3D printing of geopolymer composites for the conversation of underwater wracks

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Motivation: Sunken ships and aircraft from World War II in the Baltic Sea are corroding, releasing hazardous substances, including white phosphorus, into the environment. To address this, structures with high concentrations of dangerous materials need to be sealed. A resistant geopolymer material is being developed from residual and waste materials, offering advantages like secondary recycling, waste reduction, and a lower environmental impact compared to traditional concrete.

Achievements/Results: Various geopolymer composites, including metakaolin, fly ash, amphibolite, rhyolite, and slag, were tested for casting and 3D printing using binder jetting (BJT) and material extrusion (MEX) technologies. MEX was chosen as it is more cost-effective and practical for mobile and underwater applications. However, issues with curing time arose. Metakaolin-based geopolymers cured too quickly, while fly ash-based composites took too long. The printer is being modified to mix in the curing agent just before material deposition to address these issues. The project also aims to replace composite materials with recycled or waste products.

In the initial stages, pre-casting methods and 3D printing were successfully developed, and the Polish market and IPR strategy were analyzed. The project explored slag from plasma combustion of toxic waste as a geopolymer filler, confirming its environmental viability. Amphibolite was found suitable for manufacturing underwater mounting nets. Recycled carbon fiber from wind farm recycling was selected to reinforce the composite.

WP3 focused on enhancing the material's antimicrobial properties to prevent microorganism growth in aqueous environments, leading to a publication and book chapter. Tests revealed the positive effects of slag on frost resistance but showed faster degradation with slag addition. Future research will focus on assessing composite absorbability and resistance to acids, salts, and alkalis.

Conclusions and Impact: Paste extrusion is suitable for 3D printing geopolymer composites, especially underwater, given the short pot life. Metakaolin and fly ash composites are effective for construction. Using stainless steel components helps prevent printer corrosion, ensuring longevity. To improve underwater printing, a mixing extruder should be used, and further exploration of waste materials as construction materials is encouraged.

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