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CCFF

Robotic Concrete Extrusion for Funicular Formworks

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Synopsis

Today architectural workflows for the development of complex geome-tries and their translation to physical objects rely on computational processes. The generation of form has become intrinsically tied to computer simulation in response to data sets and external information. Prior to the advent of these technologies, forms were generated and understood through analogue methodologies that depended on the behavior of the material in response to a set of physical conditions. The ambition of the research, 'Catenary Concrete Funicular Formwork' (CCFF), is to investigate hi/low tech possibilities for generating form and space at the interstices of the digital and the handmade. The study leverages the use of physical catenary and funicular modeling in conjunction with the precision of robotic concrete extrusion for the development of pattern-based thin concrete shells.

Key words: Architecture, concrete, patterns, robotics, 3D printing.

1. Introduction

"It may be noted that although reinforced concrete has been used for over a hundred years and with increasing interest during the last decades, few of its properties and potentials have been fully exploited so far. Apart from the unconquerable inertia of our own minds, which do not seem to be able to adopt freely any new ideas, the main cause of this delay is a trivial technicality: the need to prepare wooden forms."

With these words, Pier Luigi Nervi question material practices with respect to the use of concrete. It is a statement of provocation for disrupting standard practice in favor of alternative methods for working with concrete. Like Nervi, other architects and engineers during this time were also attempting to push the boundaries of the material by reconceiving this a priori heavy and brutal material as something light, delicate and thin. Within this vein of thought, today's architects and designers are once again being hindered by the same 'trivial technicalities' that Nervi referred to. In an attempt to explore new possibilities for material practice, the research CCFF attempts to break away from our preconceived notions of how to work with concrete.

2.1. Historical Context

Reflecting on modern concrete, reveals that, the material as we know it today, has a very short history, with stone construction being its predecessor. As a point of departure, Catenary Concrete Funicular Formwork focused on two historical periods in architecture.

2.1.1. From Romanesque to Gothic

Stone in compression seems like a good material to build mountains but not buildings, with the exception of those in the form of caves. Indeed, typical Romanesque stone structures were dark and cavernous like caves in the mountain, where mass was needed in order to allow structural forces to be dispersed as much as possible.

With the rise of the Gothic structural systems, this began to change. Forces were engineered through slender columns, buttresses and vaults, resulting in a minimal structure, that provided incredibly elevated light filled spatial experiences. Not only did this period change our methods for construction, but, culturally, it shifted our perception of the material itself. This change allowed a highly intricate arrangement of stone patterns that communicated impermanence, lightness and fragility – all things that embody spirituality and a higher order. (Fig. 1).

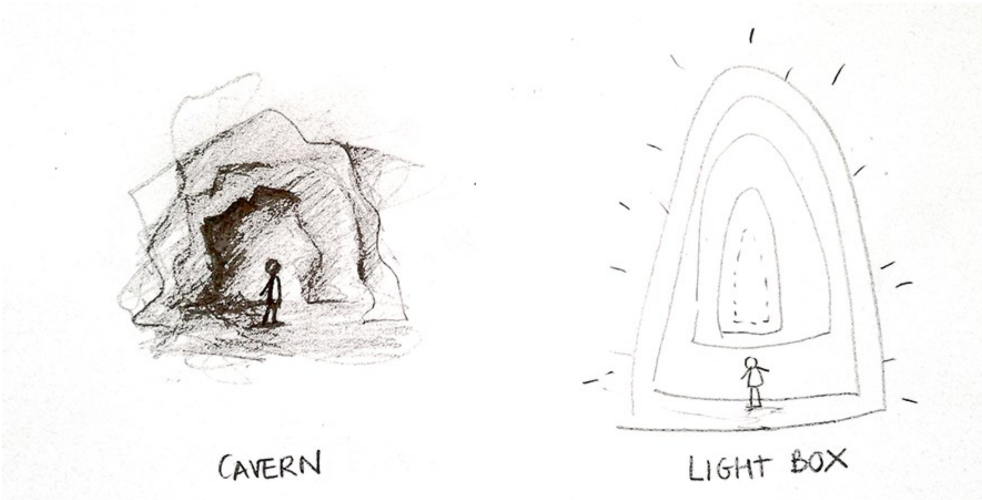

Figure 1.

2.1.2. Isler, Nevi and Fisac

From this point forward, and moving into the XX century, architects inherit modern concrete as the new stone making, searching for methods to creat even lighter architectures by reinventing this heavy material through a refined understanding of structural principles and new technologies.

During the sixties, one of the new approaches to form-finding with a heavy material like concrete can be seen in the work of Swiss engineer Heinz Isler. His experiments to identify ideal lighter and thinner forms for concrete shells produced nearly an infinite spectrum of possibilities based on the simple principles of catenaries. In the same period, the work of Pier Luigi Nervi was based on the limitations of the capacity of concrete and its improvement through the introduction of formal folds, curvatures, corrugations and patterns in a surface. Alternatively, the work of the Spanish architect Miguel Fisac explored the formal expressiveness of this material by exposing concretes plasticity. Using very rudimentary flexible formworks, Fisac revealed the true nature of concrete, which he believed to be the materials genetic imprint. (Fig. 2).

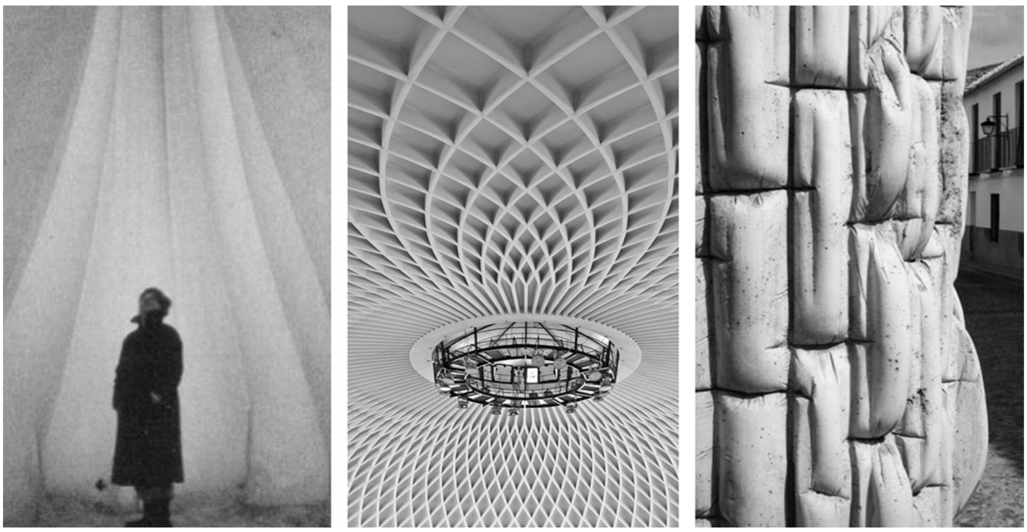

Figure 2.

3.1. Catenary Concrete Funicular Formwork

Borrowing these craft form-finding methods, CCFF adopts the one that Isler most commonly used to find the ideal shape of his thin shell concrete structures: the 'Hanging cloth reversed'. For this method, Isler would apply a thin coat of plaster to the cloth and allow it to deform under its own weight. Once this composite hardened, it could be reversed to produce a self-supporting structural shape. Learning from this process, the objective of the research is to create malleable, lightweight shells, but rather than creating them thin and continuous as Isler’s, the investigation focused on making them permeable and plastic.

3.1.1. Neo-gothic robotics through making

The process required a high level of control over how the concrete was deposited onto a flat cloth that would later be hung. A precision that was more akin to the gothic artisans’ ability to “draw” thin lines with stone for creating an intricate lattice like structural system. Therefore, the research leveraged a hybrid method where the physical catenary and funicular modeling was combined with the field of robotics and cement extrusion for the development of pattern-based thin shells.

The research began by carefully exploring cement mixes in conjunction with tool development. By manually depositing cement through pastry bags, allowed for an initial understanding of the material but the process was limited in consistency and accuracy. This difficulty in controlling the flow of the concrete and pattern led to an exploration of the use of robotics and the 3D printing technique known as Contour Crafting. This stage of the research leveraged readily available rapid prototyping technology for the development of an extrusion tool that can be fitted to the end of a six-axis robotic arm. (Fig. 3) Through the integration of robotic extrusion, the depositing process was precisely controlled, allowing for intricate interlacing and repetition of patterns without the need for a traditional formwork.

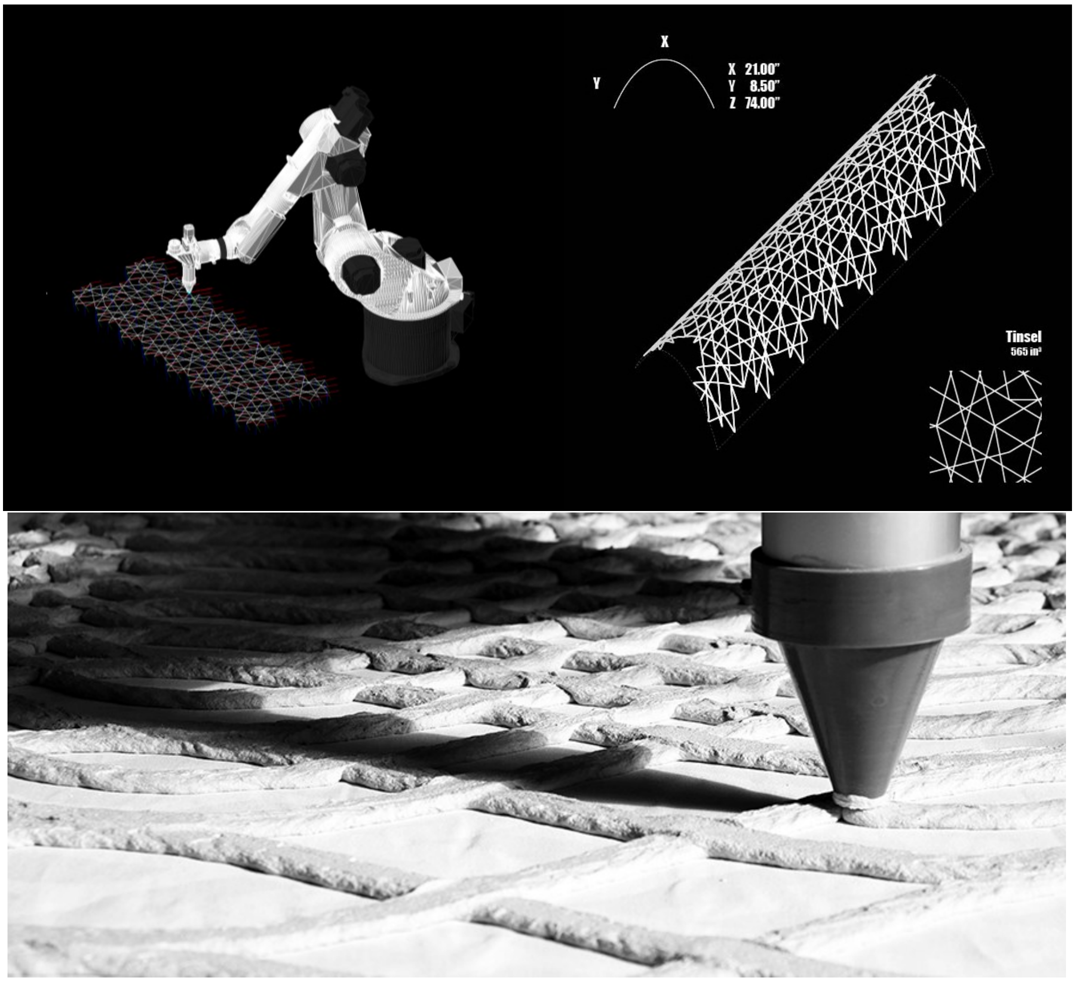

Figure 3.

4. Conclusions

The potentials of the plasticity of the research leverages the use of physical catenary and funicular modeling, the handmade, in conjunction with the precision of robotic cement extrusion, the digital. While fabric formed architecture and concrete has been around for some time, the application of material computation to achieve complex patterns and geometries using low-tech construction processes is yet to be explored.

The result of the research (Fig. 4) is a sampling of the attempt to unify the delicacy of material computation and artistic imperfection of hybrid formed structural screens through a material typically thought to be rough and heavy. The combination of fabric formwork and cement extruding is not a replacement for conventional ways of casting but questions the material process traditionally associated with it. At the same time it offers new possibilities in the use of contour crafting for the precise production of architectural objects that question the possibilities of scale, permeability, weightlessness that may be achieved with a material like concrete.

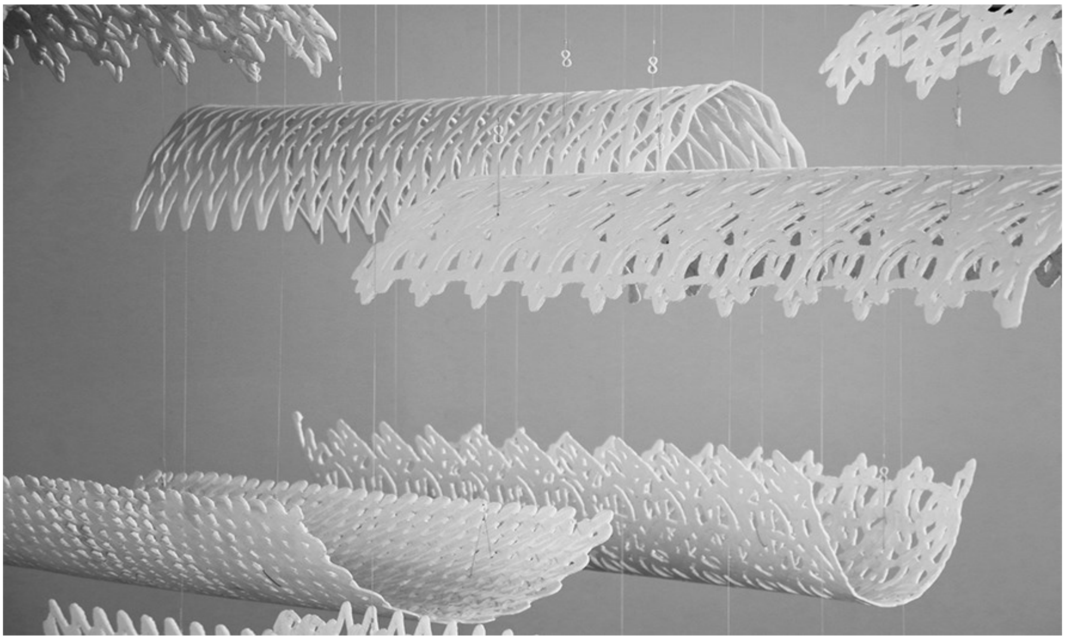

Figure 4.

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Biography

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Jonathan Rule. Assistant Professor of Practice at the University of Michigan, Taubman College of Architecture and Urban Planning. His research looks to recalibrate past methods of design, making and construction through new possibilities provided by advancements in fabrication technologies. Rule received a Bachelor of Science in Architecture from the State University of New York at Buffalo, a Master in Architecture from the Harvard Graduate School of Design and an homologación de titulo from the Escuela Técnica Superior de Arquitectura de Madrid.