Shifting Paradigms: From Excavation to Cultivation

The Status Quo

As urban populations grow, so does demand for materials and resources to support them. In the era before urbanisation, when urban populations grew at relatively slow rates, such demands seemed proportionate and could be met by supplies in local and regional hinterlands. Now, the resource demands that come with urbanisation outstrip local hinterlands, and can only be satisfied by ever-widening resource catchments and ever-lengthening supply lines. This phenomenon has generated material flows that are trans-continental and planetary in scale and reach, and has brought profound consequences for the sense of ownership and identity of future cities.

The idea of a modern city became in recent years a faceless replica of pre-defined images and with it came a monopolised palette of materials. Steel, glass, and concrete seem to be the only choices architects can think of. No matter where one starts to investigate, in a new African metropolis, in booming Asian hubs or even in Zürich: glass towers without a sense of belonging are mushrooming and reflect away in their mirror facades any rootage or connection to the specificity of a common place.

‘The ties that used to bind the city together—whether they were social, through coherent building, or economic, through trade in the souk, or religious, through the coexistent presence—were all lost in the misguided and visionless modernisation of the built environment’ (Al-Sabouni 2016). These words were spoken by Marwa Al-Sabouni, a young Syrian architect who blames a ruthless and unreflected architectural practice and wrongly understood modern urbanisation to be partially responsible for the civil war in Syria.

Of all the materials used in contemporary building, sand is one of the most ubiquitous. Sand is used as an aggregate in concrete mixes, the most common building material world-wide. However, supplies have become scarce. In Southeast Asia, whole islands are disappearing due to landslides caused by the mining of sand from ocean floors. Countries like Morocco in North-Africa are losing their beaches due to illegal sand scraping practices. Urban planners in Florida have recognised the threat and have been thinking about alternatives to sand, and have even piloted the use of recycled glass as a sand replacement to maintain their image of their city as a beach tourist destination.

Constructing future cities will inevitably require a mentality shift to the question of where our material resources come from, and if the mining mentality should shift towards a cultivating approach. Future cities cannot be constructed according to a universal one-size-fits all logic that underpin cities of the recent past. Such logic relies on linear thinking in which materials are produced, used, and discarded. Seen from this perspective, the project for urban sustainability must overcome such linear and universal approaches. Rather, the project of sustainability requires a decentralised and circular approach that both acknowledges the global dimension and is sensitive to the ecological, social, cultural, and economic capacities of particular places in order to thrive and endure.

As a response to this challenging situation the Future Cities Laboratory research team of Alternative Building Materials has been concentrating its work on developing alternative construction materials. Based in Singapore and Zürich, it studies application strategies in specific settings, taking into account the availability of raw materials, human resource capacities, and skills. The ‘alternative’ aspect of this focus emerges from an exploration of innovative and entrepreneurial thinking. This approach has informed and continues to inform newly established laboratories in Asia, Africa and Europe. It is
the declared aim of the group to widen the pallet of available construction materials and develop ways of thinking materiality as part of a circular economy.

The research is motivated by a set of challenging questions. Can a grass replace structural elements conventionally made out of steel or timber? Can building materials made out of mycelium structures or hardened by bacteria be a widespread alternative building technology? Could a city conceived along these lines offer neighbourhoods that are as dense as high-rise forms? And could a conscious choice of materials create a new feeling of belonging? Could waste be a future resource for the building sector?

A Paradigm Shift

The research undertaken at FCL suggests that the twenty-first century will face a radical paradigm shift in how designers and builders produce materials for the construction of human habitat. While the period of the first industrial revolution in the eighteenth and nineteenth century has resulted in a conversion from regenerative (agrarian) to non-regenerative material sources (mines), our time might experience the reverse.

Society will see ‘a shift towards cultivating, breeding, raising, farming, or growing future resources ... hand in hand with a reorientation of biological production’ (Hebel and Heisel 2017). There are various approaches to this work. Resources can be cultivated within the conventional soil-based agricultural framework, or micro-organisms that so far have not been considered useful for the energy or building industry could be bred in soil-less farms. A third approach is the industrialisation of natural and bio-chemical processes to rebuild bio-materials synthetically within a controlled environment. All three approaches are important. The last two, in particular, have the capacity to contribute elegantly to the current trend of incorporating small-scale industrial and agricultural production units within urban environments.

When considering the use of natural and organic raw materials within the current norms of digitally controlled, prefabricated, mass produced products, the imperfections of living materials become a key aspect in the process of material development. The underlying effort, alongside a continuous interest in advancing material properties, is the standardisation of natural processes in order to guarantee predictable and controllable properties in every material lot.

The work also concentrates on organisms, which are often seen as unwanted or labelled repulsive. For example, while the pharmaceutical industry uses bacteria with undisputed success to produce some of our most powerful medications such as antibiotics, architecture and construction has not activated nor exploited their capacities. The same is true for other organisms, such as mushroom mycelium.

Another group of materials have been known for centuries as reliable and accepted resources for construction, yet have never advanced to the level of an industrialised product—they have been, as it were, locked in a box called vernacular. Bamboo as a construction material is the perfect example of this curious phenomenon of being hidden in plain sight. The potential of bamboo lies not in applications of the raw material, but in its extremely strong fibre. The approach of extracting and reconfiguring bamboo fibres is suited for prompting the industry to develop new production methods and products.

The cultivation of building materials requires a resilient and ethical economical model. Especially when addressing the first option, of producing soil-dependent cultivated materials, there are significant side-effects in an uncontrolled and profit-driven agricultural model. A cautionary tale can be seen in the palm oil industry; whereby natural forests are burned in order to gain more area under crops. A positive side effect is the changing profiles of building experts.

By definition, the work is multidisciplinary: biologists, bioengineers, ecologists, chemists and material scientists collaborate with architects and civil engineers to create a broader understanding of how to approach complex tasks. Supplemented by economists, this multidisciplinary work promises to sharpen our view on alternative urban models, whereby production is an integral part of a future urban society, requiring new types of spaces and infrastructures.

Bamboo Composite Materials

Steel-reinforced concrete is the most common building material in the world, with developing countries using close to 90 per cent of cement and 80 per cent of steel consumed by the construction sector globally. However, very few developing countries have
the ability or resources to produce their own steel or cement, forcing them into an exploitative import-relationship with the developed world. But there is an alternative: bamboo. Bamboo grows in the tropical zone of our planet and its distribution coincides with developing regions. The plant belongs to the botanical family of grasses and is extremely resistant to tensile stresses. In fact, bamboo is one of nature’s most versatile products.

Bamboo is also a highly renewable and eco-friendly material. It grows much faster than wood and is relatively easy to obtain in large quantities. It is also known for its capacity to capture carbon and could therefore play an important role in reducing carbon emissions worldwide. The great social, economic, and material benefits of bamboo are currently not reflected in the demand for the material, despite its abundant availability.

Research aims to exploit bamboo’s untapped potential by exploring new types of composite bamboo materials. Investigations have focused on the tensile strength of bamboo and explored possibilities of extracting and transforming fibres into a manageable industrial product: a viable building material with the ability to rival steel and timber on residential and commercial scales. This composite bamboo material could be produced and applied in any of the familiar shapes and forms common in traditional construction, but could also be tailored for specific applications that best take advantage of the material’s tensile strength, such as newly developed reinforcement spanning systems for ceiling and roof structures.

Waste Materials

Waste is a result of human action and interaction, bringing raw natural materials from one state of being into another through applying various forms of skills and energy. They assert that waste was seen for centuries as something specific which neither belonged to the family of natural resources nor to the one of finished products. ‘Waste was a by-product, unable to be categorised in our dialectic understanding of raw vs. configured’ (Hebel, Wisniewska and Heisel 2014).

Waste, however, could also be understood as an integral part of what we define as a resource. We could thereby acknowledge its capacity to figure as the required substance or matter from which we could construct or configure a new product. At the same time, the product could be seen as the supply source for other artefacts after its first life span. This metabolic thinking understands our built environment as an interim stage of material storage, or in the words of Mitchell Joachim: ‘The future city makes no distinction between waste and supply’ (Joachim 2013).

Urban Mining is a rather young phenomenon, embracing the process of reclaiming compounds and elements from otherwise wasted or at least undesired products or buildings, which contain high levels of valuable materials. In their text ‘Mine the City’, Ilka and Andreas Ruby describe the contemporary shifting awareness that raw materials are not to be found anymore in a natural realm, but more and more in the cultural domain of buildings (Ruby and Ruby 2010).

The material resources of construction are becoming increasingly exhausted at the place of their natural origins, while inversely accumulating within buildings. For example, today there is more copper to be found in buildings than in earth. As mines become increasingly empty, our buildings become mines in themselves.

In the Rubys’ view, the city is to be seen as a container of buildings and mines at the same time, much needed for its own reproduction.

Thomas E. Graedel of the Yale School of Forestry and Environmental Science combines his analysis of Urban Mining with the question of how much energy can be saved by recycling wasted materials found in landfills or buildings. For him, buildings do not only store the materials to be recycled, but also a large amount of energy, which could be reactivated. He argues that the reuse of aluminium, which could be recycled from buildings, needs only five per cent of the originally used energy for its production (Graedel 2014).

Aluminium is extensively employed in buildings, but it does not remain permanently in place. Buildings are remodelled periodically, and even deconstructed, thereby freeing the aluminium for recycling. Therefore, it is not inaccurate to regard this aluminium as ‘urban ore’ and cities as ‘urban mines’.

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Urban Mining demonstrates a potential and possibility of how waste products can be resourced at the end of their first lifespan, when entering a second or third lifespan, by being transformed, reshaped, remodelled, or reconfigured. This does, however, open up the question of whether the consideration of the waste state of a product should become the starting point of its design.

In a resource scarce city-state like Singapore, this quest is highly relevant, if not crucial. The research on alternative building materials made out of waste at ETH Zürich and its Future Cities Laboratory in Singapore is currently concentrating on new approaches, products and construction techniques in order to understand, quantify and activate one of the biggest potential resources available to the building industry.

Alternative Sand Materials and Bacteria

Sand is the most used raw material for production of goods of our planet. Sand is mostly composed of quartz, a mineral form of silicon dioxide. It is one of the most abundant materials on the earth surface and also one of the strongest. Over the turn of millions of years, mountains gradually eroded into gravel, sand and dust. Rainfall carries these particles through existing watercourses to the sea. Sand is used in concrete, glass, computers, detergents and even toothpaste. It took millennia to become into being through erosion and sedimentation, and man is mining it at rivers and ocean coasts in a so-far unknown speed. Sand is the megastar of the industrial and digital era—our culture is literally built upon this resource. It is, however, a finite resource.

And not all sand is equal; the construction industry requires grain sizes and rough shapes that are only found in river beds, lakes and the oceans. These properties make it valuable to various industries, but once it is enclosed into concrete as an aggregate, sand cannot be retrieved. Desert sand on the other hand is presently unsuitable to the construction industry. Gradual wind erosion polishes the sand particles into round and even forms and therefore reduces their friction capacity; desert sand is simply too fine and spherical in shape to act as a high-friction aggregate in the concrete matrix.

This is why only aquatic sand is used for industrial purposes so far. According to John Milliman, mankind sources twice as much sand as all of our rivers worldwide are actually carrying (Milliman and Syvitski 1992). According to the Swiss TV channel SFR (Eco Spezial 2014), the global market for sand is estimated at the gigantic number of fifteen billion tons per year with a value of 70 billion USD.

The United Nations program UNEP mentions a figure of 30 billion tons (Rakacewicz and UNEP/ GRID-Arendal 2005) and the actual figures might be even higher.

Fifty per cent of the sand that once reached the sea is being sourced today from our rivers. Switzerland covers nearly 90 per cent of its sediment needs of 40 million tons per year domestically in approximately 250 gravel and sand pits due to its geoposition at a source of the erosion process in the Alps. While Switzerland documents its mining meticulously, other nations and interest groups act ruthless, often illegally and unsustainably.

Ways to activate alternatives to sand as a new resource for the building industry are currently being researched in the Future Cities Laboratory in Singapore and at the TU Delft in the Netherlands. Recycled building materials and construction waste with high mineral content such as glass, ceramics, concrete, and more can be transformed into modern, durable and competitive construction materials. This research is investigating the best methods of producing these.

Little is known so far about the use of bacteria to our advantage when designing construction materials. But they could function as adhesives and bind aggregates into compact and resilient substances. Here, a wide field of research is emerging, with an incredible potential for the future. Biochemical processes could in fact replace oil and gas as the main resources for the chemical industry.

Mycelium Materials

A cutting-edge approach in the building sector might be summarised with a bold statement ‘Grow your own house’. To form construction elements through a process of layering particles over time is a concept that is being investigated through experiments with microelements. Previously misunderstood as hazardous waste, microelements have recently been rediscovered as a rich resource with the potential to redefine the categorisation of renewable
building materials; the important distinction being microelements’ unique self-growing capabilities. Research is underway to develop methods of implementation within the construction sector. The advantages of such products are significant.

As the mycelium follow a metabolic cycle, they may be composted after their original use. In their second phase of life, they become a fertile matrix for following generations. Under the correct conditions, the material may be grown locally, reducing both the energy and time required for transportation. Finally, as they are organic matter, they act to reverse carbon emissions through the absorption of carbon.

A controlled environment is required to produce the mycelium material. Initially the space must be dark, moist and provided with the right organic nourishments. A change in environmental conditions can deactivate the growth process at any chosen point in time, such as altering the humidity levels or exposing the material to a different light or temperature. Due to their spongy rhizomatic and fibrous nature, the mycelium produces a material with high-performance structural and insulative qualities, considered very desirable by the building industry. At the laboratories of MycoWorks (under the supervision of Phil Ross) in San Francisco and the Future Cities Laboratory Singapore, it is believed that such organically grown substances have the potential to become a very real alternative to established materials within the building industry.

Bibliography


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