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STEREOFORM SLAB – A CONCRETE EXPERIMENT

BETONOWY EKSPERYMENT – *STEREOFORM SLAB*

A b s t r a c t

Today, concrete is seen as one of the contributors to the climate crisis due to its high-emission production process. The paper presents a technological experiment concerning the use of concrete in architecture, aimed at reducing the negative impact of this material. The *Stereoform Slab* pavilion, composed of a slab, a beam with delicate arches, and two supports, was designed as a prototype for a concrete span to be used and replicated in high-rise buildings. Owing to the work of an interdisciplinary team, the thickness of the slab was reduced by half compared to conventional methods, resulting in a 20% reduction in the amount of concrete required, which in turn helps to lower CO_2 emissions. This project is also an example of a technology aimed at improving the construction process while maintaining the aesthetic value of the structure. The standard structural system was enhanced with an unusual and beautiful formal expression.

Keywords: experiment, concrete, column-slab structure

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

Dzisiaj beton, w związku z jego wysokoemisyjną produkcją, postrzegany jest jako jedna z przyczyn katastrofy klimatycznej. W artykule przedstawiony został eksperyment technologiczny dotyczący wykorzystania betonu w architekturze, będący realną próbą ograniczenia negatywnych skutków użycia tego materiału. Pawilon *Stereoform Slab*, składający się z płyty, belki o delikatnych łukach i dwóch podpór, miał stanowić prototyp betonowego przęsła do wykorzystania i replikowania w wysokich budynkach. Dzięki pracy interdyscyplinarnego zespołu udało się zmniejszyć grubość płyty o połowę w stosunku do konwencjonalnej, a co za tym idzie: ilość potrzebnego do budowy betonu o 20%, co ma wpływ na zmniejszenie emisji CO_2. Jest to również przykład technologii, która miała na celu usprawnienie procesu budowlanego przy jednoczesnym zachowaniu dbałości o wartość estetyczną obiektu. Udało się wzbogacić standardowy system konstrukcyjny o nietypowy i piękny wyraz formalny.

Słowa kluczowe: eksperyment, beton, struktura słupowo-płytowa

1. THINKING ABOUT THE FUTURE

Undoubtedly, we are living in an era of technological civilization. Modern technologies influence and even shape all aspects of our lives: communication, politics, defence, economy, health, and culture. The rapid pace of technological change is causing revolutions in various fields. On the one hand, we see significant threats posed by the continuous development of technology, while on the other hand, it is hard to imagine halting this progress in the 21st-century reality. As "futurist" Natalia Hatalska points out:

> Our awareness of how radically technology is evolving today from isolated tools into a complex, autonomous system that determines the shape of democracy, interpersonal relationships, and national security – and our understanding of the mechanisms governing this system – will determine whether technology will save us in today's world, a world full of paradoxes.[1]

Technologization also affects construction and architecture. Architecture has always operated at the intersection of science, technology, and art. From its beginnings, it has been dependent on technology, starting with simple tools and moving on to construction machinery. However, today it seems to be almost absorbed by an industry based on technological expertise. Technology defines specific trends and architectural styles. Architectural thinking today is stretched between two extremes – *high-tech* and *low-tech*. Today, the dominance of science and technology (including digital one) in shaping architecture seems to push questions of form into the background. Formal changes are often driven by new technologies. Form becomes a slave to the ideas of innovation, spectacle, and efficiency, as it is technologically possible to achieve almost anything. Ecological considerations, paradoxically, are yet another aspect driving the technologization of architecture. This carelessness, fuelled by limitless technological possibilities, often seems to overshadow rationalism. If something is theoretically possible, we want it to be practically possible as well, regardless of the consequences we may have to face.

Technology has two faces. While helping to solve one problem, it generates another. Every discovery, invention, or technology carries with it potential negative consequences, if not today, then in the future, and these are usually unpredictable. The introduction of new technologies or their evolution brings consequences that will require new technology or its improvement. This leads to an attempt to control technology with another technology, resulting in a self-perpetuating cycle of technologization.

2. HOW MUCH TECHNOLOGY MAKES SENSE

The present, marked by the threat of climate catastrophe, demands a response from architecture. If technology is the cause of the crisis, it is also expected to provide the remedies. In efforts to reduce our impact on natural resources, the architectural world is divided. *High-tech* architecture utilizes the latest materials, complex technological solutions, and intelligent systems to optimize the design and construction process as well as control the internal environment and living conditions. *High-tech* technology is never finished – it constantly evolves[2] and escalates. There is also a noticeable shift away from the uncritical affirmation of technology. In its search for efficiency, effectiveness, durability, sustainability, and simplicity, low-tech architecture employs traditional, conventional building methods and natural materials. While not anti-technology, *low-tech* is focused on using all forms of technology as efficiently and sparingly as possible. It always seeks the simplest solution to a problem, which is essential in an era of resource scarcity. Both tendencies have their challenges and possibilities. *High-tech* buildings are dependent on an excess of technology. Excessive technology

[1] N. Hatalska, *Wiek paradoksów. Czy technologia nas ocali?*, Wydawnictwo Znak, Kraków 2021, pp. 19–20.
[2] *Ibidem*, p. 38.

and mechanization have led to the creation of precisely crafted, fully controlled buildings that consume energy all year round (via devices), isolated from the external world, and almost antiseptic. We are also witnessing the aestheticisation of technology, which leads to the alienation of architecture. *Low-tech* architecture, on the other hand, struggles to meet the demands of more complex structures. A challenge in this reductionist approach is the risk that buildings will be stripped of aesthetic expression.

3. CONCRETE

Evidence of the ecological crisis appears daily and is undeniable, with the construction industry being particularly responsible for climate change. "The carbon footprint associated with the construction, use, and eventual demolition of buildings accounts for about 40% of global emissions."[3]

Used for over three millennia, concrete became the hope of construction by the late 19th century and the foundation of new architectural solutions. By the mid-20th century, together with steel, it dominated the construction industry as it enabled building taller, faster, and more affordably. Concrete became synonymous with progress and a part of technological innovation. It is an example of a material and the related technologies that helped solve housing problems at the time, and enabled the development of infrastructure in healthcare, education, transportation, energy, and industry. Concrete has influenced and continues to do so both the cultural and natural environment. As Michał Wiśniewski points out: "Concrete, understood as heritage, reveals the ambivalence of the modernization paradigm – it becomes a record of the changes that have shaped the reality around us. It also shows us that modernization, even when wrapped in the myth of the abstract white box, has its consequence."[4] The concrete legacy has become a significant burden today.

"After water, concrete is the most widely used substance on Earth. However, its benefits obscure the enormous threats this material poses to the planet, human health, and culture."[5] Alongside plastic, concrete has become a fundamental material of the new geological era. The environmental impact of concrete is immense. Today, due to its high-emission production, concrete is seen as one of the causes of the climate crisis. It accounts for 4 to 8 per cent of global CO_2 emissions, consumes nearly 10 per cent of the world's industrial water usage[6] and enormous amounts of sand – to name just a few of its negative effects.

Today, it is difficult to imagine an alternative to concrete that would allow its elimination in construction. The use of concrete does not, and probably never will, fit within the scope of *low-tech* ideas. However, there are emerging efforts to apply eco-friendly solutions to reduce its negative environmental impact.

> To reduce emissions, renewable energy sources are being used in production, efforts are being made to improve energy efficiency, seek alternatives to cement clinker (by changing

[3] F. Springer, *Szara godzina. Czas na nową architekturę*, Wydawnictwo Karakter, Kraków 2024, p. 21.

[4] M. Wiśniewski, *Dziedzictwo betonowego pudełka / The Legacy of the Concrete Box*, "Herito" 2024, no. 53, p. 27.

[5] J. Watts, *Beton: najbardziej destrukcyjny materiał* świata, "Autoportret" 2019, no. 4(67), https://www.autoportret.pl/artykuly/beton-najbardziej-destrukcyjny-material-swiata/ (access: 20.05.2024).

[6] *Ibidem.*

the composition of mixes), and most importantly, to introduce carbon capture and storage technologies – although this is costly, and the industry has not yet implemented it on a commercial scale.[7]

Additionally, recycling concrete or using recovered concrete elements are also being explored. Another solution is seeking ways to reduce the amount of concrete used in a structure. Particularly noteworthy are those solutions that can be seen as a bridge between technical achievements and the formal aspirations of architects – where technology not only mechanically shapes the form but actively supports it. It is impossible for architecture to function outside the technological and economic system, including those related to the use of concrete, but real efforts to bring about change must be made.

4. *STEREOFORM SLAB*

In 2019, a unique pavilion called *Stereoform Slab* (Ill. 1) was presented at the Chicago Architecture Biennial. The pavilion, initiated by the American company Skidmore, Owings & Merrill LLP (SOM), was not just a project of a simple structure, but an experimental full-scale prototype of an alternative building system. It required the collaboration of many specialists from different fields. The pavilion was designed by SOM's interdisciplinary research team, and realized through industry partnerships with leading organizations including McHugh Construction, real estate investment and development firm Sterling Bay, Denmark-based Odico Construction Robotics, and Autodesk, an innovator in generative design implementation.[8]

Ill. 1. Author: Dave Burk/SOM, Source: https://parametric-architecture.com/som-embarks-to-reduce-carbon-footprint-using-stereoform-concrete-slab/ (access: 4.09.24).

[7] *Ibidem*.

[8] Explore the Future of Building Design and Technology with SOM at the 2019 Chicago Architecture Biennial [in:] SOM, 6.09.2019, https://www.som.com/news/explore-the-future-of-building-design-and-technology-with-som-at-the-2019-chicago-architecture-biennial/ (access: 4.09.2024).

The creators set out to explore the role of the most common element in modern construction: the concrete slab. The pavilion, consisting of a slab, a delicately arched beam, and two supports, was designed as a prototype of a single-story concrete span intended for use and replication in high-rise buildings. Removed from its intended context, the structure also became a simple architectural expression of the pavilion's primary function: providing shelter through a roof. The structure emerged from considerations of both the ideal efficiency and form of concrete material, while simultaneously demonstrating a more sustainable approach to its use. The system is conventionally cast in place using formwork "sculpted" by Odico Construction Robotics robot. Owing to this approach, the profiles were reduced (the slab thickness was halved compared to conventional slabs), which in turn reduced the amount of concrete needed for construction by 20%, leading to a reduction in CO_2 emissions. This is a significant achievement in construction, where concrete production currently accounts for 8% of global CO_2 emissions. According to SOM, 40–60% of emissions are generated during the construction of concrete structural elements in American high-rise buildings. Therefore, the savings achieved in this part of the construction process have a huge impact on the environment, especially in the context of the common practice of *over-engineering*,[9] where structures are designed with excessive safety margins. Minimizing material waste and reducing the production time of complex formwork also brings significant savings. The creators aimed for the system to be scalable, easy to construct, and no more expensive than conventional building systems.

> This pavilion demonstrates the exciting potential for design, technology, and building collaborations to make a significant impact on the way we approach large-scale construction. This is particularly important as we consider the on-going development of urban environments and, therefore, the increasingly pressing need for sustainable solutions,[10]

explained Scott Duncan, SOM Design Partner. "The design of *Stereoform Slab* expresses a more intelligent allocation of material, evocative of forms in nature. When applied to the entirety of the built environment, this technology can pave the way to a more expressive, sustainable, and innovative future of architecture,"[11] he continued.

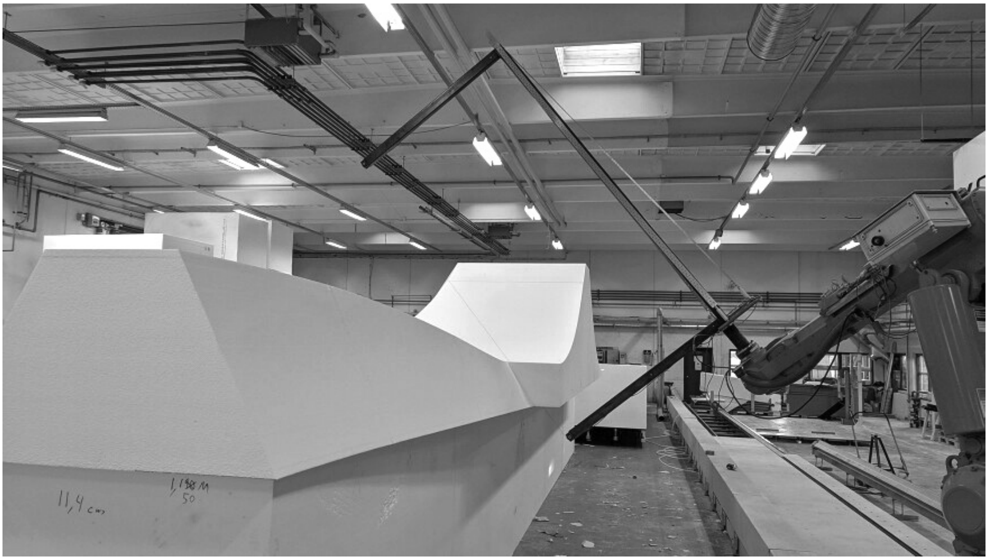
The pavilion, measuring 70 feet in length, 24 feet in width, and 14 feet in height (21.34 x 7.32 x 4.27 meters), which serves as a potential module for a multi-story structure, was erected by the concrete contractor in less than a week. Typical reinforced concrete structures incorporate 10- to 12-inch-thick plate slabs (25,4cm – 30,48 cm), which, though simple to build, require more concrete and rebar than other slab configurations. The *Stereoform Slab* system is a mere 6 inches thick (15,24 cm), and is supported by a "smart band beam" whose tapering form, optimized through computational design, efficiently transfers loads to columns spaced 45 feet apart (13,72 m). The traditional supporting arch was transformed into a catenary curve, which supports the slab where the tension is greatest. "We've flipped tension and compression," says Kyle Vansice, a senior architect at SOM. As the slab runs

[9] E. Stenberg, K. Zemła, *Betonowa płyta po raz drugi unosi się w powietrzu*, "Autoportret" 2023, no. 4(83), p. 4, https://www.autoportret.pl/artykuly/betonowa-plyta-po-raz-drugi-unosi-sie-w-powietrzu/ (access: 20.08.2024).

[10] Explore the Future of Building Design…, *op. cit.*

[11] *Ibidem*.

toward each column, it thickens and then tapers where the forces of compression are greatest.[12] “We’re able to achieve longer spans than a conventional flat plate, which means fewer columns and less concrete in the foundations of the building,” argues Scott Duncan.[13] The *Stereoform Slab* design expresses a more intelligent allocation of material, reminiscent of forms found in nature. The technology also positively influenced the aesthetic shape of the structure. Although the pavilion’s roof is a smooth, rectangular slab, the way it is supported seems to have a subtle, poetic quality. Concrete waves flow from the slab and merge onto its square columns. The expressiveness and sculptural quality of the structure increase the appeal of this system for potential clients, who are drawn to the authenticity of exposed ceilings.

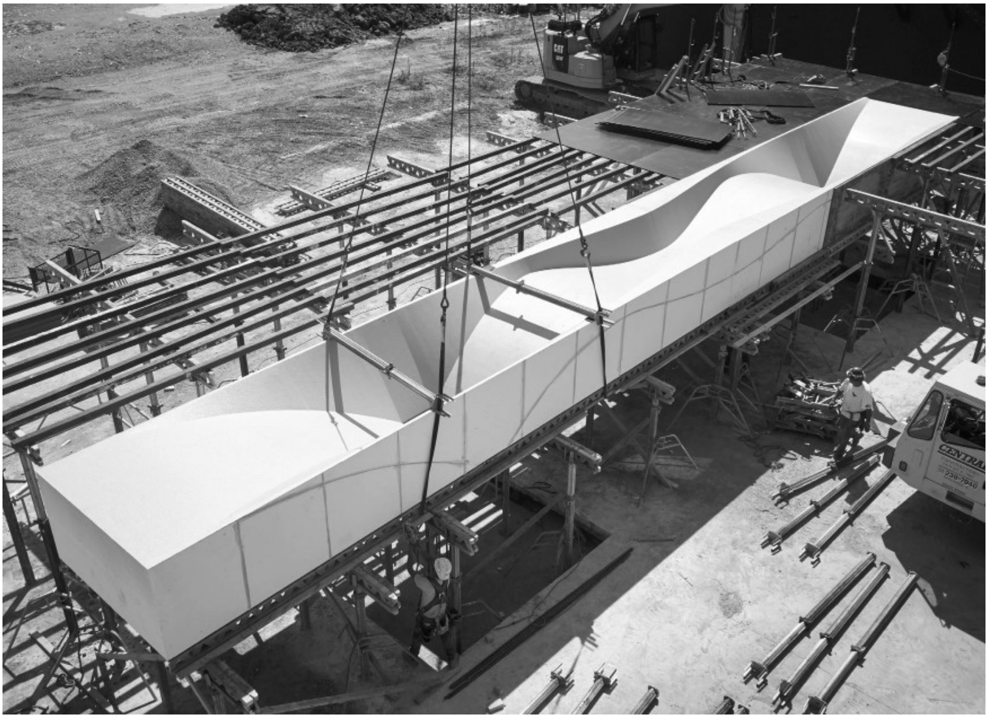


Ill. 2. SOM and Odico used robotics to shape the EPS formwork, author: Dave Burk/SOM, source: G.F. Shapiro, *op. cit.*

Odico Construction Robotics in Denmark created a mould (Ill. 3) for the alternately rectilinear and sinuous concrete forms. The mould made of expanded polystyrene was cut into shape by a 7-axis, robotic abrasive wire-cutting arm, which sliced and formed it like a giant lathe (Ill. 2). This diamond-tipped, articulated band saw runs on custom digital-fabrication software, working from CAD drawings. The machine cuts forms that highlight the strengths of concrete while concealing its weaknesses – forms whose casting becomes a manifestation of the force flows within the concrete. The ideal way to increase the strength of the slab was to place the arch at the furthest point between the two columns.

[12] Z. Mortice, *Curves and CO2 Reduction Coexist in Chicago’s Colossal Concrete Installation* [in:] Autodesk, 28.01.2020, https://redshift.autodesk.com/articles/concrete-co2 (access: 4.10.2024).

[13] G.F. Shapiro, *Award: Stereoform Slab’s Optimized Structure Reduces Embodied Concrete* [in:] Architect Magazine, 12.07.2020, https://www.architectmagazine.com/awards/r-d-awards/award-stereoform-slabs-optimized-structure-reduces-embodied-concrete_o (access: 4.09.2024).

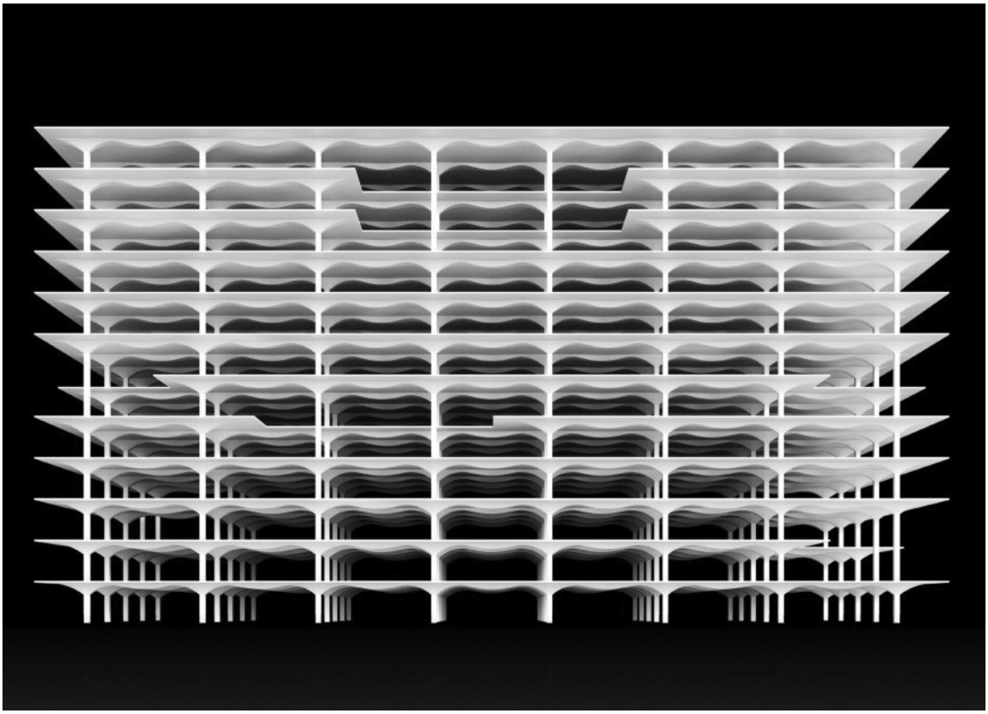


Ill. 3. Optimal formwork being placed within conventional slab shoring, author: Dave Burk/SOM, source: M. Yablonina et al. (eds), *Distributed Proximities. Proceedings of the 40th Annual Conference of the Association of Computer Aided Design in Architecture*, vol. 2, *Projects, field notes, videos, awards, workshops*, 24–30 October 2020, Association for Computer Aided Design in Architecture (ACADIA) 2021, p. 152

According to Asbjørn Søndergaard, Odico's chief technology officer, this technique is much faster than CNC milling because material is not removed layer by layer, pulverizing material incrementally, instead the cuts are made just straight through. The inconvenience, which can be used creatively, is the fact that it limits the form to "ruled surfaces," which must be defined by the straight line of the cutting wire. EPS is a petrochemical plastic product, Søndergaard acknowledges, but the EPS formwork takes less energy to produce than wood formwork and can be "almost 100%" recovered and recycled.[14] According to SOM and Odico, this versatile and potentially mobile method of producing building systems using digitally manufactured forms could become suitable for creating wider spans and taller buildings, while consuming less energy and materials. The robotic lathe arm could be packed in a shipping container and sent to a building site, creating a "factory on the fly."[15] The lightweight forms can be divided into modules, which would facilitate transport to the construction site (if not created on-site) and transportation within the site itself.

[14] G.F. Shapiro, *op. cit.*
[15] Z. Mortice, *op. cit.*

Owing to the cooperation of specialists from various fields, through a small and remarkably simple pavilion placed in the urban space, it was possible to demonstrate how, with the help of robotic technology and generative design, it is possible to create both more beautiful and more sustainable structures in high-rise buildings (Ill. 3). The project also succeeded in going beyond a purely functionalist and technological approach to engineering design, enriching the standard construction system with an unusual and beautiful formal expression.



Ill. 4. Stereoform Slab designed at-scale within the framework of a conventional office building, source: M. Yablonina et al. (eds), *op. cit.*, p. 152

5. CONCLUSION

The *Stereoform Slab* is the result of pragmatic explorations for optimal efficiency and a more sustainable approach to material usage, as well as the "ideal" form for a column-slab structure. It exemplifies a technology aimed at improving the construction process while maintaining a focus on the visual value of architecture. It is a positive example of a project where the aesthetic quality of the structure evolves from the material to the form. While it may not be a revolution in concrete usage, it is undoubtedly an attempt to build structures with a lower carbon footprint. This technology could provide a solution in response to the inevitable changes we will have to embrace in the coming decades: densification of cities, a shift toward multifamily housing, increased functional flexibility, and minimizing the ecological consequences of building construction, as well as reducing the energy consumption associated with building operation. This multiplied, non-hierarchical structure can transform and change its purpose to meet the evolving needs of users, thereby extending its lifespan. Flexible typologies, easily adaptable to changing needs and standards, are timeless.

People never cease in their efforts to implement new technologies. Time will tell whether the experiment described above will turn out to be another techno-dream or an effective solution addressing contemporary climate and environmental challenges.

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[6] Shapiro G.F., *Award: Stereoform Slab's Optimized Structure Reduces Embodied Concrete* [in:] Architect Magazine, 12.07.2020, https://www.architectmagazine.com/awards/r-d-awards/award-stereoform-slabs-optimized-structure-reduces-embodied-concrete_o (access: 4.09.2024).

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