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# The CorkCrete Arch

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1 The CorkCrete Arch assembled in the Faculty of Architecture of the University of Porto.

Developed by the Digital Fabrication Lab (DFL-FAUP), the CorkCrete Arch was a design-based research work concerned with using robotic fabrication technologies as design drivers for the production of a novel building system (Brookes 2018). By exploring the combination of two different materials – cork and concrete (GRC - glass-fiber reinforced concrete) - the goal was to merge the sustainable and insulation properties of the first with the structural efficiency of the second (Sousa et al. 2015, Sousa et al. 2016). The result is a lightweight and performative material system suited for customized prefabrication and easy on-site installation. From the production point of view, this project represented a complex challenge. Since it is not a single material installation, as many robotic experiments are, the process had to coordinate the different physical tolerances resulting from employing diverse materials and fabrication processes (i.e. robotic and manual).

To do so, the design and material deployment of the Arch were envisioned from the beginning in an algorithmic fashion. This allowed its full development in a single parametric design environment, from conception to materialization. Based in the catenary curve, the geometry of the arch was conceived to challenge the different fabrication processes required for its material production. Aiming at employing a milling process, the outer face of the cork panels was designed as a double curved surface with a customized engraved texture. The inner surface was kept flat in order to avoid an extra milling process and production time. This decision explains the emergence of a segmented line in the arch, separating the cork and the GRC materials. Aiming at using hotwire

PRODUCTION NOTES

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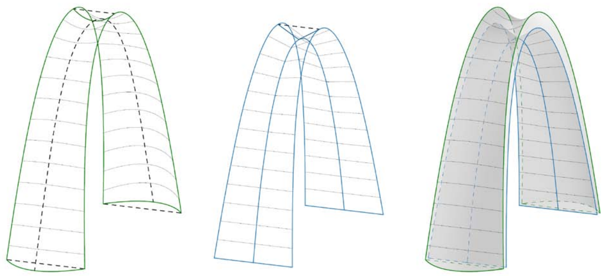
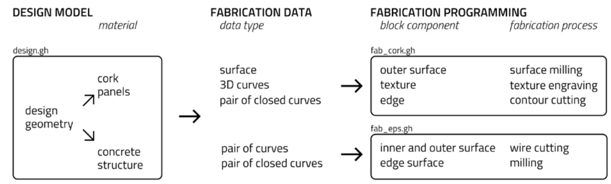
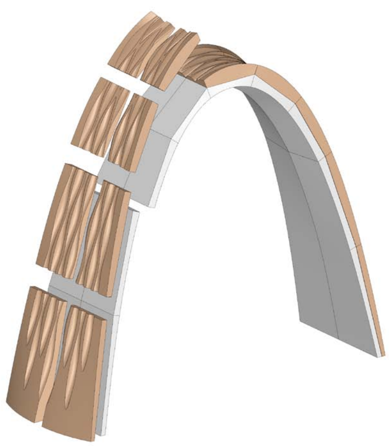
|---|---|
| Project: | José Pedro Sousa |
| Team: | Pedro de Azambuja Varela |
| | Pedro Filipe Martins |
| Production: | DFL - CEAU/FAUP<br>Digital Fabrication Lab<br>Faculty of Architecture<br>University of Porto |
| Partners: | Amorim Isolamentos |
| | Mota Engil |
| Materials: | Concrete (GRC) |
| | Cork (MDFacade) |
| Location: | Porto |
| Date: | 2015 |



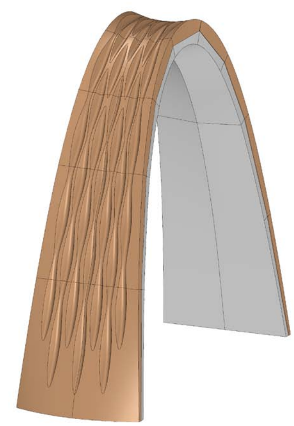
2 Geometry generator lines. In green, the cork surface, in blue the GRC surface.




3 The digital continuum process from design to manufacturing with Rhinoceros / Grasshopper / KukaPrc.



4 Simulation of the separation of the arch in its constituent parts. Cork is represented in brown and concrete (GRC) in gray.

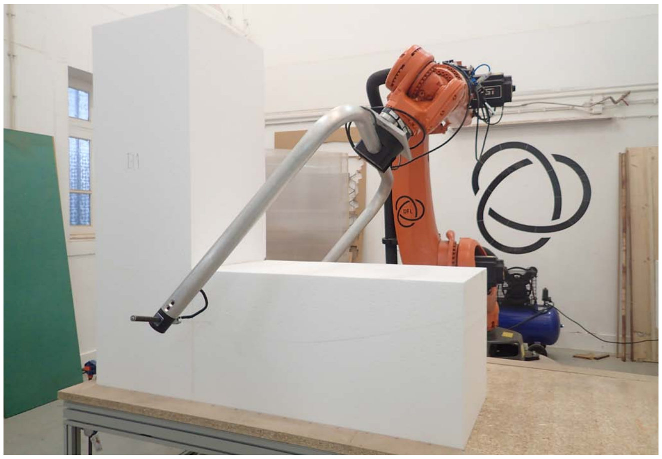


5 Simulation of the complete CorkCrete Arch.

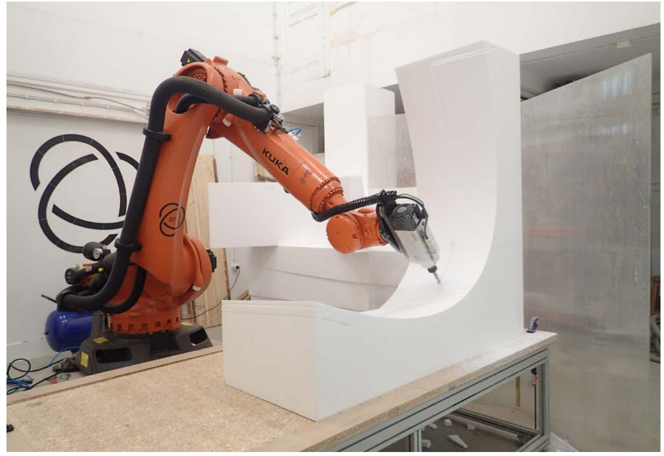
cutting (Feringa and Søndergaard 2014), the inner surface of the GRC panels was designed as a ruled surface featuring a subtle crease effect in the top. Although it resembles a classic form, the shape of the structure has thus specific geometry details that challenge the use of robotic fabrication technologies.

All the robotic works for fabricating the cork panels and EPS molds took place at the DFL laboratory. The fabrication of the cork panels involved a sequence of 3 steps: machining the double-curved surface, engraving the variable texture, and finally cutting the skewed contour. Regarding the fabrication of the EPS molds for the GRC panels, a more elaborated process was followed. Using robotic hot-wire cutting, two curved slices were cut from EPS blocks and the perimeter contour was cut through robotic milling. While the resulting outer part was glued to the bottom curved surface to define a frame for the projection of the GRC, the inner part was saved to be later inserted inside the GRC panel. The wasted material from the molds production was thus embedded in the final structure to provide a smooth surface for fixing the cork panels. The EPS molds were then shipped to the precast Factory of Mota Engil and used for the manual projection of a 15mm thin layer of GRC material.

Once completed, the CorkCrete Arch was manually assembled several times, and in different places, which proved the ease of construction due to the lightness of this building construction system. From the structural point of view, it was stable enough to be installed on the FAUP garden without any fixation to the ground. From the aesthetic point of view, the contrasts between the cork and the concrete materials (e.g. dark/bright, textured/smooth, soft/hard...) triggered the curiosity of the people who felt compelled to visit and touch it. From the technological point of view, robotic fabrication proved to be a flexible and precise process to manufacture building components. The techniques employed in the production of the CorkCrete Arch opened possibilities for real industrial implementations. Future research avenues will explore the CorkCrete system in the design and construction of larger structures.



6 Robotic hotwire cutting of the EPS moulds surfaces.



7 Robotic trimming the contours of the EPS moulds.

8 Manual spray of GRC into the mould.

9 Final GRC panel suspended after demoulding.

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## ACKNOWLEDGEMENTS


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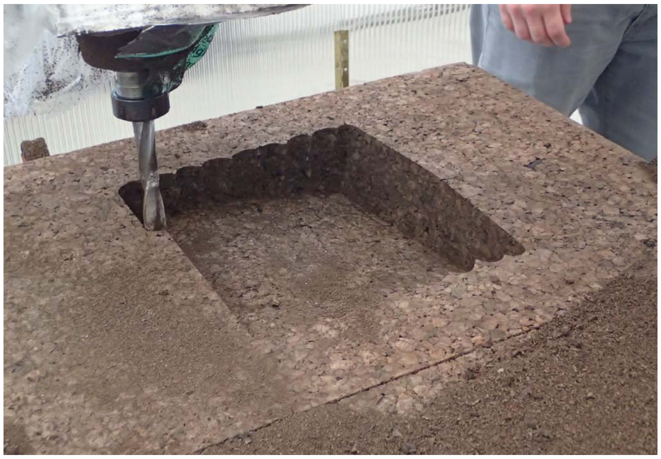

10 Robotic milling the outer surface of the cork panels.

11 Robotic engraving of the texture.

12 Robotic cutting the panels' contour.

13 Aspect of the finalized cork panels.

**José Pedro Sousa** is Assistant Professor and the Director of the Digital Fabrication Laboratory (DFL), at the Faculty of Architecture of the University of Porto (FAUP). Graduated in Architecture from FAUP, he has a Master in Genetic Architectures from ESARQ-UIC (Barcelona), a PhD in Architecture from the University of Lisbon, and was a Special Student at MIT and a Visiting Scholar at UPenn (USA). He has developed an intensive professional activity merging the realms of teaching, research and practice, with a focus in exploring the conceptual and material opportunities in architecture emerging from the use of computational design and digital fabrication technologies.

**Pedro de Azambuja Varela** is an architect and PhD researcher with the Digital Fabrication Lab (DFL), at the Faculty of Architecture of the University of Porto (FAUP). After working in architecture offices in Vienna and New York and developing his own practice AZVAvisuals mainly focused in visualization for architecture, completes a post-graduation in Digital Architecture (CEAAD) in 2013 and in 2014 enrolls in the PhD program of FAUP. Concurrently to the development of various cork vaulted experiments and pavilions, Pedro is actively developing his PhD thesis in the Digital Fabrication Laboratory at FAUP, where he regularly publishes papers on Stereotomy.

**Pedro Filipe Martins** is an architect and PhD researcher with the Digital Fabrication Lab (DFL), at the Faculty of Architecture of the University of Porto (FAUP), focusing on the application of robotics in concrete construction. Graduated from the Architecture Department at the University of Coimbra in 2006, where he also currently teaches, in the MSc program. After developing experience in several architectural practices, received a PhD grant for graduate studies at FAUP. His research is being developed on the integration of digital fabrication technologies in concrete construction and architecture, with an emphasis on the use of robotic strategies for complex, non-standard concrete prefabrication.

**14** Assembly of the GRC panels.

**15** Fixation of cork panels.

**16** Underneath view of the GRC geometry.

**17** View of the outer cork texture.

**18** View of the CorkCrete Arch in the Faculty of Architecture of the University of Porto.