I ABSTRACT

Vacuumatically pre-stressed structures (vacuumatics in short) can be defined as the rigidifying of a flexible system of foils with enclosed structural (filler) elements by extracting the air within these foils (figure 1).

Since the “invention” of the principle with the vacuum bracing in the late 1960’s only little research has been carried out to explore the full potential of this promising technique implemented within the building industry, especially with respect to the structural and geometrical potential of vacuumatics in combination with their repositioning qualities.

This paper sets out to illustrate the spatial qualities of this appealing “new” medium in “architectonic” design, and its potential application as flexible concrete formwork: vacuumatics!

2 INTRODUCTION

Our current society can be characterised as rapidly changing, merged with globalised technology and infected with individualism. People tend to control and arrange their own lives and “personalise” their (living) environment by means of the newest technologies, adapting to the latest trends and striving for personal well-being and well-doing. This “individual” approach towards life requires a dynamic attitude of designers and architects in contrast to the building industry, which in these modern times seems to be trapped in its ancient techniques.

Besides the latest “trends” of personalisation, “randomness” and diversity of architectural structures, it can not be ignored that free-form design and so-called blobs are very actual phenomena within present-day architecture (figure 2). Furthermore, buzzwords like “adaptable”, “responsive”, “kinetic” and even “smart” and “intelligent” are more and more common in contemporary (building) design. Interiors and prototypes of “buildings” are already able to anticipate to our senses and it is not unthinkable that soon buildings will be able to change their shape initiated by people’s behaviour or even by the latest weather forecast. A flexible and personalised living environment with changing identities will be inevitable (figure 3).
A rather "new" and relatively low-tech (and therefore possibly economically attractive) way to realise this dynamic environment may be found with the introduction of the so-called vacuumatically pre-stressed structures, or in short: vacuumatics.

3 VACUUMATICS

A vacuumatically pre-stressed structure is in fact a flexible system of foils with enclosed structural (filler) elements that utilises atmospheric pressure as a rigidifying tool by extracting the air within these foils. The principle is best illustrated by several "every-day" products like the vacuum splint (figure 4), the "Memo" beanbag (figure 5) or perhaps most familiar the vacuum packed coffee bag (figure 6).

The created vacuumatic pressure (or negative pressure) causes the otherwise incoherent filler elements (in this case expanded polystyrene beads or coffee) to be tightly compressed and secured into their present configuration, hence acting as a sort of glue that bonds the individual elements rigidly together and "freezes" the current geometry of the structure.

Probably the most important (and very useful) characteristic of vacuumatic structures is the fact that once the air (pressure) is reintroduced into the structure the full "initial" flexibility of this structure is restored. This appealing play of flexibility versus rigidity (or the reversibility of the structure) together with its (final) self-supporting capacity, enables the production of complex organic shapes capable of being optimised to specific conditions or required behaviours (figure 7).

3.1 Macro-geometry & Free-from design

In order to literally mould vacuumatic structures into a certain (predetermined) shape, referred to as the macro-geometry of the structure, some sort of tooling is required that "forces"
the filler elements into their “final” configuration. This process might be somewhat similar to the formwork used with the production of concrete structures, but especially the ability to locally adjust this macro-geometry has huge potential with regard to its effectiveness and application in the contemporary free-form design practice. Attractive ways to achieve certain intended shapes are manually adjusting the geometry or applying an additional external (or internal) device, like for example pneumatic arches (figure 8) or mechanical “arms” (figure 9). This enables (sections of) vacuumatic “buildings” to be adjusted to any required condition (figure 10). Eventually they could even function as fashion icons or an “information medium” to attract passengers by repositioning themselves and “striking poses” to point out important aspects of the buildings or their surroundings. Quite similar to human fashion modelling: “freeze frame”!

Although almost any type of filler elements may be applied with vacuumatic structures, their enhanced structural properties under compression are essential since this ensures the structure’s “final” capacity with regard to strength and stability, and thus safety. Granular shaped elements are known to pack closely together under compression and therefore have excellent properties for vacuunically pre-stressed structures 2 (figure 11).

Nevertheless, considering the transportation issues of the applied filling, together with the sustainable and ecological aspects of building structures, it is also quite feasible to look for a filler material that is largely available worldwide, relatively cheap and most important: biologically degradable. For instance, thin-shell structures build up out of straw appear to have extraordinary structural properties under vacuumatic pressure. The hardness and tensile strength of the material together with its “interwoven” character delivers the right ingredients for flexible vacuumatic structures (figure 12). Temporary structures could be build with “on site” material, without major logistical effort.

3.2 Micro-geometry & Personalised identity

Another important component of influence on the actual appearance and behaviour of vacuamics, besides the filling, is the skin that encloses the filler elements. Not only does it protect the structure from any (outside) harm, and thus pos-
sible damage by sealing it off from the outside air (pressure), it also acts as an “aesthetic tool” as it intensifies the recognition of the filler elements in vacuumatic state by revealing their individual geometries (figure 13). This can be explained by the fact that the outside air pressure causes the skin to be wrapped tightly around the filler elements, often accompanied by folds and wrinkles, and by doing so creating the structure’s surface texture, referred to as the micro-geometry. This characteristic of vacuumatic structures enables its surface texture to be retrofitted to create unique, at random and “personalised” identities for every specific application, for example by integrating imprints of objects (or even people) into the (micro-) geometry (figure 14).

4 VACUUMATICS FORMWORK

Considering the multitude of hazards for vacuuminically pre-stressed structures in daily life, with respect to the essential air-tightness of the foils, these types of structures will be particularly suitable for temporary assemblies. When combining this with the most important characteristics of vacuumaics; lightness in weight, great form-flexibility and the ability to be re-shaped over and over again, vacuuminically pre-stressed structures could provide the ideal “solution” for the production of complex free-form concrete structures. By simply subdividing the total construction of vacuumaics into a load-bearing zone and a decoration zone, respectively referred to as core-form and art-form3, the flexibility of the system from a practical point of view will be increased considerably. The low-tech (and therefore presumably economically attractive) aspect of the actual manufacturing will only further encourage the introduction into the modern building industry. Several preliminary experiments have shown the structure’s potential to create free-form concrete structures (figure 15) and “personalised” surface textures (figure 16), using vacuuminically pre-stressed structures as a formwork.
5 CONCLUSION & DISCUSSION

Vacuumatics are interesting structures, feeding the imagination while they stimulate an active experience and perception of the space created and enclosed by them. The hazard of damaging the enclosing skin and subsequently jeopardising the structural integrity of vacuumatically pre-stressed structures remains probably the biggest obstruction of introducing these structures into the current building industry as independent, primary and "permanent" load-bearing structure. On the other hand vacuumatics seem to be an "ideal" and more importantly feasible technique to produce concrete structures with complex macro- as well as micro-geometries.

The next step of this research will be the further development of the vacuumatics formwork principle and its implementation into the modern building industry.

6 REFERENCES


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