JAN KUBEC*

A STRUCTURAL BUILDING MATERIAL WITH SENSUAL QUALITIES

STRUKTURALNY MATERIAŁ BUDOWLANY O ZMYSŁOWYCH WALORACH

A b s t r a c t

Concrete, at one point the programmatic building material of classical modernism, was discredited in the eyes of many in the postwar years on account of lacking sensitivity. But regardless of its vintage, if the architectural conception is convincing, this material's qualities will come to the fore. At present, architects employ concrete in its many facets as a matter of course. When it is to be visible, its appearance can be calibrated from deliberately coarse and rough to smooth and polished – not to mention the wide range of different colours and forms. Concrete's sensual qualities often contribute significantly to the architectural effect. The selection of projects in this paper includes some surprising ways of using concrete.

Keywords: nature of artifice, modified material

S t r e s z c z e n i e

Beton, w pewnym momencie, programowy materiał budowlany klasycznego modernizmu, został zdyskredytowany w oczach wielu w latach powojennych. Niezależnie jednak od daty powstania projektu, jeśli koncepcja architektoniczna jest przekonująca, cechy tego materiału zostają wydobywane na plan pierwszy. Obecnie architekci w oczywisty sposób wykorzystują beton w wielu aspektach. Kiedy ma być widoczny, jego wygląd może być skalibrowany z celowo grubej, szorstkiej do gładkiej i wypolerowanej powierzchni – nie wspominając o szerokim zakresie różnorodnych kolorów i kształtów. Cechy zmysłowości betonu często przyczyniają się znacząco do efektu architektonicznego. Wybór projektów w tym artykule zawiera pewne zaskakujące sposoby współczesnego wykorzystania betonu.

Słowa kluczowe: natura sztuczności, materiał modyfikowany

* Ph.D. Arch. Jan Kubec, Faculty of Architecture, Silesian University of Technology.

1. The Nature of Artifice

There is an implicit judgment that comes up in every expression that has to do with the idea of nature: a natural food, a natural smile, a natural landscape, a natural attitude. They are all about something positive, genuine, morally superior to the artificial. This was not always the case. In the span of a half century, the role of nature in society and its very definition have changed. While the archetypical image of the 1960s is that of National Geographic specials that portrayed essentially amoral systems of cause and effect, for instance, the female manatee that eats the male after mating, or the hunt of a baby gnu by a pack of lions. In the last thirty years, there has been a deep shift to the attitude to nature. Is there anyone left who still believes that there are natural environments untouched by humans, even if at distance through acid rain, the hole in the ozone and global warming? The idea of amoral nature, caused by an awareness about and reaction to human action, has been replaced by the idea of absolutely moral nature.

We are currently seeing extraordinary demand for the natural as a consequence of an extraordinary growth in the artificial. At the same time, we are shifting away from the idea of natural as something completely free from human intervention. Today, because our frame of reference has shifted to a global human shaping of a landscape, accepting as natural phenomena and materials what we would have once labeled as artifices made by human hands.

2. Natural or artificial material? Modified material

We could swim in the vast sea of artifice and material for years. Ingenuity finds fertile terrain in chemical and mechanical surface treatments that can change surfaces that have striven for compactness for centuries. Let us take concrete as an example. After the "rough" period, when concrete surfaces were made from formworks of wooden boards that were splined or joined, the advent of a new generation of plasticizers and release agents launched concrete into its "velvet" era. Surfaces were meant to be soft and the structural innovation that the Casa da Musica in Portugal was able to spur in the opposite direction was cut short only for aesthetic effect. Today, a major change in direction and dogged pursuit of innovation has flowered into the need to process it, print it, and engrave it. Concrete's foundations have become shells and frameworks that cut patterns of varying depths (including over 80 mm) and can provide up to 100 uses with the same, consistent result. The materials used for frames are thermosetting or flexible plastic. It makes use of multi-layer material, including supporting or shaping layers, layers that print surface treatments, soft layers, filtering and draining layers, and so forth. Some of the most common ways to add an aesthetic to surfaces in order to hide the artificiality or naturalness of the material include sandblasting and abrasion by making opaque with porosity, as well as mechanical processes of a greater scope that make full-fledged incisions, exfoliation and abrasions. Aesthetic transformations also involve coloring the body through pigments or applying layers of paint. Or image transfers. On concrete, the process can be achieved with retarding agents that let the image be transferred during casting, or using acidification techniques whose intensity matches that of the acid applied. Glass has followed the same fate: processed, made opaque, photographized, and colored. And the same for metal: molded, oxidized, photographized, and colored. And stone: hewn, honed, photographized, made transparent and recomposed. The material becomes unrecognizable. In the Eberswald library, Herzog and De Meuron worked with the photographer Ruff to use a two-dimensional photographic application on concrete and glass, erasing the materials' natural-artificial quality. That which seems real is no longer so.

3. Building with concrete: new impulses

The advancement of construction materials and applications has, time and time again, enriched the architectural discipline. Particularly building with concrete has often changed due to innovations in construction technology. A number of promising approaches, in which the parties involved have pushed the limits of what is currently possible, are introduced in the following. They all emphasize the high significance of construction research for the architectural discipline and indicate that there still are ample opportunities for progress in building with concrete.

Building with textile concrete

Textile concrete, a composite material comprised of very fine grain concrete (maximum grain size 1mm) and textile reinforcement, permits manufacturing extremely light and delicate construction components. The highly flexible reinforcement supports the creation of free forms. The new opportunities this material offers have been subject to research for a number of years at the Chair of Building Construction and Design at RWTH Aachen within the framework of a special research area. The newest prototype is an exhibition pavilion, comprised of four square screens made of textile concrete each 7 m wide and with 60 mm strong cantilevered surfaces.

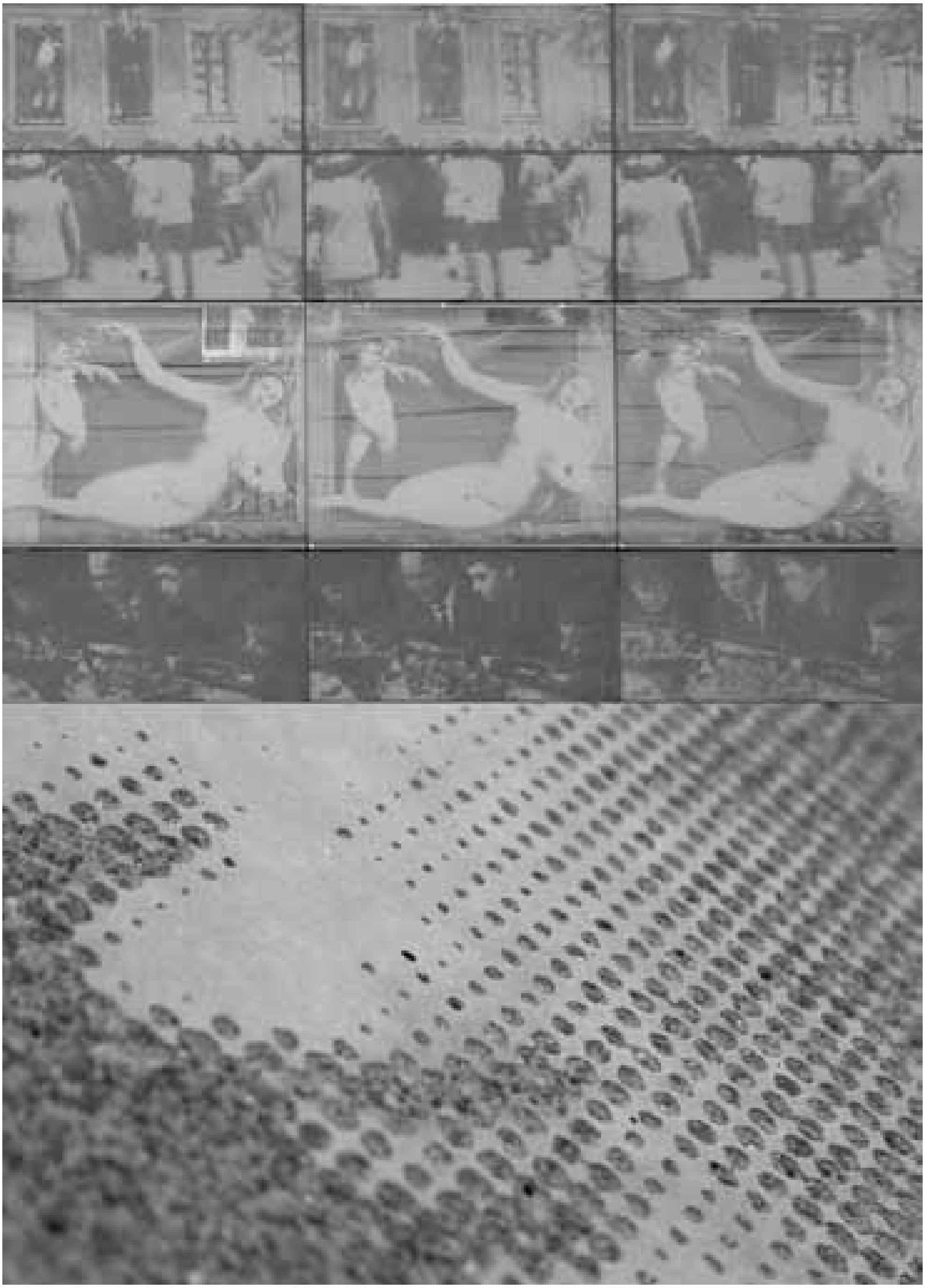
Freely shapable formwork made of wax

Within the European Union's research project TailorCrete, freely shapable formwork made of wax was created at the Chair of Architecture and Digital Fabrication at the ETH Zurich. It permits repeated melting and re-use. As result, a completely zero-waste formwork method is proposed for free-form concrete construction elements poured on-site. This new method is compatible with conventional modes of operation and tools used on site. At the same time, it permits integration of state-of-the-art technology for the creation of wax elements, including computer- and robot- controlled adjustable moulds. A set of successfully created full-scale prototypes indicates that this system comprises a remarkable expansion of the existing repertoire of production techniques for free-form concrete construction.

Textile formwork for concrete constructions

Innovative types of concrete formwork made of textile are part of a research focus of the Centre for Architectural Structures and Technology (CAST) of the University of Manitoba.

Founding Director Mark West describes the particularities and advantages of the system: "Ever since concrete was invented by the Romans, rigid moulds are used to form it. Exchanging a rigid mould with a flexible membrane alters our understanding of concrete and concrete architecture in a fundamental way. The prismatic and rectangular forms that we typically associate with concrete have nothing to do with the material as such". Different from rigid materials, a flexible membrane can only bear tensile stress. Thus, textile formwork

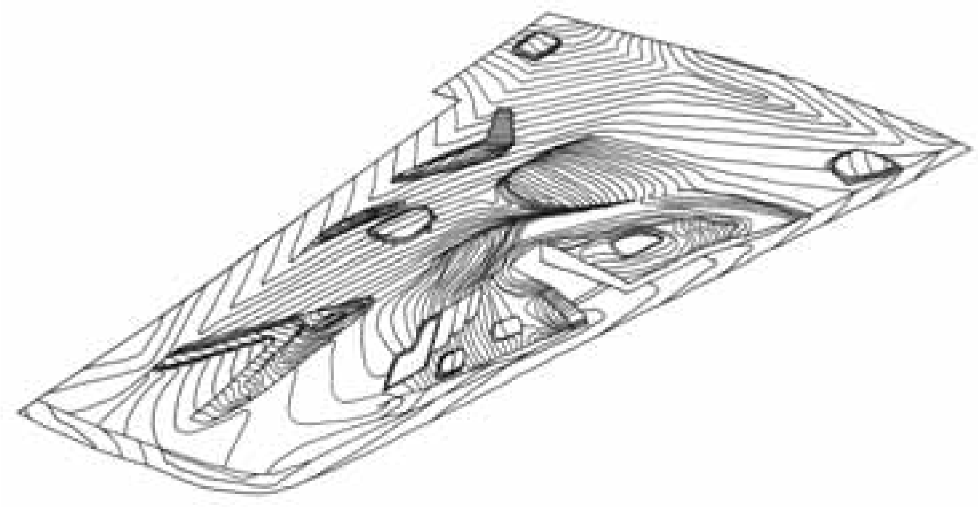


Ill. 1. Herzog & de Meuron, Eberswalde Technical School library, 1999, detail of the façade (photo: Damian Radwański)

follows the spatial curves of tensile resistance in a natural way. Tension is the absolutely most efficient way of resisting stress and a principle found everywhere in nature. Therefore, fabric moulds are hundreds of times more efficient than conventional rigid formwork in terms of material usage. The use of flexible membrane formwork for concrete construction offers two perspectives at the same time: for one, efficient and sustainable use of materials; in addition, a completely new formal language with geometries that resemble biological or other natural structures. Concrete and its flexible mould act together as a system that produces dynamically formed constructions. In this regard, a type of architecture is supported that features a particular narrative or dramatic appearance. Load curves resulting from gravity become visible in its forms. A designer can change forms resulting from fabric formwork by altering the boundary conditions of the textile, by introducing intermediate fixation points, or altering the type or the pre-stretching of the textile. Further sculptural or structuring effects can be created by targeted bucking or folding of the textile sheet prior to pouring concrete. Preferred materials for textile formwork include woven polyethylene (PE) or polypropylene (PP) geotextiles typically used in landscape architecture or road construction. They permit repeated re-use, require no release agents such as formwork oil, and when no longer needed as formwork, they can also serve their original purpose as a geotextile. This makes a completely zero-waste formwork method a reality. All examples displayed here were created with formwork comprised of simple, flat, un-tailored textile sheets. The multitude of forms and applications that can be achieved by using simple sheets is remarkable. They have been used for walls, beams, and columns, as well as cellings, panels, and thin shell structures – as prefabricated components or poured on site. This construction technique has been tested in full-scale prototypes and commercial applications. Digital tools to calculate the geometry of textile formwork are currently under development.

Gradient concrete – construction material optimised internally

By targeted, gradual adaptation of porousness with concrete construction components, material characteristics such as density, firmness, and thermal conductivity can be precisely optimised to meet actual load-bearing requirements, and excess material can be avoided. The technology behind gradient concrete was developed and is extensively researched at the *Institute for Lightweight Structures and Conceptual Design* (ILEK) at the University of Stuttgard. In principle, the arrangement of different degrees of porousness, the introduction of varying aggregate materials, or the combination of multiple kinds of concrete can be used for the gradation of concrete. When air entrainment agents, prefabricated foam, or hollow microstructures are introduced in a targeted way, this kind of control of air entrainment leads to variations in density. In addition, controlled de-mixing of concrete by e.g. centrifugation is possible, as well as spray techniques that enable gradation by incorporating two basic mixes within a spray nozzle or within the aerosol. Advantages include resource conservation through reduction of mass of construction components, e.g. ceiling slabs that – when gradation relates to load bearing – can lead to savings of up to 60 percent in weight. Also, highly recyclable, multi-functional construction components can be created, such as wall constructions with targeted distribution of load-bearing and thermal insulation characteristics. As result, uniform construction components with dense exposed concrete surface can contain a core with thermal insulation properties. If aerogel concrete is used within the core area, a construction component with passive house capacity is created with a wall thickness of 37 cm and a U-value of 0,1 W/m^{2}K. Thus, the approach introduces a perspective that transcends homogeneous thermal insulation concrete components with



Ill. 2. LAAC Architecten, Redevelopement of a Square in Innsbruck, 2008, axonometry (Author's drawing)

wall thicknesses that are no longer economically feasible. An interview with Werner Sobek, Director of the ILEK, offers his insight on the opportunities presented by such an internal optimisation of concrete construction components: What prompted these developments?Very important is a fact that the idea of gradation of concrete is actually not that far-fetched. Being able to influence load-bearing characteristics and building physics characteristics at the same time is very appealing. However, gradient concrete cannot be created with unskilled labourers on site. For this purpose, Werner Sobek and his team require new machines, something they are already working on. How realistic is the use of aerogel concrete in this context? While comprising a possibility to create highly thermally insulating concrete constructions, Sobek explains, they are still pretty much at the beginning with aerogels. They need two to three more years of fundamental research in order to seriously say whether it makes sense or not. Perhaps these fillers need to be replaced by others in order to reach projected goals. For asking how long does it typically take until research results at the ILEK become part of construction practice? Sobek answers that approximately 10 to 15 years. We need to be patient. Gradient concrete is something he has already been working on for 20 years now. The idea was to optimise the performance and minimise the weight of a construction component, yet not by altering its exterior silhouette, but instead, by employing the same procedure to optimise its inside. This resulted in formulating three fields of inquiry. The first question is: how can we develop a prognosis on the required distribution of porousness? The second question deals with how to determine structural integrity. The third question relates to manufacturing. For some questions, an answer is found already after two to three years. In the field of manufacturing, this took more than 15 years.

Naturally, there is a huge interest in gradient concrete within the construction industry. There are smart people at the top echelons of companies who say, if gradient concrete permits saving 20, 30 or 50 percent of weight, and thus, also the energy required to create cement and related emissions, it becomes an obligation to be involved.

Experimental house made of wood concrete

In order to explore the possibilities offered by “wood concrete”, a mix of cement and wood chips or shavings, a research group at the Chair of Design and Housing at the Bauhaus University Weimar developed a prototype test building that offers room for 50 new workplaces. The green: house is part of a campus expansion that is also intended to demonstrate new future-oriented ways of conceptualisation, construction, and material selection in architecture. A new type of wood concrete was developed that offered an interesting alternative within prefabricated construction techniques. In combination with wood frame construction, its building physics characteristics can compete with solid construction. The high degree of prefabrication permits short shell construction times and a high degree of installation. More than 20 partners in the industry, in companies, among specialist consultants, and the university were involved in the realisation of this model project that matches the passive house standard.

4. Stimulated topography: Redevelopment of a Square in Innsbruck

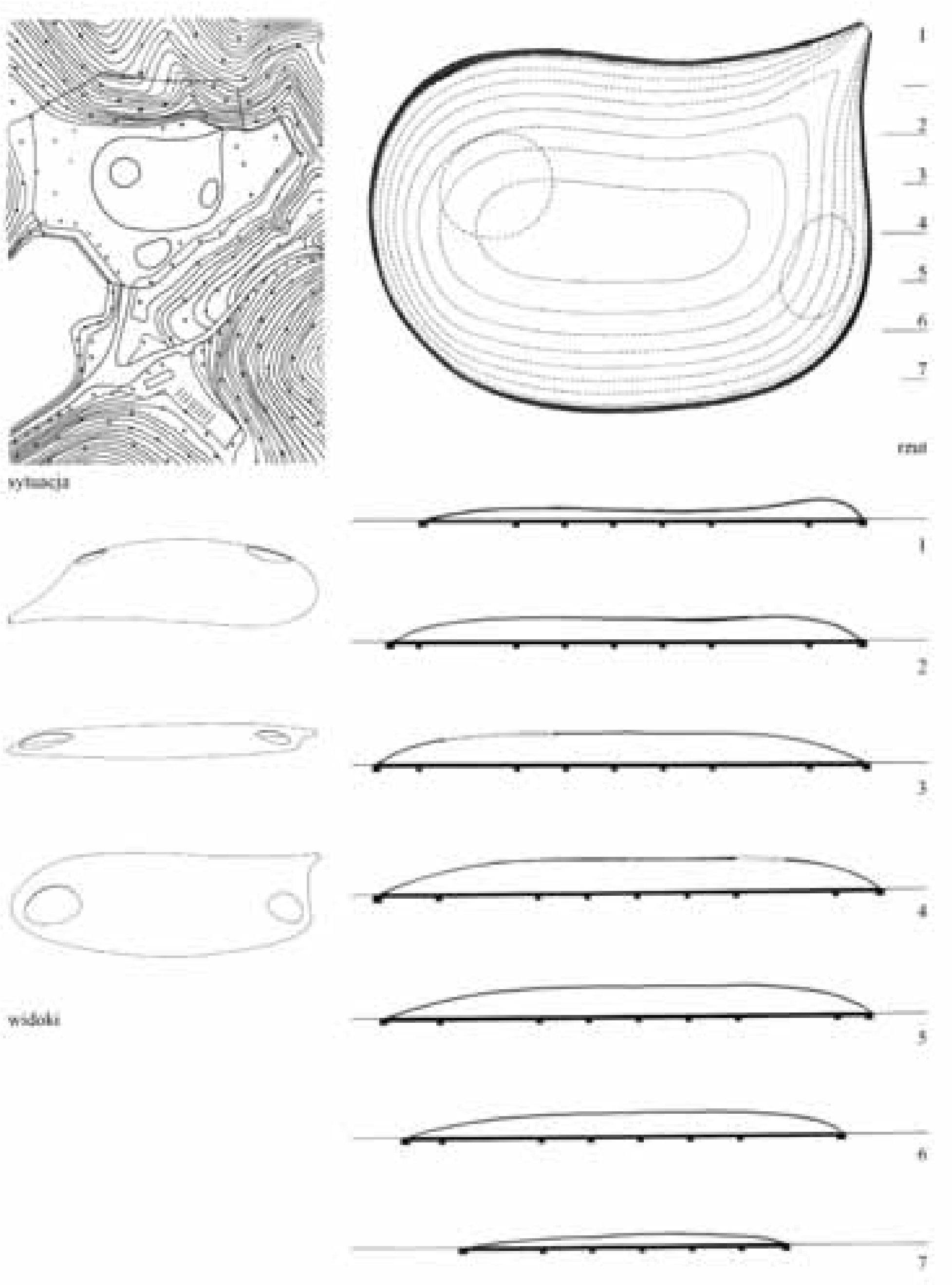
Architects: LAAC Architecten, Innsbruck, 2008

Until recently Landhausplatz, a public square situated between Innsbruck’s Central Station and the historic centre, was little more than a 9000 m^2 surface – roughly coinciding with the parking garage below it – not occupied by buildings. Now the square – which was reconstituted based on the winning entry to a design competition held in 2008 – has a decidedly urban flair: the ground plane has been transformed into a sculpted topography that invites different forms of exploration. From above the exuberant, artful landscape may seem a bit foreign and shallow amid an urban context characterised by the right angle. But from a pedestrian’s perspective, it quickly becomes clear that the different geometries provide spatial definition and, consequently, fulfil a number of functions. They create, for example, places that are sheltered and others that are exposed; two areas clearly assigned to sidewalk cafés; and integrated entrance and exit ramps. Last but not least, the new terrain is ideal for small children on bicycles and tricycles, as well as for youths on skateboards. The different age groups coexist – there is no need for signs prohibiting certain activities; instead, youth clubs worked together with the provincial government to develop a “behaviour codex”. Although it may come as a surprise in light of the top-notch quality of the concrete’s surface, the high-precision grid pattern of the seams, and the thorough computer-aided planning process, the entire topography is made of concrete panels – employing the particularly robust B7 mix – that were fabricated on site. The concrete workers first gave shape to these concave and convex geometries with the help of foam-glass gravel, and in the case of the areas surroundings the trees, of the loose substrate, which they then covered in a 15 to 20 cm thick layer of thick, quick-setting concrete. Next, the slanted concrete surfaces were grooved, and the upper tiers were polished.

5. Topographic imagination: N-Museum in Kagawa

Architects: SANAA, Kazuyo Sejima and Ryue Nishizawa, 2004

In the last few years the trends of design have shifted the attention from the object to the void and the well-known axiom “figure/ground” has undergone an acceleration. It is a process of design not only with the figure/object but also with the background/void. Actually,



Ill. 3. SANAA, N-Museum in Kagawa, 2004, site plan, views, sections, floor plan (Author's drawing)

in this case, the term "ground" cannot be taken literally. The inevitable focus on the "urban void" has led to take in an landscape indefiniteness which in some cases has been actualized in projects that seem operational topographic system, projects that state their distance from the classic rule, and that relate the building to the ground, that appears conventionally flat, delimited, stable, defined and homogenous, like a temple's base ment/stylobate, for instance[1].

As Stan Allen wrote in an article about Kazuyo Sejima more than 20 years ago[2], her work must not be confused with the architecture classified as essentialist minimalism, which tries to strip the work of everything that is non-essential in order to manifest its formal ideality[3]. In effect, while some connections can be made with minimal art, the work of Sejima, Nishizawa and both in SANAA is neither essentialist nor idealist. As they state in the initial quotation, they do not strive to construct ideal forms – figures -, but rather to make the concept – the organisation of the components or spaces – explicit.

The project is a private museum, which was built on Naoshima Island in the Seto Inland Sea of Japan. It is a single exhibition space currently conceived for one artist. The Foundation commissioning the building requested a museum that organically fuses art and exhibition space, creating a space where art and architecture are one and the same. After considering how the light and space might least interfere with the art, we imagine a space that feels infinite. This we hope to achieve with a simple 200mm thick concrete shell embracing a large single room. There are no angles in this space and the shape and size of the room will never be clear from the inside. And, although the exhibition space is not a work of art, it should provide an open background for the artwork. More than a background, the space strives for a specific endless environment. Light should be only physical element existing beside the art. It is a moment of synthesis where a conciliation in longer sought between distant terms, and it is instead claimed that the architectonic project is architecture and landscape at the same time.

6. Summary

The recent history of technology teaches us that material, whether natural or not, is now to be considered artificial when it takes on a quality or a function triggered by manipulation. Aesthetic manipulation of surfaces is an age-old subject that seeks to camouflage, to create the Ersatz. A very appealing theme is that of "senseware", as Kenya Hara said in 2009, "Material that draws from creative instincts and stokes human beings' tendency to create". An excellent example is a model with a natural materials basis, from which completely biodegradable artificial fibers are derived.

[1] J. Kubec, *O architekturze na styku obszaru zurbanizowanego i krajobrazu otwartego*, Wyd. Politechniki Śląskiej, Gliwice 2017.

[2] S. Allen, *Sejima's Theater of Operations*, Assemblage 30, August 1996, p. 99–107.

[3] Allen mentions Tadao Ando and Alberto Campo Baeza as contemporary examples of this minimalism.