3D Printed Earth-Fiber Textiles

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ACM Reference Format:
Sherry Aine Te and Lola Ben-Alon. 2023. 3D Printed Earth-Fiber Textiles. In *Symposium on Computational Fabrication (SCF '23), October 08–10, 2023, New York City, NY, USA.* ACM, New York, NY, USA, 2 pages. https://doi.org/10.1145/3623263.3629160

1 INTRODUCTION

Fabric is a versatile material made of entwined fibers, serving as a fundamental component in everyday items, from clothing to architectural finishes (Kumar and Hu, 2018). 3D printed fabrics, like chain mail armors (Bradley, 2015), are crafted through additive manufacturing, featuring intricate designs and distinctive structural properties.

3D printing arranges reinforcement fibers in a three-dimensional framework within binder materials (Figure 1; Yu et al., 2021), improving strength, stiffness, and damage resistance by distributing loads in multiple directions (Compton and Lewis, 2014). These 3D structural fibers also introduce anisotropic properties, with mechanical characteristics that vary with load direction (Ma et al., 2019).

The use of natural materials in 3D printing lags behind synthetics. While 3D printing has advanced, most materials are synthetic polymers and metals, as natural materials, such as clay-based materials and plant fibers, exhibit wide variability that can affect performance.

This study aims to develop earth-fiber textile tectonics for flexible 3D printing in wearables and construction. It seeks to promote low-carbon fabric production using readily available materials. The key questions this research hopes to address are:

- What are the optimum 3D printing processing parameters for earth-fiber mixtures, including layer height, printing pace and speed, extrusion flow?
- What is the structural tearing capacity of different geometries considering digital weaving protocols?

2 METHODOLOGY

This research methodology (Figure 2) utilizes a 3D printing process that originates from a digital model, prepared in modeling software, Rhinoceros 7 (Robert McNeel and Associates, 2023), and processed through a slicer to transform into a g-code, which contains the geometric information. The material is then loaded and extruded using a PotterBot 10 Pro 3D printing machine (D Potter, 2023), and the printing parameters (nozzle size, speed factor, extrusion factor and layer height) are assessed. The experiments are evaluated based on their appearance and design results. Three geometrical iterations were tested for performance analysis: (1) plain weaving; (2) netting; and (3) printing on top of a fabric substrate.

ACM ISBN 979-8-4007-0319-5/23/10.
https://doi.org/10.1145/3623263.3629160

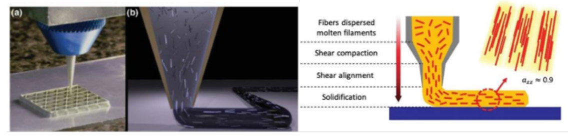

Figure 1: Orientation of fibers within an ink (Source: Compton and Lewis, 2014); High degree of material orientation in the printing direction (Source: Yu et al., 2021)

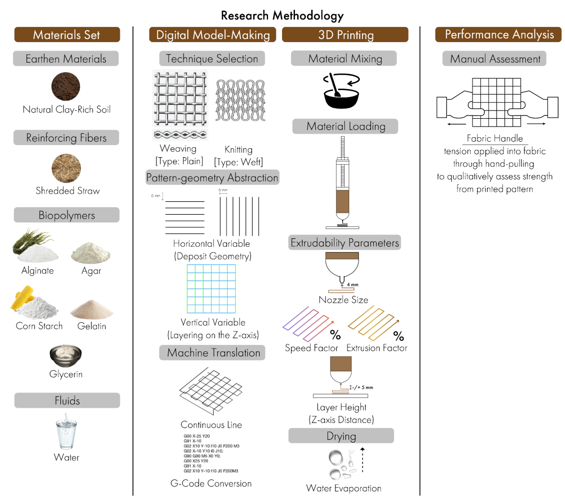

Figure 2: Research Methodology Diagram

2.1 Materials Set

The soil used in the fabric is harvested from the Hudson Valley, and consists of a brown-grey loam with approx. 10% clay content. Wheat straw was added to the mixture as a reinforcing agent, as well as food-grade polysaccharides, which acted as stabilizing agents.

2.2 Geometries

Multiple geometric iterations explored various mechanical and structural traits. They applied patching, netting, and mesh reinforcement techniques, abstracted from weaving mechanisms where layers represented wefting or warping. Geometries were categorized by density (line deposits per square unit) and complexity (pattern intricacy). Iterations were devised by combining layers from printing trials to enhance fabric buildability. For instance, in the mesh reinforcement iteration, each layer serves as structural

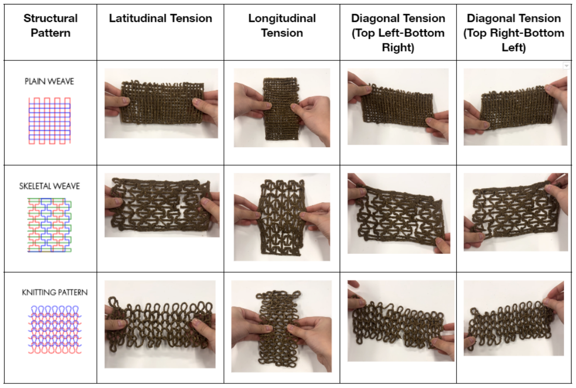

Figure 3: Results of Performance Analysis through Fabric Handle.

support, and due to the low pattern density, layers merge into one to form a fabric.

2.3 Performance Analysis

The resulting prints were tested to their diagonal stretch to assess the deviation of the fabric from its original pattern. The resulting prints were examined through manual application of 1) lateral tensile force, 2) longitudinal tensile force, 3) top-left, bottom right tensile force and 4) top-right, bottom left tensile force.

3 RESULTS AND DISCUSSION

Figure 3 summarizes the fabric stretch patterns. Plain Weave exhibits the highest overall strength but is weak diagonally. Skeletal Weave has the lowest strength and significant deviation from its pattern, also weak diagonally. Knitting Pattern falls in the middle with moderate lateral/longitudinal strength but weak diagonally. These insights inform geometric choices for fabric applications.

The results show that the strength of the fabrics highly correlates with geometry density; more line deposits create more fiber touchpoints in the soil mixture. Density also allows for vertical pattern stacking. Mechanical properties depend mostly on glycerin ratio; more glycerin enhances flexibility and smoothness, less glycerin results in stiffness. Layer height affects fabric flatness; lower heights distribute the soil mixture more flatly during extrusion.

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