Construction 3D Printing without Portland Cement

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The implementation of 3D printing in construction has gained traction due to its potential to improve efficiency in multiple ways, including material usage, construction time, and waste reduction [1–3]. In addition, the technology can enhance jobsite safety while enabling the fabrication of more complex, precise, and architecturally unique structures [1–3]. Despite these advantages, most current construction 3D printing technologies rely heavily on Ordinary Portland Cement (OPC) as the primary binder in printable mortar or concrete [4,5].

In many cases, construction 3D printing materials contain higher OPC content than conventional concrete or mortar, as they require increased paste content (binder + water) to ensure adequate pumpability and enable smooth transport through hoses from the mixer to the print head without clogging [1,6,7]. While this improves the material's printability, it also increases the overall cement consumption. As a result, 3D printing mortar and concrete often have a higher carbon footprint than conventional mixtures. This issue is significant because concrete production already contributes approximately 6-8% of global CO_2 emissions, largely due to the production of OPC, which emits approximately 0.7-1 ton of CO_2 per ton of cement produced [8,9].

To address this challenge, Eternite Materials, Inc. has developed Aeternum-3D™, a customizable 3D printing mortar/concrete system based on its proprietary, patented cement, Aeternum™. Aeternum uniquely combines widely available aluminosilicate clays and other common materials, enabling up to a 50% reduction in carbon footprint compared with conventional OPC-based printable materials [10] The global warming potential (GWP) of mortar made with Aeternum™ versus OPC is presented in **Figure 1**.

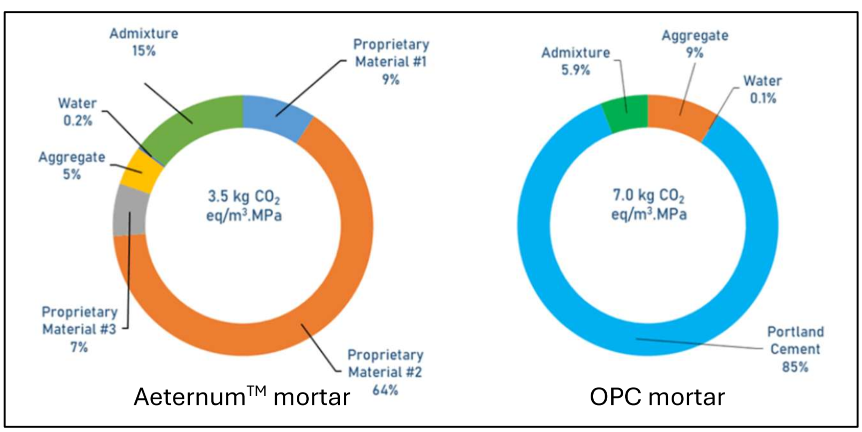

Figure 1. GWP of mortar made with (left) Aeternum™ and (right) OPC at the same binder content and comparable workability [10]

Utilizing Aeternum™ as its primary binder, Aeternum-3D™ can be tailored to be compatible with a variety of 3D printing systems and project requirements, including strength and durability targets. This adaptability allows engineers to optimize mixture design for specific applications, improving overall project efficiency while avoiding unnecessary overdesign.

In addition to its lower environmental impact and customizable performance, Aeternum-3D™ exhibits a noticeably brighter color than OPC-based materials, as shown in **Figure 2 (A and B vs. C)**. This higher reflectance can increase surface albedo, enabling the material to reflect more solar radiation. As a result, structures built with Aeternum-3D™ may demonstrate improved thermal performance and reduced heat absorption compared with darker OPC-based materials (study ongoing).

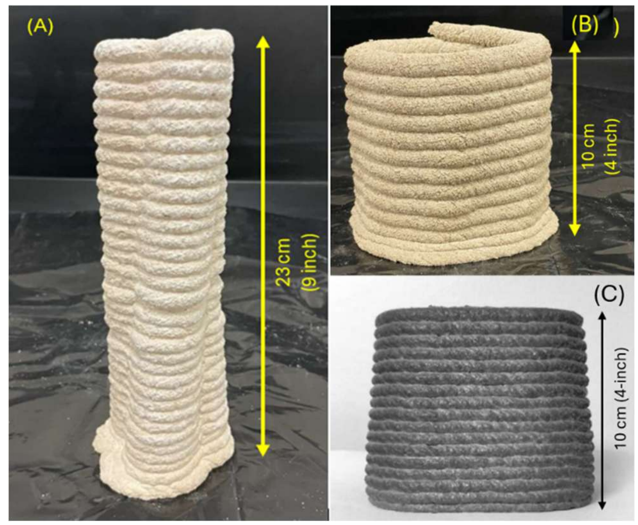

Figure 2. 3D-printed objects produced using Aeternum-3D™: **(A)** a twisted clover tower with approximately 5^0 rotations per inch of height; **(B)** a twisted hexagonal tower with approximately 5^0 rotations per inch of height; and **(C)** a specimen made using Portland cement as the binder [11]

The test prints shown in **Figure 2 (A) and (B)** are essential for evaluating the buildability of Aeternum-3D™, that is, the rate at which the material can be built vertically during printing without structural failure (e.g., collapse or significant deformation).

The printed specimen shown in **Figure 2 (A)** was completed within 4 minutes. Based on this result, the estimated buildability rate of Aeternum-3D™ exceeds 2 inches of vertical build per minute (>10ft/hr) for the given geometry. This vertical build rate is relatively high compared to several commercially available 3D printing mortars [2,12]. The compressive strength of Aeternum-3D™ (**Figure 3**) increases from about 2370 psi at 3 days to 3250 psi at 28 days and 3680 psi at 56 days, surpassing the 3000 psi target at 28 days and indicating strong performance with continued long-term strength development.

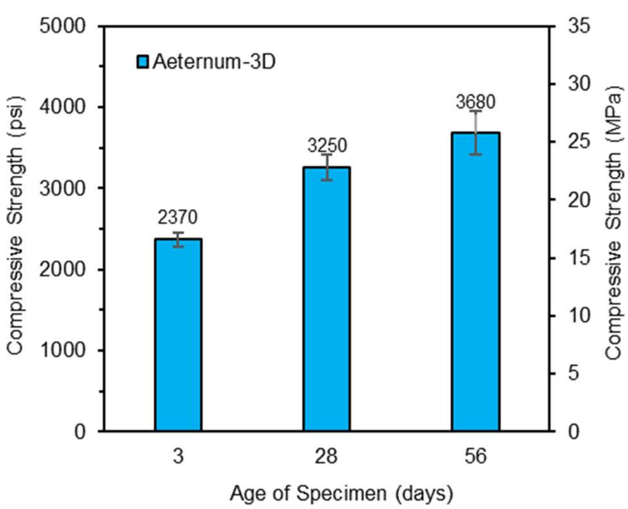

Figure 3. Compressive strength of Aeternum-3D™ with a target 28-day compressive strength of 3000 psi.

Based on both the test print performance and the measured compressive strength, Aeternum-3D™ demonstrates strong potential to further improve sustainability and performance in construction 3D printing applications.

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