Durability of Large-Scale 3D Printed Materials for Transportation Infrastructure

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Abstract

Large-format extrusion-based polymer Additive Manufacturing (AM) or 3D printing is being used for transportation infrastructure applications including culvert outlet diffusers and precast concrete formwork. This research assesses the durability and dimensional stability of thermoplastic composite material systems under different environmental exposure conditions. Accelerated exposure in the laboratory was conducted for moisture absorption, freeze-thaw cycles, and UV weathering. Specifically, this thesis investigates the use of bio-based renewable polymer composites for transportation infrastructure applications by correlating accelerated laboratory durability tests with site-specific environmental durability for selected applications.

The thesis compares the performance of bio-based composite materials, Wood Fiber/ Polylactic Acid, (WF/PLA), Wood Fiber/Amorphous Polylactic Acid, (WF/aPLA), and synthetic materials, Carbon Fiber/ Acrylonitrile Butadiene Styrene (CF/ABS). The durability of the material is evaluated using visual and quantitative surface analysis methods, dimensional stability, and retention of mechanical properties after accelerated exposure. The surface analysis methods implemented are Contact angle measurement and surface roughness measurement. The representative mechanical properties selected are flexural strength and flexural modulus.

Standard test methods for mechanical performance and durability assessment were adapted and implemented for large-format extrusion-based 3D printed materials to account for print toolpath and bead size. The performance of both semicrystalline and amorphous PLA polymer systems was evaluated and compared to determine the feasibility of these bio-based materials for 3D printed applications in transportation infrastructure. Non-contact full-field digital image correlation with the GOM Aramis system was used to measure strains and displacements in the flexure tests. The durability assessment is based on the retention of mechanical properties, surface analysis, and dimensional stability of exposed specimens relative to baseline specimens.

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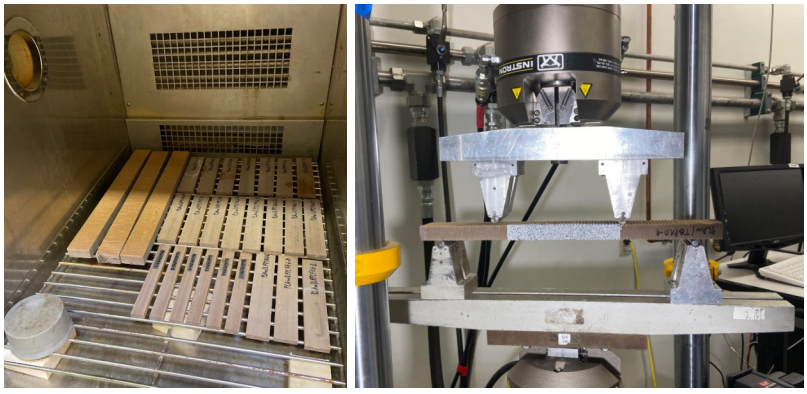

a) b)

Fig. 1: a) WF/PLA specimens in Espec environmental chamber, and b) Four-point bending mechanical test setup

References

[1] Bhandari, S.; Lopez-Anido, R.A.; Anderson J.; Mann A., "Large-Scale Extrusion-Based 3D Printing for Highway Culver Rehabilitation", In ANTEC 2021 Virtual Conference, SPE-Inspiring Plastics Professionals, 2021.