The ACORN, the SQUIRREL and the OAK | Towards a circular, segmented, concrete shell system as sustainable building floor thanks to automated construction, computational design and digital fabrication

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Statement | The construction industry is responsible for about **50% of the carbon emissions**. We need to reduce the environmental impact of our concrete structures. Building clever and efficiently has the potential to **save 50%** of carbon of a structure. Savings in our **building floors** represent a large-scale potential impact. As concrete's natural behaviour is **compression**, **shell structures** allow reducing both concrete mass and tensile reinforcement.

ACORN | VISION ON SUSTAINABLE CONCRETE FLOORS

By using a **low-carbon structural system**, relying on a **reconfigurable concrete formwork** and leveraging **circularity of construction**, the ACORN project on Automating Concrete Construction envisions how our apartment and office buildings can become more sustainable to **reduce the environmental impact** of our construction industry. Towards an alternative solution for **building floors**, ACORN proposes an efficient **concrete shell** made of segments that are digitally **prefabricated off-site** and swiftly **assembled on-site** (Fig.1). The **shell behaviour** favours compression stresses, removes the need for a high level of complex reinforcement, easing fabrication, lowering the carbon footprint and allowing concrete recycling. The shear key connections shaped as **half-joints** provide assembly guides, prevent sliding failure, and are reversible for disassembly and reuse. They act as supports for the successive shell segments during the assembly, requiring only a set of telescopic props for positioning and decentring the shell.

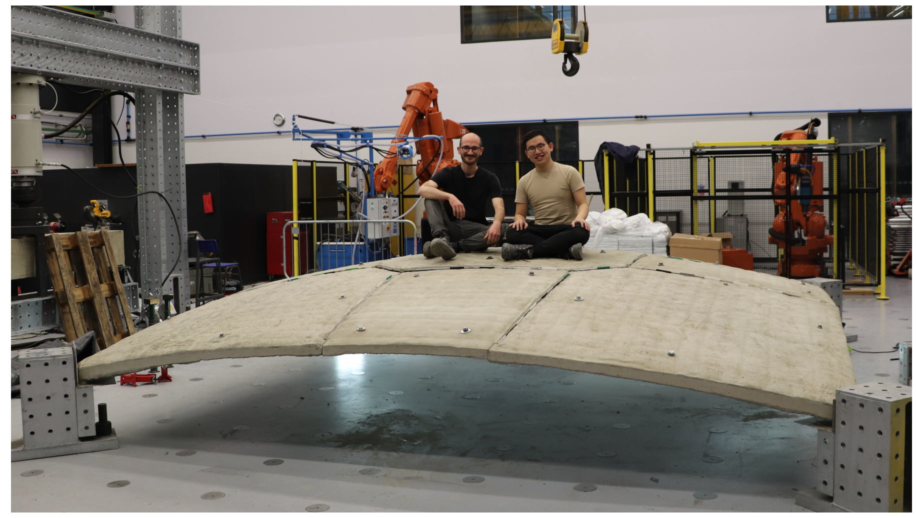

Fig.1: Physical demonstrator of a segmented concrete shell fabricated off-site for on-site assembly and potential dis/re-assembly for circularity.

Fig.2: Automated robotic concrete spraying of a shell segment on a reconfigurable pind-bed mould supporting a flexible formwork.

SQUIRREL | INTEGRATED FRAMEWORK FOR COMPUTATIONAL DESIGN & DIGITAL FABRICATION

Benefitting from off-site fabrication and factory automation, the efficient but geometrically-complex doubly-curved shell segments are produced using a 2m x 2m **reconfigurable reusable mould** of actuated vertical pins that support a **flexible formwork** consisting of composite strips, saving carbon and waste as opposed to single-use custom formwork moulds for concrete shells. The large concrete segments with variable thickness and strenghtening ribs are cast precisely and rapidly through **robotic concrete spraying** with a 2m reach and at a rate of 12kg/min (Fig.2). These fabrication abilities and constraints inform the **digital design and optimisation** process to guarantee the buildability of the shell, following a **construction-aware design** approach. To drive acceptance of this new culture in the construction industry, the SQUIRREL framework will provide an **end-to-end digital tool** for the integrated design and fabrication of these shells by structural engineers.

OAK | LARGE-SCALE DEMONSTRATOR

The OAK **physical prototype** demonstrates the potential and feasibility of the project with its 9 concrete segments spanning **4.5m x 4.5m** for a rise of 0.55m. The concrete material consists of fine-grained concrete with glass-fibre reinforcement to provide some ductility and a minimum tensile capacity against the variety of load cases a floor experiences. The thickness varies from 30mm at the apex to 60mm at the supports, for an average of $1/100^{th}$ the span. A set of ribs that follow the natural force flow stiffen the shell (Fig.3). The resulting shell floor system only weighs **100kg/m^2** while fulfilling the classic dead and live load cases and combinations. Thanks to its reversible connections, the shell will be reassembled several times: for testing the assembly process, for showcasing its integration into a **complete structural unit** with columns, ties and a raised floor, and for assessing its load bearing capacity and further understand its structural behaviour.

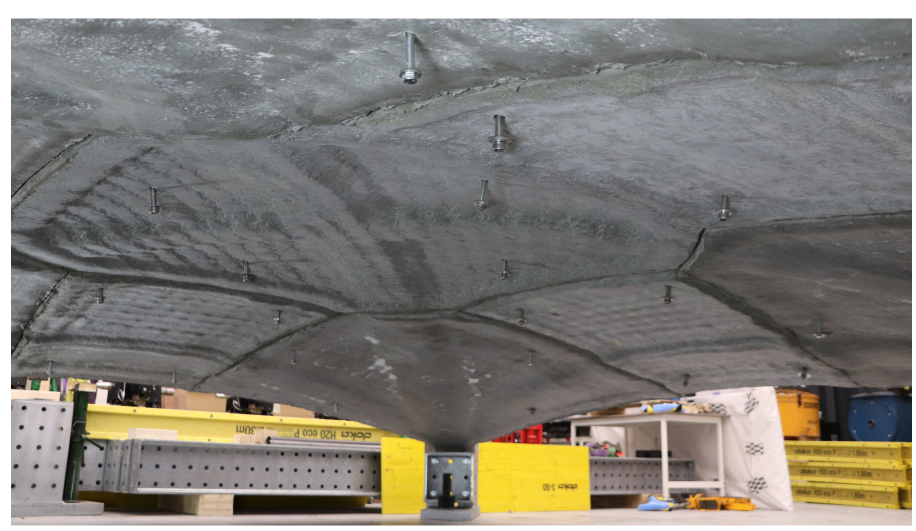

Fig.3: Concrete materiality displaying structural behaviour and fabrication process: shell segmentation, rib pattern, and spray texture.

The ACORN project on Automating Concrete Construction is funded by UKRI through the ISCF Transforming Construction programme (grant number EP/S031316/1)

https://automated.construction/

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