On the Development of a 3D Printer for Combinatorial Structural Composite Research

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ABSTRACT

abstract

Biocomposite materials have enabled the fabrication of tough lightweight structures for load- and impact-bearing applications of which an example is fiber-reinforced plastics used in aerospace. If applied to the field of construction, biocomposite materials can save lives, otherwise lost to earthquakes and other disasters that cause collapse of buildings. The main culprit is the low resistance of structures exposed to dynamic shear stresses, typical of earthquakes. Recent work on the application of biocomposites to structural composites has clearly shown the advantage of these materials in resisting dynamic shear. Adding natural or synthetic reinforcement fibers may alleviate the need for conventional steel rebars and make it possible to print buildings by conventional 3D printing technology. The main hurdles are to find the right type of composite that is compatible with 3D printing and the right process for deposition of such material. In the past, combination of carbon fiber, glue and concrete has been demonstrated to enhance the toughness of resulting structural composites. Inspired by the microstructure of oyster and mother of pearl, laying down these materials mitigates the localization of deformation by distributing the imposed displacement over a large area. The intricate structure of these layers, and the minute details of the interfaces are important for affecting good dynamic shear resistance. It turns out, a partial slip of sandwiched layers occurs before it stops and deformation is transferred to the adjacent area. This energy-absorption capability underlies the high-toughness behavior of nacre and similar structures. By mimicking nacre, bone and tooth, it is possible to benefit from their good properties, however, it is important to determine the type of material, layering scheme, geometry, and other factors that affect mechanical properties. A recently-developed medium-sized 3D printer was developed to deposit structural materials. These include cement, plaster, polymer and clay. Combinatorial structural composite research (CSCR) comprising the simultaneous fabrication and characterization of multiple specimens with different microstructures allows fair comparison of mechanical properties of various structural composites. Novel application of deposition techniques to the extrusion of plaster, cement and clay paves the way to layer these materials along with glue and fibers in desired schemes. Use of ANCOVA tables in the selection of various types of ceramics, polymers and reinforcement materials for the fabrication of different composites will be discussed. In addition to selection of the type of the materials, deposition schemes such as those of solid and hollow structures, different layer thickness applications, and the effect of timing will be elucidated. Microscopy conducted on the fractured surfaces enables the investigation of the mechanisms of fracture and failure for these CSCR composites. The details of experiments conducted, microscopy performed and the results of mechanical tests will be presented.

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Topics: Composite materials