AADR

PRINT ARCHI TECTURE !

Edited by

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Contents

You cannot resist an idea whose time has come *Victor Hugo*

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Turning ideas into successful and disruptive technologies is an extremely context-sensitive process. Place, time, resources, and parallel innovations in adjacent fields need to fall together to ignite innovation. This book portrays such a moment in time when Additive Manufacturing (AM) made the leap from the scale of product design to the dimension of entire buildings. Within a few years, AM matured from basic research to industrial applications in the Built Environment. The Built Environment – Additive Manufacturing (BE-AM) symposium, organized by the editors of this book, has been accompanying and moderating this process since 2015. The series of events did not only show the immense velocity of development, but it also revealed the vast amount of ingredients that need to be part of the recipe. This book seeks to shed light on those ingredients and how they together form novel technologies. While the presented projects in this book are witnesses of their time, they also form nodes within a larger network that spans over time, place, disciplines, technologies, and the demands of a broader socio-economical context. The time has come for AM to enter and

Figure 11. Una Casa Tutta D'un Pezzo: The use of a Binder Jetting process in construction was illustrated by Enrico Dini Image Source: Reproduced with the permission of Enrico Dini

Figure 12. Analytics from the BE-AM online database, as at July 2021 Source: www.BE-AM.de

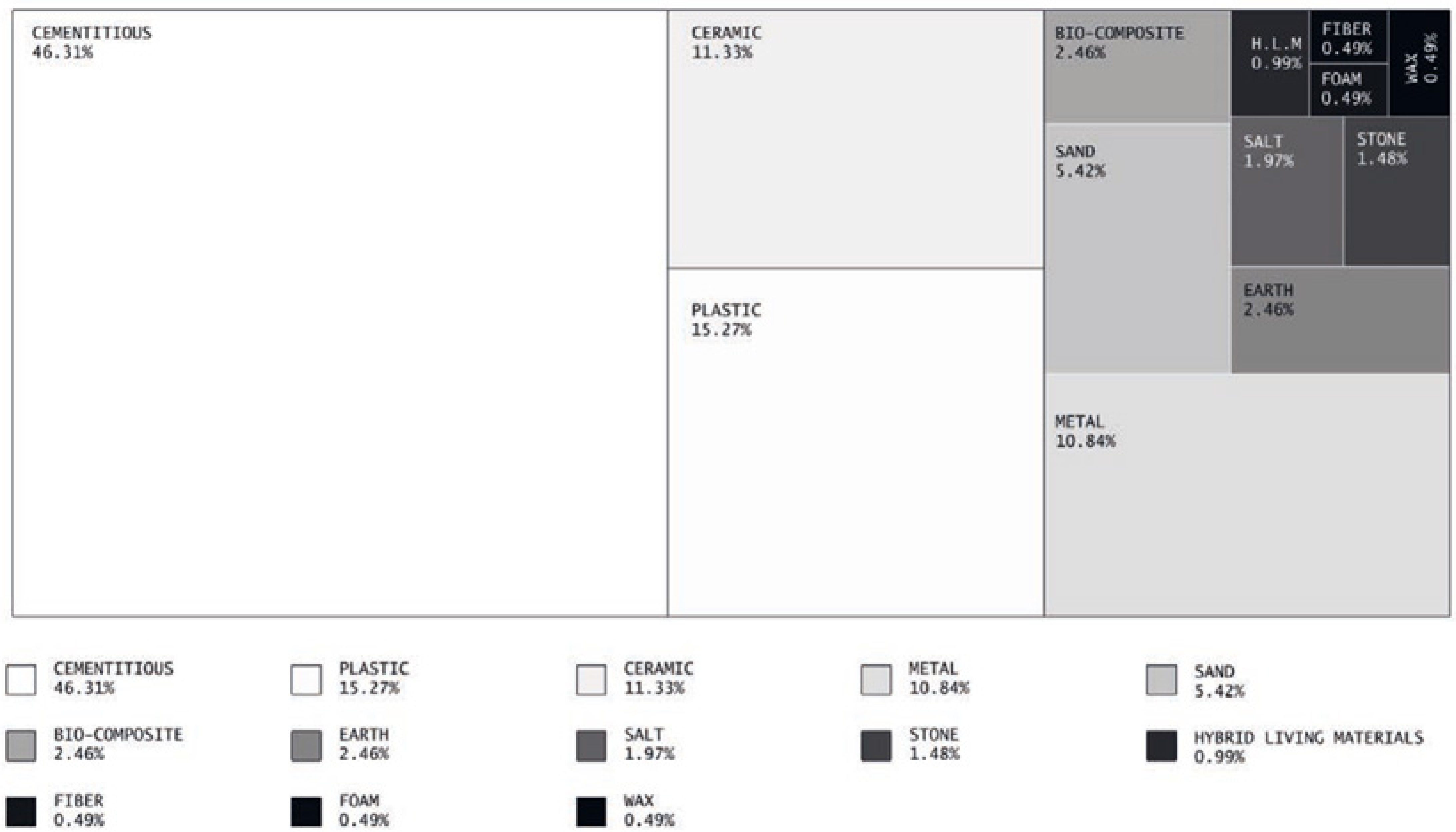

Figure 5: Helical pipes printed in mid-air

path to ensure an overall constant wall thickness even in regions with low local layer–heights. Local layerheights in one print could vary from 0.1mm to 1mm.

Defining a suitable orientation for the extruder nozzle at each point. One idea is to always print perpendicular to the last layer, but collision avoidance usually does not allow that and good compromises have to be found. Reducing robot vibrations and minimizing extrusion rate changes will result in noticeably cleaner prints. That smoothness is achieved by using the freedom the of the turntable, and more importantly by minimizing the nozzle orientation changes during the print.

Figures 4 and 5 show selected benchmark geometries during the printing process or as finished objects.

Outlook

The developed uv-slicing workflow worked better than expected. The benchmarks achieved were excellent, as were the project-specific final carbon PA prints. We are open to future collaborations in multi-axis printing and non-planar slicing in particular. So many robot-based 3D printing projects only use a downward-pointing nozzle – let us change that.

I personally want to reprint some benchmarks in ceramics, because I like the material aesthetics as well as the immediate recyclability.

Figure 4: View from TECLA house at night

design. Thanks to this and the addition of natural fibres and binders (NHL) as specified for the particular mix design, it is possible to obtain a printable mortar with 95% local raw material.

Printable mortar is produced through the use of the wet pan mill, a rotating kneading machine into which water is added. Mixing with a muller allows you to make a homogeneous and well-kneaded mixture effectively and quickly. Once the mixture is ready, it is conveyed through continuous pumping systems to the extruder inlet with constant flow and pressure regulated by specific sensors.

Crane System

Since 2016, WASP has been working on the WASP Crane system in order to produce 3D-printed houses in the shortest possible time and in the most sustainable way. Crane WASP is the world's first modular and multilevel 3D printer designed to collaboratively build individual and even more extensive architectural works.

The system is configured according to project needs, establishing the conditions for a safe and extremely efficient construction site. Each printer unit has a printing area of 50m2 and this makes it possible to build independent living modules with consistent shaping freedom.

For the first time, multiple printing arms have been synchronized inside a construction site just as on an industrial production line. Thanks to a software synthesis of years of research in WASP, the system is capable of optimizing movements, avoiding collisions and ensuring

Figure 5: A network of modular WASP printers allowed for multiple areas of the structure to be printed simultaneously without collision

simultaneous operation. The redundancy of the system allows a consistent reduction of the printing time and the possibility of carrying out ordinary maintenance during the printing.

Tecla

TECLA is a prototype of sustainable habitat developed by WASP and Mario Cucinella Architects to show the potential of 3D-printing technology when applied to earthen based architecture. It is a demonstration that 3D technology is able to create buildings by optimizing the construction process and minimizing the use of human and energy resources. The double dome solution made it possible to meet the demand for structure, roof and external cladding, making the house high-performance on all aspects.

TECLA can be synthesized in 200 hours of printing, using 7000 machine codes (G-code), 350 layers of 12mm, 150km of extrusion and 60m3 of natural materials, for an average consumption of less than 6kW.

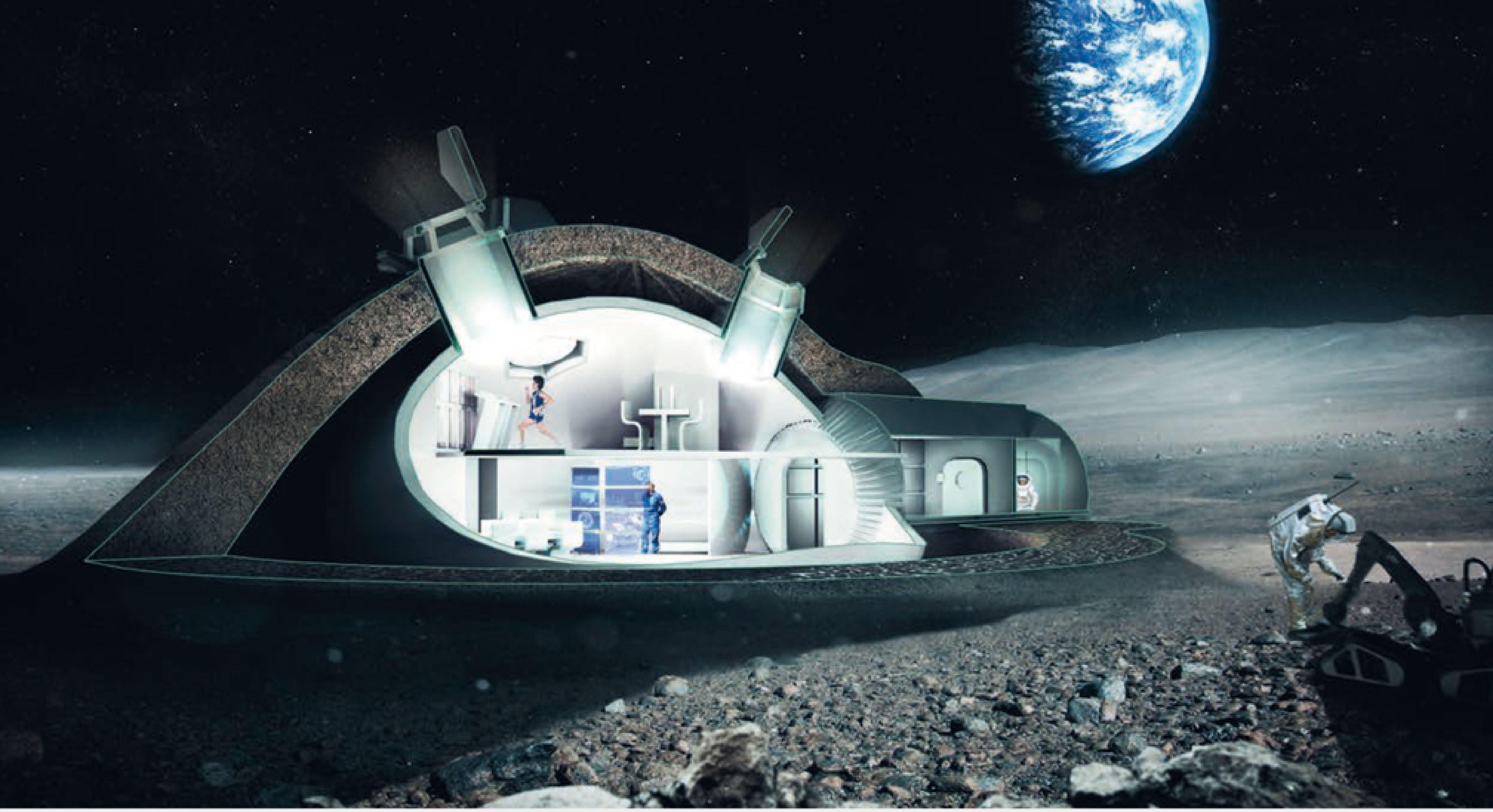

Figure 1: Lunar outpost near the moon's south pole

Lunar habitation

Foster + Partners

Foster + Partners is part of a consortium set up by the European Space Agency to explore the possibilities of 3D printing to construct lunar habitations. Addressing the challenges of transporting materials to the moon, the study is investigating the use of lunar soil, known as regolith, as building matter.

The practice has designed a lunar base to house four people, which can offer protection from meteorites, gamma radiation and high temperature fluctuations. The base is first unfolded from a tubular module that can be transported by space rocket. An inflatable dome then extends from one end of this cylinder to provide a support structure for construction. Layers of regolith are then built up over the dome by a robot-operated 3D printer to create a protective shell. To ensure strength while keeping the amount of binding "ink" to a minimum, the shell is made up of a hollow closed cellular structure similar to foam.

The practice designed the geometry of the structure in collaboration with consortium partners – it is groundbreaking in demonstrating the potential of 3D printing to create structures that are close to natural biological systems.

Simulated lunar soil has been used to create a 1.5 tonne mockup and 3D printing tests have been undertaken at a smaller scale in a vacuum chamber to echo lunar conditions. The

Figure 2: Façade mockup featuring a 3D-printed node

research partners imagine computation, Rossmanith Fassade, Kegelmann Technik and TU-Darmstadt. The system is designed around a 3D-printed aluminium node, incorporating geometric and functional complexity while reducing the complexity of adjacent elements.

The idea behind the system is to combine the benefits of Additive Manufacturing with the benefits of other conventional manufacturing techniques within an assembly. To avoid complications while mounting the elements, a key requirement for the joint design was to allow movement during assembly only in directions perpendicular to the beam's axis.

A similar system could be realized using subtractive manufacturing techniques. However, the higher geometric freedom of 3D printing processes allows for better solutions.

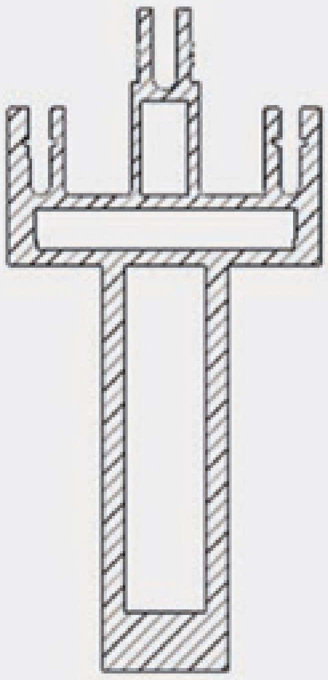

Figure 3: Detail of 3D-printed node in façade mockup

Figure 1: Proposal for a 3D-printed Façade for Deutsches Museum Munich.
Design: 3F Studio - Mungenast Tessin Morroni (Image: nuur)

3D-printed façade

Moritz Mungengast

Figure 1: The gates form three-dimensional frames that focuses the view.

Figure 6: Around 4,000 tiles that will cover the two gates. 3D-printed ceramic is a high-quality cladding material that requires low maintenance and offers high durability.

straints and internal support structure—were taken into account when the geometry of the tiles was generated. Because the tiles are being 3D printed, applying variations to their shapes allows for poetic ways of "painting with shapes". This is done, for example, by applying a white runny glaze on the convex portions of the tiles (the hills) while allowing for blue glaze pools in the concave (valley) areas of the tiles. This allows for smooth transitions between hues of blue and white that are impossible to produce otherwise.

3D-printed ceramic is a high-quality cladding material that offers low maintenance and high durability in even the most corrosive environments such as deserts and coastal areas. As such, the potential for 3D-printed ceramics goes far beyond the applications within Delft, and for this reason it will also be applied in a design by Studio RAP for a residential high-rise project.

Credits

Client: BPD, Ballast Nedam Development; Architect New Delft Blue: Studio RAP Architect PoortMeesters: VY Architects

3D ceramic printing: Studio RAP

Figure 1: The Pots Plus
(Image: Stefanos Tsakiri)

From plastic waste to furniture with robotic 3D-printing

Foteini Setaki

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WHERE IDEAS TAKE SHAPE.
Make the impossible possible!
We know that additive manufacturing offers undreamed-of potential. In addition to the printer, however, you also need the upstream and downstream processes plus the experts, who have mastered the technology. You'll only find all this at the AM highlight Formnext in November.
For knowledge transfer, industry news and connecting with the AM community all year round visit
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We live in a time when 3D printing has matured from a hobbyist and prototyping tool to a technology with potential to disrupt entire industries in and around the built environment. The developments in additive manufacturing are transforming architecture and design no less than they impact engineering and construction. The book portrays the rapid advances in research and industrial processes that have paved the road for this upheaval.

In five chapters that cover historical development, engineering aspects, the digital design process, interactions with other technologies and potential for functionalization through additive manufacturing, the editors have curated a text that illustrates how a complex network of actors inspires and influences each other to make this technological transformation possible.

The book follows the trail of scientists who prove the technology's viability and documents design explorations, prototypes and entire buildings that are demonstrating their readiness for the commercial market.

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