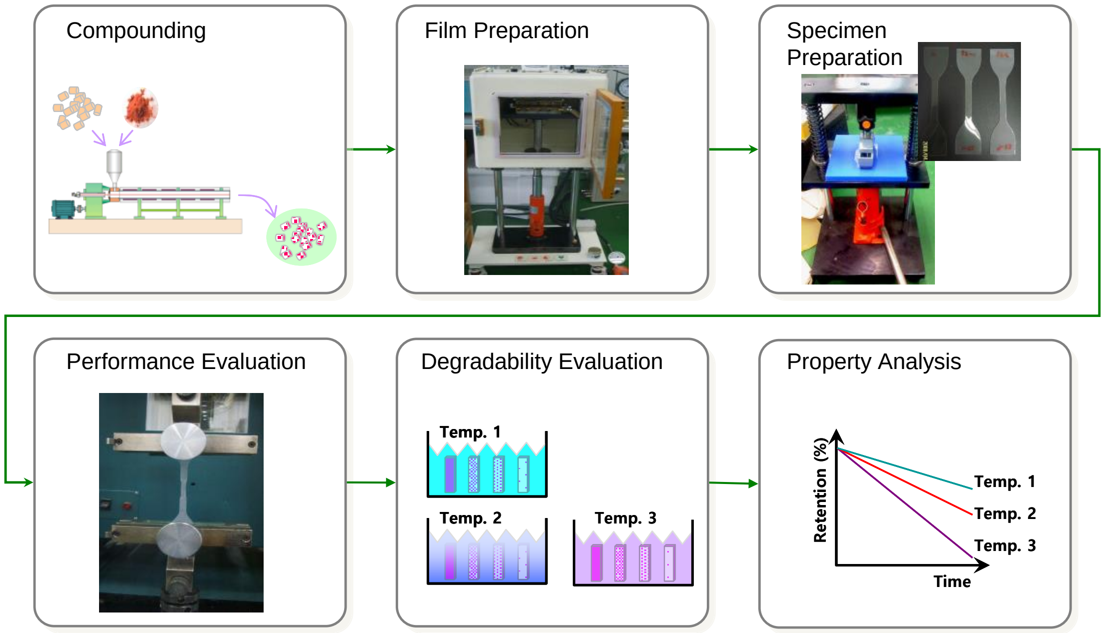

Figure 10. Test procesure of PLA for green geosynthetics.

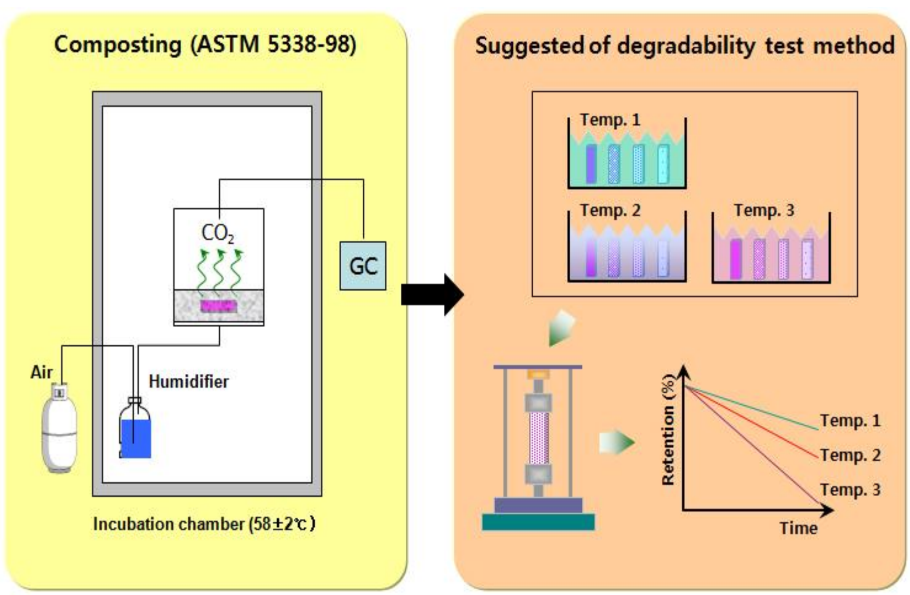

Figure 11. Suggested evaluation procedure of degradability of PLA.Spacing and Indenting.

Figure 12 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.

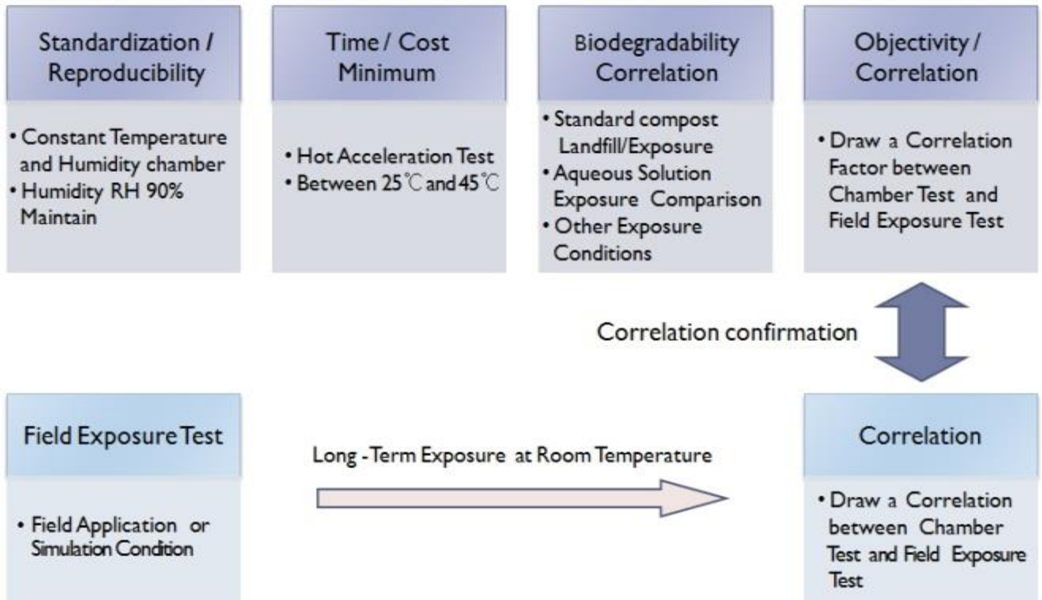

Figure 12. Proposal of standardization guide of biodegradability for green geosynthetics.

4. CONCLUSION

Through the overall environmental performance analysis of biodegradability as green geosynthetics, it is seen that biodegradable mechanism of is possible to control theoretically and to control bio-degradability of PLA used green geosynthetics. 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 geosynthetics. 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.

5. REFERENCES

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