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VACUUMATICS 3D-FORMWORK SYSTEMS: CUSTOMISED FREE-FORM SOLIDIFICATION

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Summary: The form flexibility and adaptability of vacuumatics enables them to be effectively applied as fully flexible and adaptable formwork systems to create geometrically complex shapes and customised surface textures in concrete.

1 INTRODUCTION

In contemporary building design it cannot be ignored that so-called “blobs” (from: binary large object) are very current phenomena. In reality, these “free forms” of buildings and structures are realised by applying a pre-formed (decorative) skin onto a regular primary or secondary, mostly rectilinear, load-bearing structure. The main reason for this building method can be found in the fact that the current building industry is mainly rectilinearly oriented, and thus not capable of anticipating to the 3-dimensional free-form tendency in architectural design. A different approach to design as well as manufacturing is required in modern building design. This paper introduces an adaptable moulding technique to create complex 3-dimensional geometries in concrete, citing ongoing research on Vacuumatics 3D-Formwork Systems (figure 1).

Figure 1: Vacuumatics 3D-Formwork Systems

2 FREE-FORM MATERIALISATION

From a material point of view it would seem evident to use curable liquid-like materials to create the desired irregular and fluent shapes. Concrete for instance is a strong material in solidified state yet fluid in origin. It has therefore practically unlimited form possibilities. The latest developments in concrete technology, like Ultra High Performance Concrete (UHPC), Fibre Reinforced Concrete (FRC) and Self-Compacting Concrete (SCC), enlarge the potential of concrete as a structural material. The limiting factor at the moment, with respect to the acceptance of concrete in the free-form design practice, is the manufacturability and adaptability of its formwork system. Any change in shape or surface texture can be regarded as complex, time-consuming, labour-intensive and thus financially unattractive. What is needed is a flexible and adaptable formwork system to realise the requested geometrically complex shapes and surface textures in concrete. This would encourage the statement that the choice of building material should be based on the best performing structural system that meets the user's needs, rather than on the difficulty of design or construction.

3 VACUUMATICS

Vacuumatically prestressed structures, "vacuumatics" in short, rely on the structural principle of prestressing incoherent (structural) elements inside an enclosed skin by introducing a (partial) vacuum inside this enclosure[1, 2, 3]. The atmospheric pressure acting on the covering skin causes the skin to be tightly wrapped around the surface of the filler elements, hence "freezing" the configuration of the filler elements in their current state. This technique leads to rigid load-bearing structures.

The main advantages of vacuumatics are their form flexibility and adaptability. An important factor that determines its adaptability is the so-called "flexibility control" (figure 2). Without any negative pressure (0% vacuum) the filler elements inside the flexible enclosure possess hardly any consistency and are able to flow freely inside this skin. By increasing the amount of vacuum pressure the consistency of the filling gradually increases, resulting in a more or less plastic behaviour of the structure. This enables the structure to be shaped while keeping its newly given form. Finally, in fully deflated state (100% vacuum) the vacuumatic structure becomes rigid, largely depending on the exact properties of the materials used. The reversibility of this rigidifying process enables vacuumatics to be (re)shaped all over again.

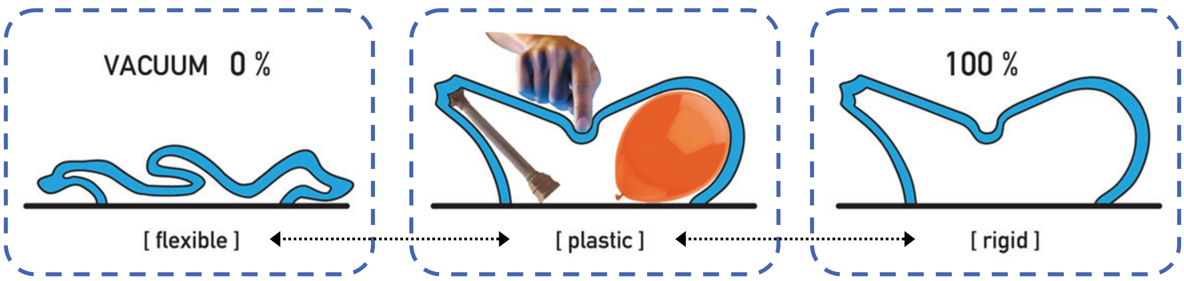

Figure 2: flexibility control

4 FORMWORK SYSTEMS

The abilities of vacuumatics to be repeatedly “free-formed” and to create customised surface textures provide the ideal boundary conditions for a truly flexible, re-usable and, most importantly, fully adaptable moulding technique to create geometrically complex shapes in concrete. Our research on vacuumatics 3d-formwork systems focuses on three essentially different types of formwork systems (figure 3): as an addition to standard formwork (a), an “infilled-frame” formwork system (b) and a self-supporting closed formwork system (c).

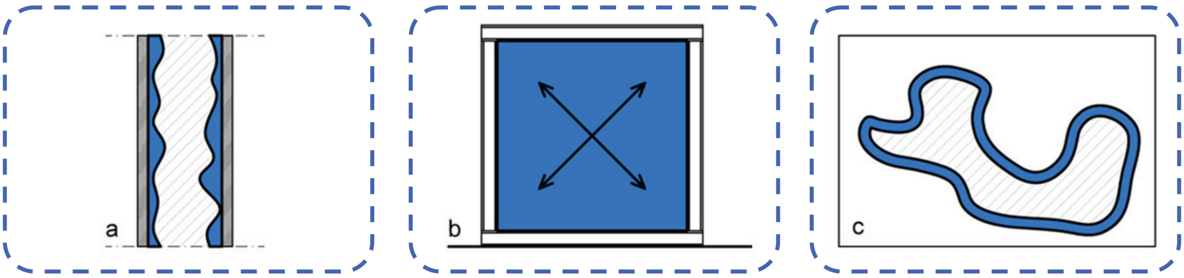

Figure 3: vacuumatics 3d-formwork systems (a, b and c)

4.1 Addition to standard formwork

With this type of formwork system the vacuumatics part is added to a standard formwork structure. After the curing of the concrete the vacuumatic structure can simply be re-inflated, or rather “re-flated”, and peeled off, while leaving behind its imprint in the concrete surface. In contrast to profiled rubber sheets the surface texture of the vacuumatic structure can easily be adjusted by repositioning the filler elements. If required, the filling can even be replaced entirely to create a completely new type of surface texture.

4.2 Infilled-frame formwork

The infilled-frame formwork system consists of an external load-bearing frame structure filled in by a double-sided vacuumatic structure. The edges of the formwork system remain fixed, which facilitates easy connectivity of the cast elements, whereas the flexible inner part of the formwork system can be adjusted or re-shaped to new geometrical requirements. After curing the double sided vacuumatic structure can easily be taken apart and re-used.

4.3 Self-supporting closed formwork system

With this type of formwork system a closed vacuumatic structure acts as a self-supporting formwork structure in which the concrete is poured. Not only the overall shape of the structure can easily be adjusted to new requirements, but also the surface texture can be retrofitted to new demands. The materialisation of the skin and filling of the vacuumatic structure largely determines its load-bearing capacity.

5 RESULTS

Several preliminary tests of the different types of formwork systems have already been carried out and the potential of each individual system has been illustrated. The identity of the formwork system is preserved by the cured concrete, revealing the shape and configuration of its filling material, as well as the folds and creases of its skin material (figure 4). This contributes to the vivid sensorial experience of customised designs in concrete. In order to literally mould vacuumatics into the desired shape some sort of morphological tooling is required that forces the filler elements into their requested configuration.

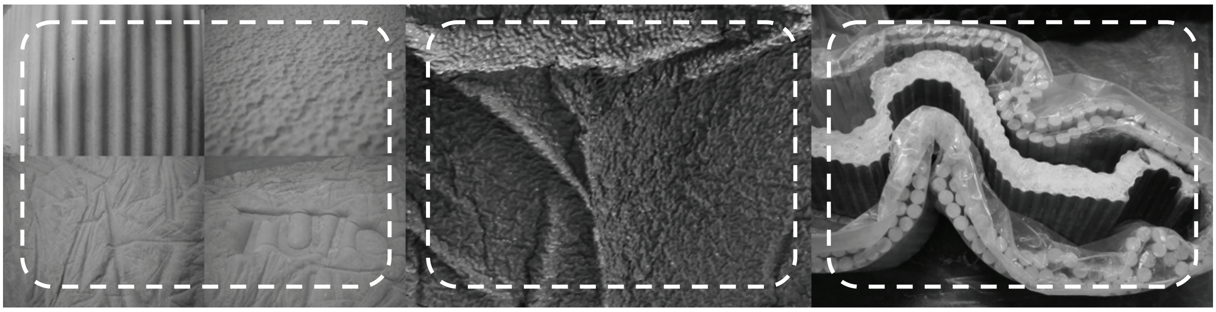

Figure 4: customised shapes in concrete

6 CONCLUSION AND OUTLOOK

Considering the fact that the manufacturability and the adaptability of the concrete formwork are the limiting factors with respect to the creation of complex geometries in concrete, vacuumatics 3d-formwork systems provide an ideal solution. As a solidified liquid concrete has the unique material quality to reveal the specific characteristics of its formwork system in solidified state. The re-usability of vacuumatics contributes to an economical and sustainable manufacturing of customised concrete structures.

Our research aims for a fundamental understanding of the structural and geometrical behaviour of vacuumatics 3d-formwork systems. We see great potential once their application is fully promoted in collaboration with the latest developments in concrete technology, like UHPC, FRC and SCC.

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