JOSEPH DAHMEN
University of British Columbia School of Architecture and Landscape Architecture

Soft matter: Responsive architectural operations

ABSTRACT
Soft systems attempt to account for non-linear processes whose complexity derives from shifting interrelationships between elements. The move towards soft systems, whose stability is rooted in dynamism, represents a significant shift across disciplines with important implications for the way we approach architectural environments and materials. This article investigates the effects of physical and operational softness on the experience of architectural space through the lens of a recent installation using mycelium biocomposites, an emergent soft material. This contemporary exploration of architectural softness builds in new and technically sophisticated ways on earlier experiments in architectural softness that explored the promise of creating responsive and flexible architectures.

On 7 December 1972, five hours after launch, Apollo 17 astronaut Jack Schmitt snapped official NASA photograph AS17-148-22727 with the mission’s Hasselblad camera. The image, later retitled ‘Blue Marble’, was to become one of the most iconic photographs in human history. The dissemination of the Blue Marble photograph, which captured for the first time the frailty of planet earth in its entirety, coincided with the widespread adoption of the theory of continental drift by the scientific community, in which landmasses previously thought to be static were shown to be in constant motion. Sanford Kwinter identifies these two events as encapsulating a shift from linear systems, whose

KEYWORDS
mycelium biocomposites soft systems sustainable architecture biotechnology mushroom-based materials growing buildings
predictable behaviour is the result of discreet parts operating independently, towards non-linear ‘soft’ systems, whose complexity derives from the shifting interrelationships between elements. The delicate thin membrane at the earth’s surface captured in the *Apollo 17* photograph, writes Kwinter, is driven by its very ‘softness’, its capacity to move, to differentiate internally, to absorb, transform, and exchange information with its surroundings, to develop complex, interdependent sub- and super-systems whose global interactions ... create secondary effects of damping and self-regulation ... a system is ‘soft’ when it is complex and maintained by a dense network of active information or feedback loops ...

(1993)

The move towards soft approaches in the traditionally hard sciences reflects – and attempts to account for – complex geological and biological processes, whose stability is rooted in dynamism. This move towards softness, writes Kwinter, represents the most dramatic shifts in thought since the Renaissance, and has important implications for the way we approach environments and materials in the Anthropocene.

**SOFT ARCHITECTURE**

The two decades since the publication of Kwinter’s ‘Soft systems’ (1993) have witnessed a growing interest in softness across disciplines: soft engineering methodologies, in which ecological principles are used to reduce erosion and incorporate habitat (Hirai 2011), soft systems methodology, a framework for addressing situations of disorder which lack formal definition of problems (Checkland and Poulter 2006), and soft power, which examines the transformative potential of culture as an alternative to military domination (Nye 2004), to name but a few. Concurrent with these explorations of epistemological and operational softness, a range of contemporary architectural projects have explored the aesthetic parameters of soft spaces and environments, recently documented by Bhatia and Sheppard (2011). These new projects build on the inspired (if short-lived) architectural experiments in literal and existential softness during the 1960’s by protagonists such as Hans Holien, Coop Himmelb(l)au and Ant Farm. Collectively, their earlier projects sought to invest architecture with new values of flexibility and responsiveness by replacing the traditionally ‘hard’ materials of architecture with flexible, lightweight membranes that were literally and figuratively transformable and portable, in keeping with the broader cultural shifts taking place. En route to this goal, many of the projects sought to reduce architecture to its essence as an interior environment, eschewing the fixity of traditional materials in favour of membranes separating interior from exterior space.

Building on these early projects, more recent architectural forays into softness employ technically sophisticated environmental engineering to reduce architecture and architectural space to its primary elements by operating on atmospheres directly. The *Blur Building* (Figure 1) (Diller and Scofidio, 2002), *Cloudscapes* (Tetsuo Kondo and Transsolar, 2009), and *Digestible Gulf Stream* and *Domestic Astronomy* (Philippe Rahm, 2008 and 2009, respectively) attempt to replace the age-old tendency of architecture to delineate space through the placement of solid walls with a desire to operate on space itself, in the form of mists, aerosols, fogs and thermal gradients. The dynamic flexibility of these
projects responds in productive ways to the normative roles materials play in traditional approaches to architectural form and space, offering an evocative experience of dynamic temporal spaces. Despite the power of the architectural experience produced, however, it is debatable how much these projects deliver on the promise of soft systems identified by Kwinter to ‘differentiate internally’ and ‘absorb, transform, and exchange information with its surroundings’. In fact, the complex static arrays of plumbing and powerful mechanical systems required by these projects are often in stark contrast to the ephemeral effects they produce. When the fog dissipates (or in the case of the Blur building, the breeze on Lake Neuchatel blows in the wrong direction), the ponderous mechanical equipment and infrastructure it requires suggests the limitation of the current atmospheric approaches.

**MATERIAL AND OPERATIONAL SOFTNESS**

If most current explorations of architectural softness eschew materials altogether in favour of operating directly on atmospheres, what would a soft approach to architectural materials themselves look like? And what effect might soft materials have on the experience of architectural space? Pursuing these questions requires a more detailed exploration of the specific modalities and valences of materials themselves, which might be considered soft in two ways. Soft materials are first and foremost, less resistant than hard materials to forces acting upon them. Physical softness is, of course, relative. A pillow that...
compresses under the weight of the human body is palpably soft (Figure 2). In contrast, a sun-baked earthen adobe block that feels hard when used as a seat, is soft in the register of a building: measuring its compressive strength shows that the adobe block only resists one tenth of the weight supported by a comparable block made of concrete. The physical softness of earthen systems has advantages; a raw rammed earth wall constructed with natural clays will accommodate movements that would crack a much harder, and more brittle, concrete wall (Figure 3). Left unprotected from the elements, the materially soft adobe block will rapidly revert to its prior state as soil, with passage of time imprinted on the soft surface in the form of erosion (Figure 4). Working with the lower resistance of physically soft materials can be challenging, but offers benefits largely under-explored.

A second type of softness, which we might call operational, complements the physical softness of an adobe block. This second type of softness is a function of the conditions of its manufacture and the relationship of these processes to the environment. Soft operational approaches can be less taxing on the environment, but require flexible knowledge capable of adapting to dynamic local contingencies. Returning to the earlier example of earthen adobe blocks, traditional methods dictate that adobe builders establish a borrow pit close by the construction site, minimizing the human energy expended in transporting soil. The blocks are dried in the sun, using free ambient energy to dry the natural clays that bind the blocks together. Knowing where to find soils with the correct proportion of clays requires a nuanced knowledge not only of soil

Figure 2: Pop Rocks (AFJD Studio and Matthew Soules Architecture, Vancouver, 2012). Physcially soft urban installation of local recycled materials. Photo: Krista Jahnke.
Figure 3: Rammed Earth N51 (Dahmen, 2006). Rammed earth wall fabricated with natural clay binders accommodates movements, eliminating cracking or the need for expansion joints.

Figure 4: Unprotected adobe blocks are physically and methodologically soft. Left unprotected from the elements, they soon revert to soil.

Figure 5: Soft methodology, hard material: geopolymer masonry blocks produced by Watershed Materials from natural soils and aluminosilicate clays. Photo: Watershed Materials.
mechanics, but also of highly varied local terrain and the dynamic geophysical processes that shape it (McHenry 1984). Although soft adobe blocks are unlikely to meet the demands placed on contemporary structures, soft methodologies can be applied to manufacturing processes to produce physically hard, resistant materials, as well as soft and pliant ones.

**SOFT OPERATIONS, HARD MATERIALS**

Watershed Materials, a start-up company that harnesses the untapped potential of geological regions to produce a new class of geopolymer masonry (Figure 5), is a good example of a soft manufacturing methodology that produces a hard material. The company has invented a manufacturing process that creates conditions in which aluminosilicate clays present in varying amounts in a wide range of natural soils can be rendered reactive by exposure to alkaline environments and used to bind together inert soil aggregates. The process enables the company to produce masonry blocks that develop the same strength and durability as conventional concrete blocks with a fraction of the environmental impact (Muñoz et al. 2015). Instead of relying on energy-intensive Portland cement, Watershed employs a dynamic readjustment of soil formulation to manage the complex interrelationships and changing behaviours that occur with the varying mix of different clay fractions in source soils. Soft manufacturing methodologies capable of assimilating high levels of dynamic variation make it possible for the company to produce reliable strength and durability from a constantly changing stream of geological resources. Although the blocks interchangeable with conventional concrete blocks, their structurally ‘hard’ attributes contrasts with their visually soft appearance, owing to the subtle variations which express to the unique geological attributes of the source soils.

**SOFT OPERATIONS, SOFT MATERIALS**

Of all softmethodological pathways, biotechnology in particular suggests particularly promising new territories for producing architectural materials (Tandon and Joachim 2014; Armstrong 2012) and a growing number of architects have explored the production of buildings through biological means (Joachim et al. 2006; Joachim 2010, 2015; Benjamin 2015). Biocomposites using mushroom roots as a binder for cellulosic materials have been explored due to its rapid growth and its valuable role in local ecosystems. Mycelium biocomposites are soft both physically and operationally, and point to an exciting future in architectural materials.

Typical mushroom-based material production goes like this: cellulosic material (such as sawdust or agricultural waste) is heat-sterilized to remove mould and other competing micro-organisms. This sterilized substrate is blended with nutrients and inoculated with mushroom spores, after which it is incubated to encourage the growth of mycelium, the threadlike root of mushrooms. Mycelium is a biological polymer that produces a cross-linked three-dimensional matrix of structural polysaccharides throughout the interstitial spaces of the substrate. Once colonized with mycelium, the substrate is then moulded into shapes, which typically measure less than half of a cubic metre due to biological limitations in the growth process. The shapes can be removed from their moulds after several days, at which point they are typically cooked at low temperatures to dry them and kill the mycelium, preventing future unintended growth (Figure 6).
The finished blocks develop the approximate strength and thermal resistance of polystyrene foams, making them a possible substitute for these environmentally toxic architectural materials currently in wide use in buildings.

The development of mycelium biocomposites is still in its infancy and demonstrations of potential architectural applications have consisted mainly of temporary installations, where concerns about structural performance and durability can be managed with acceptable levels of risk. One such installation was Hi-Fy, a 40-foot mycelium biocomposite tower designed by The Living for an exterior courtyard at MoMA PS1 in New York, where it remained for approximately two months (Hartman 2014). In the longer term, it is conceivable that these materials could make their way into mainstream construction practices; Ecovative, a start-up company dedicated to commercializing mushroom-based building materials and packaging that provided the bricks for the tower project, has attracted over $10m in venture capital investment since its formation in 2009 (Upbin and Tilley 2014).

**SOFT INSTALLATION**

*Mycelium Mockup*, a recent temporary installation by AFJD Studio, uses living mushroom bricks to create a visceral experience of mycelium biocomposites (Figures 7–11). The installation is an exploration of material and methodological softness that suggests an autopoietic future in which edible buildings grow from regional biological resources. Rather than cooking the bricks to prevent ongoing growth as was the case in *Hi-Fy*, the installation is fabricated of moist bricks within days of demoulding. Alive, *Pleurotus ostreatus* fungus plays an essential role in the natural world, aiding in the decomposition of...
cellulosic materials and converting them to biologically available elements. The material softness of the bricks is complemented by operationally soft approach that utilizes Pleurotus ostreatus, a local fungus, to bind together a substrate of sawdust, a by-product of the regional Pacific Northwest wood products industry.

In the installation, the individual living blocks continue to grow after assembly, overcoming the challenges of the biological mould size limitations. A naturally occurring polymer coating produced by the fungus called chitin bridges between the adjacent faces of the individual blocks, transforming the individual blocks into a single living monolithic wall (Figure 6), which develops stiffness due to its double curvature as the wall dries. A week before the installation, the mockup wall is subjected to a sudden drop in temperature, which causes the mycelium to enter the fruiting stage, interrupting the articulated surface of the wall with irregular fan-shaped oyster mushroom fruits (Figure 7). During the installation, part of the mushroom fruit is harvested and served as hors d’oeuvres to visitors, providing a heightened aesthetic experience of the material (Figure 8). A pile of broken blocks in a state of decomposition offers an experience of its full life cycle. As darkness falls, the wall serves as a screen for video projections that investigate the tensions implicit in the desire to control natural processes (Figure 9). At project end, what is not eaten by humans is consumed by the mushrooms themselves, returning valuable organic matter to the local ecosystem (Figure 10). The installation provides a glimpse into an alternative future in which biological processes are harnessed to create dynamic buildings that respond and adapt to the needs of human inhabitants.

Mycelium Mockup provokes broader questions about our relationship to architectural materials, suggesting a future in which dynamic materials that contribute to local ecosystems are grown rather than manufactured, and engage with temporality in new and productive ways. These materials offer an alternative to the frenetic pace of development in contemporary market economies, in which buildings erected and razed in pursuit of ever-increasing returns on investment. As financial considerations reduce architecture to a spatial product, most architectural materials are discarded long before their useful life is over, spending longer adding to the toxicity of landfills than they do in the form of a building. Rather than building for the ages, sustainability in the context of rapid cycles of demolition and speculative construction calls for flexible and radically biodegradable materials. In contrast to conventional architectural materials, the living mycelium blocks of Mycelium Mockup encode organic decay into their basic structure, anticipating future demolition and using it as an opportunity to provide valuable material to local ecosystems. As the service life of buildings grows ever shorter, the proportion of time devoted to construction and demolition increases. Beyond end-of-life considerations, the prospect of silently growing buildings promises to be less disruptive than conventional carbon-intensive construction methods, the result of autopoeisis expressed through silent growth rather than shrieking saws and clanging hammers. In contrast to a relentless cycle of consumption, Mycelium Mockup suggests an alternate future in which soft living materials transform over their lifetime, adapting to change and serving needs that are simultaneously structural, aesthetic and visceral.

Operational softness operates in conjunction with biophysical resources, replacing the modernist tendency to obliterate natural systems with technology with a desire to work in conjunction with those same systems. The shift
towards soft operations can impact energy use, relying more on endosomatic metabolic processes governed by biological limits rather than exosomatic processes that are in principle limitless but conversely depend on finite repositories of energy (Fernandez-Galiano 2000). Beyond its effect on energy use, a soft approach might enable architects to work in concert with changes wrought by the passage of time as positive qualities rather than attempting to deny or resist temporal transformation. In summary, soft methodologies applied to the production of architecture might enable architects to harness biophysical

Figure 7: Chitin growing around and between mycelium blocks fuses two separate masonry blocks into single monolithic whole.
Figure 8: Mycelium Mockup mushroom growth at seven days (AFJD Studio, 2015). Photo: Krista Jahnke.
potentials of regional ecosystems to produce architectural materials that articulate regional attributes and engage in positive ways with temporal changes. Architects work at the intersection of materials and culture, and questions of material and operational softness must engage with both sides of this equation. Energy is stored in materials as embodied energy, but as Fernandez-Galiano points out, also in architectural form, as information. Just as genetic information stores the biological memory of a species, architecture contains its
cultural memory (2000). The social and material artefacts store energy as information, and a soft approach must acknowledge both material performance and cultural relevance. How will we be remembered?

REFERENCES


**SUGGESTED CITATION**


**CONTRIBUTOR DETAILS**

Joe Dahmen is a designer whose work engages resource use in architecture and landscape architecture. He is Assistant Professor of Design and Sustainability Integration at the University of British Columbia School of Architecture and Landscape Architecture and a Faculty Associate of the Peter Wall Institute for Advanced Studies. He collaborates with artist and Canada Research Chair Amber Frid-Jimenez as AFJD, a transdisciplinary design firm operating at the intersection of design and technology. He is also co-founder of Watershed Materials LLC, a start-up company funded by the National Science Foundation that uses advances in nanotechnology to produce low-carbon masonry materials. He received a Master of Architecture from the Massachusetts Institute of Technology.

Contact: University of British Columbia School of Architecture and Landscape Architecture, 6333 Memorial Rd., Vancouver, Canada, BC V6T 1Z2.

E-mail: jdahmen@sala.ubc.ca

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In recent years, cities have been increasingly at the forefront of debate in both humanities and social science disciplines, but there has been relatively little real dialogue across these disciplinary boundaries. On the one hand, journals in social science fields that use urban studies methods to look at life in cities rarely explore the cultural aspects of urban life in any depth or delve into close-readings of the representation of cities in individual novels, music albums/songs, graphic novels, films, videogames, online ‘virtual’ spaces, or other artistic and cultural products. On the other hand, while there is increasing discussion of urban topics and themes in the humanities, broadly considered, there are very few journal publications that are open to these new interdisciplinary directions of scholarship. This means that scholars in Language and Literature fields are forced to submit their innovative work to journals that, in general, do not yet admit the link between humanities studies of the representations of cities and more social-science focused urban studies approaches.

The Journal of Urban Cultural Studies is thus open to scholarship from any and all linguistic, cultural and geographical traditions—provided that English translations are provided for all primary and secondary sources citations. Articles published in the journal cross the humanities and the social sciences while giving priority to the urban phenomenon, in order to better understand the culture(s) of cities. Although the journal is open to many specific methodologies that blend humanities research with social-science perspectives on the city, the central methodological premise of the journal is perhaps best summed up by cultural studies-pioneer Raymond Williams—who emphasized giving equal weight to the “project (art)” and the “formation (society).” We are particularly interested in essays that achieve some balance between discussing an individual (or multiple) cultural/artistic product(s) in depth and also using one of many social-science (geographical, anthropological, sociological...) urban approaches to investigate a given city. Essays will ideally address both an individual city itself and also its cultural representation.

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