

RETHINKING CREATIVITY

ETH Meets You in Davos
During the World Economic Forum's Annual Meeting
21 – 24 January 2020

Concrete Choreography

Students of the [Master of Advanced Studies in Digital Fabrication \(MAS DFAB\)](#) from ETH Zurich investigated how emerging digital technologies could be used to create a contemporary take on the column typology - a key feature of architecture for thousands of years.

This novel concrete printing process was developed through an interdisciplinary collaboration between [Digital Building Technologies](#) and [Physical Chemistry of Building Materials](#), both research groups of ETH Zurich that are supported by the National Center of Competence in Research in [Digital Fabrication \(NCCR DFab\)](#).

In addition to supporting the weight of a structure, traditionally columns have been decorated to increase a building's aesthetic appeal. In fact, columns have been so integral to the human environment that they are often used in non-structural ways, as monuments or purely decorative features.

Furthermore, those columns have been made from concrete, which is the most widely used substance on earth, after water. By some estimates, concrete is [responsible for as much as eight per cent of the world's CO2](#) and consumes a 10th of the world's industrial water, which renders it an environmental challenge. We are reliant on concrete and that will not change in the near future, but any technology that enables us to use less concrete is hugely beneficial.

Therefore, the MAS DFAB students were keen to explore the possibilities that could be unlocked by new design paradigms and fabrication methods in the realm of concrete. The result was *Concrete Choreography*, an installation first seen at Riom, Switzerland, for the Origen Festival of Culture in the summer of 2019. The installation consists of nine columns, each 2.7 metres high, produced during a 10-week project. Transported by truck to the site in the Swiss alps, the pillars formed a stage and an interactive environment, in which dancers would perform.

Further research into design, material and reinforcement allowed the printing process to become more robust. In December 2019, a new version of the installation, including more slender post-tensioned columns, have been constructed for the ETH Zurich Pavilion in Davos during the World Economic Forum's Annual Meeting 2020.

The pillars have been fabricated by a fully-automated, robot 3D printer that built them up, layer-by-layer, at a rate of 180 millimetres per second. Now, one three-meters-tall column takes less than two hours to print, using a special fast-setting concrete mix.

Background Information

The aesthetic potential of this new approach is demonstrated in the designs: each of the columns has its own fluid shape and surface texture. They were created using computational design, a process in which computers generate possible geometries based on parameters set by human designers. This allows complex designs to be developed and tested far more quickly than otherwise because computers handle much of the complexity and form variation.

However, printing the final designs, including surface ornamentation, was no simple matter. In fact, it was achievable only because the concrete 3D printer can print in 'high resolution' with each layer just five millimetres thick and 25 millimetres wide.

Adding to its aesthetic possibilities, this new process could introduce a more ecological way of building with concrete. The layering process means that the pillars can be hollow, so they use less material than traditional methods of construction. They also do not require any 'formwork' during the construction process.

Formwork is a mould, usually made from wood or steel, into which concrete is poured and held in shape while it sets. Usually it is temporary, though sometimes the formwork becomes part of the completed structure. Eliminating the formwork also means using fewer materials, which adds to the durability of this method.

Through the archetypical shape of the column, Concrete Choreography explores the formal language of concrete 3D printed architectural components. The combination of an age-old material with a cutting-edge fabrication processes challenges us to rethinking design for more sustainable concrete constructions.

In the ETH Zurich Pavilion alongside the World Economic Forum's Annual Meeting 2020 in Davos, Switzerland

- **Project Team:** Ana Anton, Eleni Skevaki, Yoana Taseva, Prof. Benjamin Dillenburger (Digital Building Technologies, ETH Zurich), Lex Reiter, Prof. Robert J. Flatt (Physical Chemistry of Building Materials, ETH Zurich)
- **Technical Support:** Michael Lyrenmann, Philippe Fleischmann, Andreas Reusser, Heinz Richner
- **Funding:** This research was supported by the NCCR Digital Fabrication, funded by the Swiss National Science Foundation (NCCR Digital Fabrication Agreement #51NF40-141853), the Partnership Council for Sustainable Construction / Digital Fabrication, and by Siemens, Geberit and the ETH Zürich Foundation.

At Scientifica 2019: Science Fiction, Science Fact

- **Design and fabrication:** Ana Anton, Angela Yoo, Patrick Bedarf (Digital Building Technologies, ETH Zurich), Lex Reiter (Physical Chemistry of Building Materials, ETH Zurich), Lukas Gebhard (Concrete Structures and Bridge Design, ETH Zurich)
- **Technical support:** Michael Lyrenmann, Philippe Fleischmann, Andreas Reusser, Tobias Hartmann
- **Column data**
 - Print-time: 110 min
 - Print-path length: 1.1 km
 - Layer height: 5 mm
 - Total height: 3.1 m
 - Volume of concrete: 150 L

Background Information

At the Origen Summer Festival 2019, Riom, Switzerland

- **Concrete 3D Printing Research:** Ana Anton, Prof. Benjamin Dillenburger (Digital Building Technologies, ETH Zurich), Lex Reiter, Timothy Wangler, Prof. Robert J. Flatt (Physical Chemistry of Building Materials, ETH Zurich)
- **Tutors:** Ana Anton, Patrick Bedarf, Angela Yoo, Timothy Wangler
- **Students:** MAS DFAB 2018-2019 | ETH Zurich
Aya Shaker Ali, Chaoyu Du, Eleni Skevaki, Jesus Barney, Jonas Van den Bulcke, Keerthana Udaykumar, Nicolas Feihl, Nik Eftekhar Olivo, Noor Khader, Rahul Girish, Sofia Michopoulou, Ying-Shiuan Chen, Yoana Taseva, Yuta Akizuki, Wenqian Yang
- **Origen Foundation:** Giovanni Netzer, Irene Gazzillo, Guido Luzio, Flavia Kistler
- **Technical Support:** Michael Lyrenmann, Philippe Fleischmann, Andreas Reusser, Heinz Richner
- **Supported by:** Debrunner Acifer Bewehrungen AG, LafargeHolcim, Elotex, Imerys Aluminates
- **One column in numbers:**
Column Height: 2.70 m
Print-path length: 1.6 km
Print-time: 180 min
Print-speed: 180 mm/sec
Layer width: 25 mm
Layer height: 5 mm

Publications / References

- Anton, A., Yoo, A., Bedarf, P., Reiter, L., Wangler, T., Dillenburger, B. (2019). 'Vertical Modulations: Computational design for concrete 3D printed columns', *ACADIA 2019 – Ubiquity and Autonomy* conference proceedings, Austin Texas.
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- Reiter, L. (2019). "Structural Build-Up for Digital Fabrication with Concrete - Materials, Methods and Processes", ETH Zürich.
- Wangler, T., Roussel, N., Bos, F. P., Salet, T., and Flatt, R. J. (2019). 'Digital Concrete: A Review', *Cement and Concrete Research*, 123, pp. 2-17.
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Links to Bios

Digital Building Technologies, ETH Zurich
Physical Chemistry of Building Materials, ETH Zurich
NCCR Digital Fabrication
Master of Advanced Studies ETH in Architecture and Digital Fabrication

Background Information

Images and Video Material

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Stage Design for The Origen Summer Festival
2019

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Stage Design for The Origen Summer Festival
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Stage Design for The Origen Summer Festival
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3D printing process ongoing interdisciplinary research at ETH Zurich
© Keerthana Udaykumar, Digital Building Technologies ETH Zurich



3D printing process ongoing interdisciplinary research at ETH Zurich
© Axel Crettenand, Digital Building Technologies ETH Zurich



Columns inside The Robotic Fabrication Lab at ETH Zurich
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Background Information



Transportation and assembly: loading the columns at ETH Zurich
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Transportation and assembly: unloading the columns in Riom, CH
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Transportation and assembly: placing the columns on-site in Riom, CH.
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Opening performance of Concrete Choreography with Dancer Riikka Läser in Riom, CH.
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Details and surface texture of 3D printed concrete.

© Angela Yoo, Digital Building Technologies
ETH Zurich



Event: EX HORTO EDEN, with dancers Christoph Schaller, Lucie Horna and Stefanie Fischer; a choreography by Beate Vollack.

© Bowie Verschuuren



Concrete 3D Printed Colum, Scientifica 2019:
Science Fiction Science Fact

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Background Information



Concrete textured surface of a Concrete 3D Printed Colum, Scientifica 2019: Science Fiction Science Fact
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Post-tensioned system for a Concrete 3D Printed Colum, Scientifica 2019: Science Fiction Science Fact
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Background Information



Concrete Choreography

<https://www.youtube.com/watch?v=rvd20U-QgKw>

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