Models, Media, and Methods

Frei Otto's Architectural Research

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Continued on back cover

Models, Media, and Methods

Frei Otto's Architectural Research

Curated by Georg Vrachliotis

Yale School of Architecture Gallery
February 20–May 2, 2020

Frei Otto, suspended chain model,
Atelier Warmbronn, photograph

Director's Statement

As an architecture student, I recall happening upon Frei Otto's *IL Bulletin* and discovering a treasure trove of ideas and prompts to experiment with that opened my eyes to new methods and muses. The occasion of this exhibition and the way it delves into the archives of *IL* has given me the opportunity to reflect on that gift. Much of that stems from Otto's savvy use of media.

Photography and publications were vital to his working process, aiding directly in form-finding while drawing together a community of like-minded seekers. Before he was able to realize his ideas in built form, he put them out into the world through his teaching and through *IL*, which operated like a perpetual exhibition.

It should come as no surprise that I was thrilled when Georg Vrachliotis approached me with the idea to mount this exhibit on the sixtieth anniversary of Otto's stint in New Haven. I am grateful for his energy and enthusiasm for sharing Otto's legacy. I also appreciate the resources and generosity of the Südwestdeutches Archiv für Architektur and the Karlsruhe Institute of Technology to lend us the work.

At the School of Architecture, I wish to thank Dean Deborah Berke for her support and direction. I am grateful to Alison Walsh, exhibition coordinator; Eric Sparks for the exhibition fabrication; Erin Kim for graphics; Brian Hopkins for titles; and our installation team. Finally, I wish to thank graphic designer David Reinfurt of O-R-G inc., and Nina Rappaport, editor of this publication.

Andrew Benner, Director of Exhibitions

Dean's Preface

It is a pleasure to welcome this exhibition on Frei Otto to the Yale School of Architecture nearly sixty years after he first arrived to teach as a visiting professor. One of the privileges of being Dean is identifying and cultivating talented teachers who we can invite into our midst to expose our students to new and often challenging perspectives. This must have been what Paul Rudolph had in mind when he invited Otto to our school in 1960. *Models, Media, and Methods: Frei Otto's Architectural Research* allows us to revisit his legacy and peruse materials from his archive.

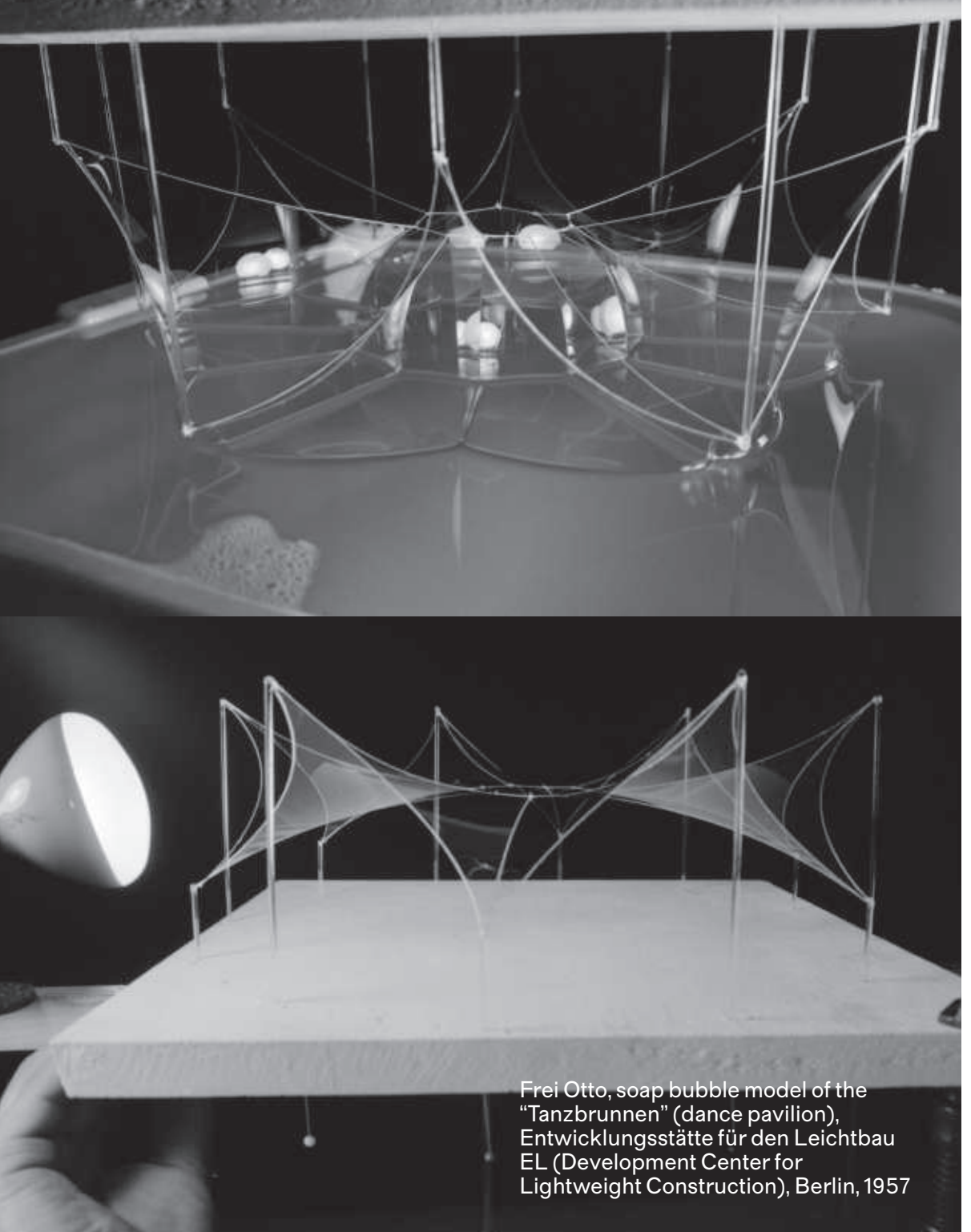
While Otto went on to a distinguished and prize-winning career, what is most remarkable is the prescience of his teaching in 1960, reflected in the publications that form the backbone of this exhibition. His pursuit of material and resource efficiency led to elegant designs, but also prefigured many of the tenets that now fall under the umbrella of sustainability. He was an early advocate of bio-mimicry and fostered a culture of material, structural, and formal experimentation that was well ahead of its time. That spirit of experimentation is one that I hope our current students absorb and take up with a new set of tools.

I am thankful to Georg Vrachliotis and the Karlsruhe Institute of Technology for opening Otto's archive to us. At Yale, I would like to thank our director of exhibitions, Andrew Benner, for working with Georg to bring the show to our gallery. My gratitude extends also to our installation crew, led by Alison Walsh, exhibitions coordinator.

Deborah Berke, Dean

Frei Otto, installing the dome for the pneumatic model of the Arctic City project, Atelier Warmbronn, 1971

Frei Otto photographing a model for the Munich Olympic Park, Atelier Warmbronn, ca. 1970



Frei Otto, soap bubble model of the "Tanzbrunnen" (dance pavilion), Entwicklungsstätte für den Leichtbau EL (Development Center for Lightweight Construction), Berlin, 1957

Models, Media, and Methods: Frei Otto's Architectural Research

Georg Vrachliotis

"Dr. Otto's presence on the campus was a very important moment in the history of the school, and his contribution was extremely valuable. He is not only considered one of the finest of teachers but his knowledge of his broad field of specialization is perhaps unmatched by anyone in the Western World. [. . .] His series of books which contains ideas and the results of his research are unique documents and unmatched so far as I know for their thoroughness and their originality."[1]

With these lines begins a letter, dated August 16, 1963, written by Gibson A. Danes, then dean of the School of Art and Architecture at Yale University. In 1960 Frei Otto was invited to New Haven as a visiting professor and apparently made a very good impression on students and colleagues. Together, with King-lui Wu, a long-time professor at the school, he taught the course "Structures: Traditional and Lightweight," an unusual topic for the time. At the beginning of the 1960s, lightweight construction was an innovative and interdisciplinary branch of research, but it still occupied a rather marginal position within architecture. Even on the Yale campus, when Otto was discussing floating tents and light membrane architecture of filigree models made of soap bubbles with the students on the top floor of the Yale Art Gallery, something almost contradictory was being created on the opposite street corner. The new building for the School of Art & Architecture, designed by Paul Rudolph, was monumental poetry in its Brutalist concrete aesthetic.

Research as Cooperation and Discourse

Danes' letter is also remarkable because instead of describing Otto's teaching methods at Yale, or individual building projects, it explicitly refers to Otto's publishing activities. Otto's books are not only "unique documents" of research, but also "unmatched [. . .] for their thoroughness and their originality." By the mid-1960s, Otto had published over one hundred essays,

reports, and books; some of them bilingual, some even trilingual. The topics ranged wide—from questions about certain materials and special construction methods to detailed and occasionally critical reports on individual projects in housing and urban planning.

For Frei Otto, knowledge production meant both its creation and circulation. Science, to him, was not a cult of genius, but communication, cooperation, and discourse. This is particularly evident in the nine *EL Bulletins*, which he published at his Institute for Development of Lightweight Construction in Berlin between 1958 and 1963. The *EL Bulletins* are simply bound pages; the texts formulated in clear language and typed with a typewriter, and they are illustrated with drawings, photos, and collages. With their thematic editions, the nine *EL Bulletins* are not only among the most remarkable testimonies to younger Otto's publishing activity, but also formed the basis for the much broader book series of the Institute for Lightweight Structures in Stuttgart, which he founded in 1964. Between 1969 and 1995 a total of forty-one issues of the *IL Bulletins* were published. Each issue was devoted to a particular theme, such as: Minimal Nets (*IL* 1, 1969), Forming Bubbles (*IL* 18, 1988), or Bamboo (*IL* 31, 1986), reflecting the huge range of Otto's research and interests. Otto's intellectual image as a research architect arose from the interplay of two important leitmotifs: The consistent documentation of his experiments and findings as well as the search for publicity. His publications would become one of the most innovative, long-lived, and also most remarkable publication projects of twentieth-century architectural history.

Thinking by Modeling

When Otto came to Yale, he was still at the beginning of his career, but he already had some practical experience as an architect.[2] In the 1950s, he had begun to address

Frei Otto, “Tanzbrunnen” (dance pavilion) tent at night, 1957

issues of social and ecological housing with designs for smaller residential buildings. However, these designs were usurped by his innovative and systematic research into lightweight construction.[3]

Otto's gracious lightweight structures, such as the so-called "Tanzbrunnen" pavilion (dance pavilion), which seemed to float above the ground, embodied the collective desire for an open society thus representing the new self-image of Germany's fledging Federal Republic.[4] Against the ideal of eternity, monumentality, and prestige was his search for structural perfection in minimal form. He sought out adaptability, and temporariness at the interface of architecture and engineering—as an artistic, technical, and social form.

In 1964, Frei Otto was appointed to an institution founded in his behalf: the Institute for Lightweight Structures at the University of Stuttgart. Here, in collaboration with architects, engineers, biologists, physicists, and artists, he quickly forged a world-class hub of interdisciplinary research.[5] It was in this period too that he won the competition for the design of the German Pavilion at EXPO 67, in Montreal. Together with the architect Rolf Gutbrod, Otto conceived an open exhibition landscape, composed of spacious visitor terraces beneath a seemingly free-floating yet meticulously structured tent-like roof. Otto designed not only the tents of the pavilion, but also all the requisite models, tools, measuring instruments, media, and visualization equipment for its design, planning, and implementation. Their venture was therefore nothing less than an apparatus-led rewrite of the cultural techniques of design; the will to build revealed in an inventor's guise. And that, in a sense, is what made it a star attraction.[6]

One way to decipher not only the technical but also Otto's social code of research is to question the epistemological dimension of the way he thought with models. Belonging equally to the spheres of art and science, his filigree models often

appear to be spatial installations with which he attempted to make the invisible measurable and the visible calculable. From the first improvised grid models to complex suspended models, each state confirms and simultaneously questions perceived knowledge. One of the most fascinating of these models is the Multihalle in Mannheim suspended model. According to Otto, it "corresponds to the tasks, but at the same time possesses that special characteristic of increased quality which is necessary to lead a building from the area of the only functional, only economic, only technical without impairing these advantages into that area where perhaps architecture begins."[7] Otto thus understood models as cultural indicators. In their theoretical potential and cultural significance, they go beyond the purely physical haptics of the individual object and can become a symbolic zero point of an architecture freed from constraints. It may sound paradoxical, but much of the epistemic potential of these models lies in the many small inaccuracies and resistances of the material. The productivity and usefulness of these experiments is based on the fact that they do not exclude the dysfunctional but allow failure to become an integral aspect of their function.

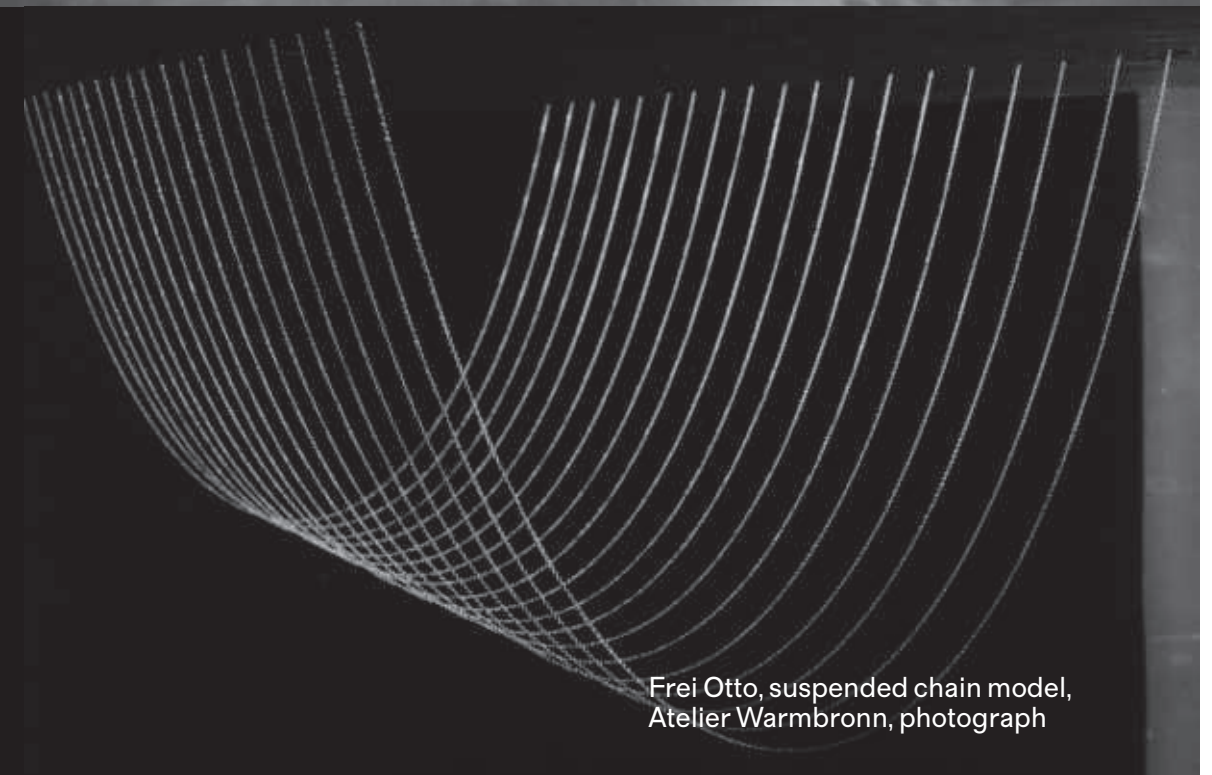
Experiment Between Artistic Imagination and Technical Reason

The experimental dimension of Otto's work is difficult to demonstrate in the built objects. Rather, it is expressed in the technical processes, the media, and social practices. Otto's design originality is an originality of processes. Even in the late 1950s he had discovered that very thin and relatively stable membranes can be formed from distilled water with a few drops of dishwashing liquid. If you dip a closed frame of bent wire into the soapy water and pull it out again, a thin soap skin is created. If the frame has the shape of a space curve, i.e. a three-dimensionally curved surface, the soap skin

Frei Otto and Carlfried Mutschler,
Multihalle Mannheim, 1975

Frei Otto, suspended chain model,
Atelier Warmbronn

Frei Otto's team conducting wind tunnel measurements on the model, Multihalle Mannheim, scale: 1:200, with Ove Arup & Partners London, 1974



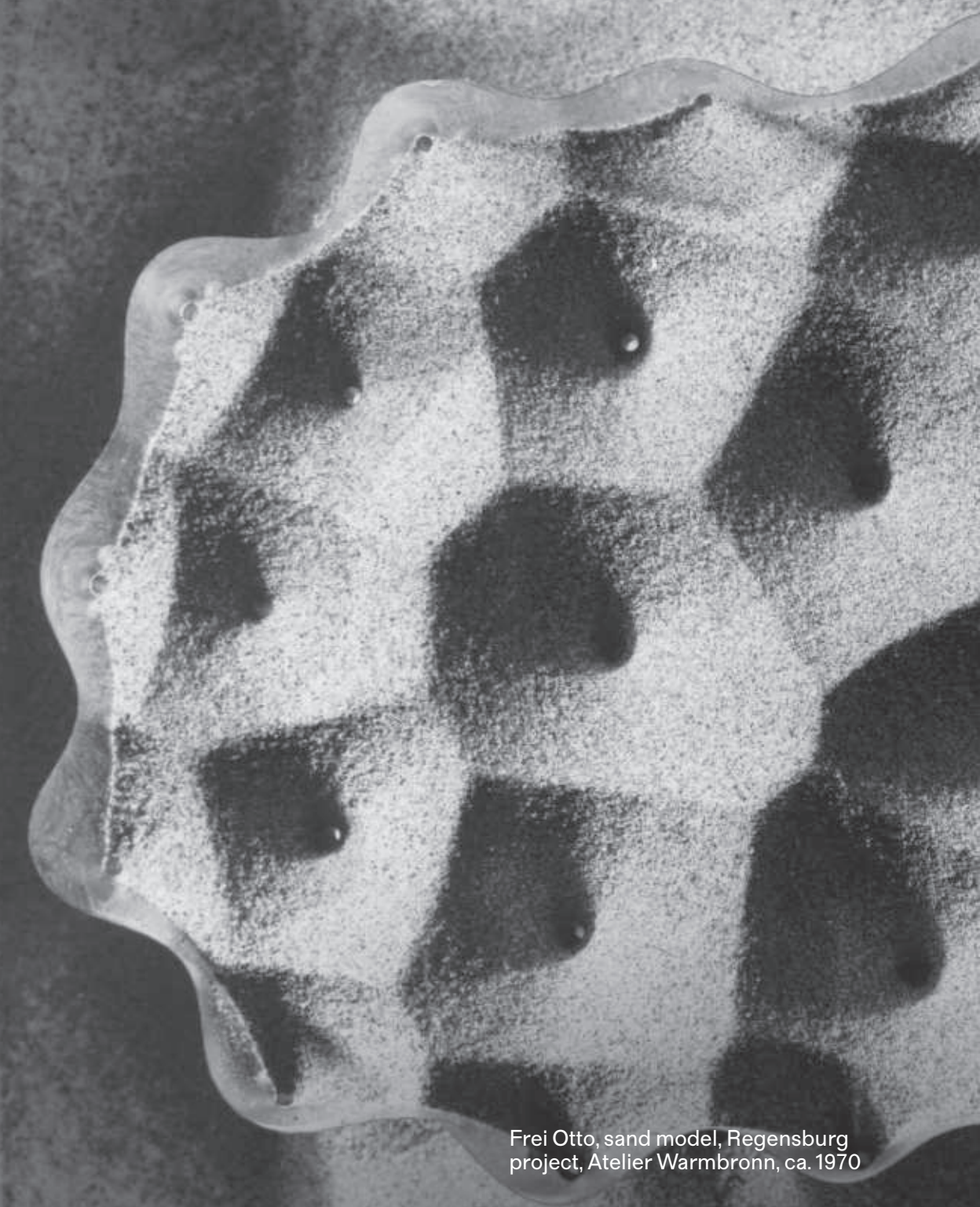
Frei Otto, suspended chain model, Atelier Warmbronn, photograph

also forms such a curve. In countless experiments Otto had observed that a membrane constructed in this way is mainly determined by its edges, i.e. the high and low points, and has specific geometric and physical properties. The surface tension on such a membrane is the same at every point and in every direction, resulting in particular stability and efficiency and the formation of so-called minimum surfaces. "During the development of the . . . tensioned skins it was fascinating to see how, in the search for construction forms with a minimum of building materials, forms of great clarity and captivating beauty were created. These were forms that could not be designed."[8] Here it becomes clear that Otto's turn to experiment was not based on a science of architecture in the narrow sense. The experiments served both as an exploration of causal relationships and as a form-generating part of the design process. Modeling, drawing, and measuring techniques along with his evaluation method formed the basis for a new experimental culture.[9] Focused on the continuous calibration of eye and hand, it emphasized scientific observation and technical skill, and a craft-intellectual self-adjustment, in which designing can mean both the production of knowledge and a starting point for a collective discourse about the future. The idea of being able to roof over forests, valleys, lakes, and even entire cities with the help of climatic shells, pneumatic roofs, or huge lattice shells is not only a question of technology, it also refers to the longing and the dream of cultivating the earth. Thus, it is not primarily a rhetoric of feasibility, but about the sphere of the history of ideas and the social imagination to think about an alternative world. Otto's idea of an interior space that integrates everything, functions as a symbol for a world as an open system—ecologically, socially, culturally. Openness here is not understood as a universal principle, but as a civil society ideal whose value one has to renegotiate over and over again.[10] Within the

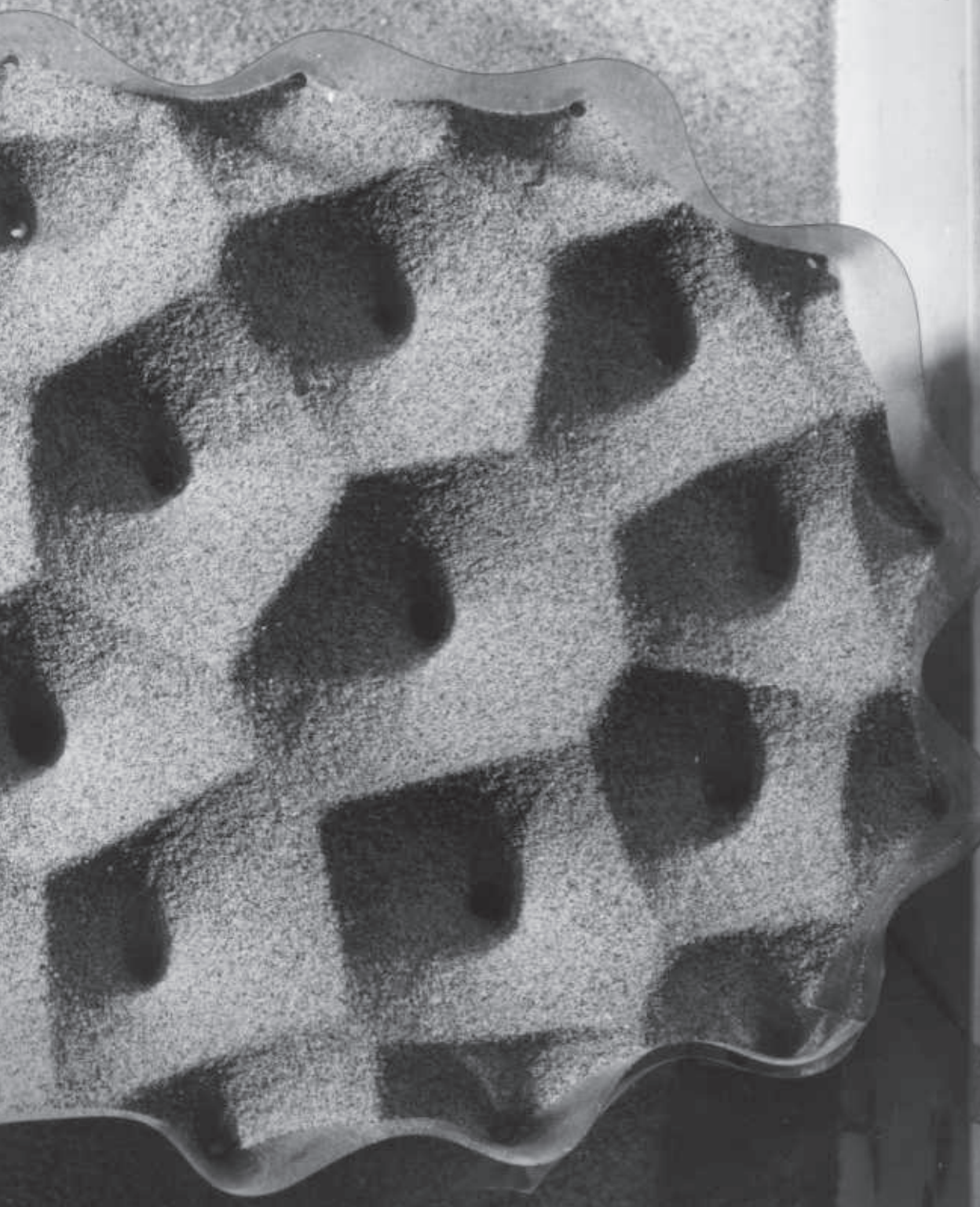
more standard Modernist architecture, the "fantastic line" would no longer have any strength, Otto wrote in a 1962 essay entitled "Imagination et Architecture" in *L'Architecture d'Aujourd'hui*.[11] It is for this reason that his experimental architecture focused on showing alternatives to the functionalist design imperative. With the term *imagination*, Otto wanted to recall the optimistic narratives of the 1920s Expressionist movements, the poetic power of a Paul Scheerbart or Bruno Taut, the literary and artistic inventiveness, and the spirituality in the world. In his experiments, Otto touched an intellectual core of design and architectural thinking: the constant attempt to keep artistic imagination on the one hand and technical reason on the other in a simultaneously creative and effective balance.

Architecture as Social Innovation

Frei Otto's architectural research was remarkable as a social innovation. He continually succeeded in questioning and overcoming the traditional claim to autonomy of architecture. For instead of just focusing on design, he was also interested in artistically elaborating on the material dimension of architecture. For him, materiality was not something that had to be forced, for better or worse, into an already established form, but rather something that could serve as a starting point for the design process itself. What at first sounds like an academic gimmick turns out, on closer inspection, to be an elegant attack on nothing less than the historically established hegemony of geometry. Otto was therefore not only concerned with rebuilding architecture, but also rethinking architecture. If one wants to tell the history of architecture, traditionally understood as the history of building and style, also as a cultural history of experiments and research, i.e. of the models, media, and methods of design, then Frei Otto's architectural research is a substantial starting point.



Frei Otto, sand model, Regensburg project, Atelier Warmbronn, ca. 1970



NOTES

1 Gibson A. Danes, letter, August 16, 1963, Stuttgart University Archive.

2 In 1950 Otto received a scholarship to the University of Virginia in Charlottesville. During this time he visited Frank Lloyd Wright, Erich Mendelsohn, Ludwig Mies van der Rohe, and Walter Gropius. He also met with engineer Fred Severud who worked on the Dorton Arena, Raleigh, designed by Matthew Nowicki (1953); the House of World Cultures in Berlin, designed by Hugh Stubbins (1957); and the David S. Ingalls Hockey Rink of Yale University, designed by Eero Saarinen (1959). See: Frei Otto, *Das hängende Dach. Gestalt und Struktur*, (Bauwelt Verl: Berlin, 1954).

3 Some examples here of structural typologies of the modern tent construction are the "four-point tent" for the horticultural show in Kassel (1955), the "Tanzbrunnen" (dance pavilion), and the "arch-supported tent" for the entrance area of the horticultural show in Cologne (1957), and the "Hump Tent" for the International Building Exhibition (IBA) in Berlin (1957). See Conrad Roland, *Frei Otto: Spannweiten; Ideen und Versuche zum Leichtbau* (Ullstein: Berlin, 1965).

4 See: Irene Meissner, "Lightweight Construction Versus a Display of Prestige. From Montreal '67 to Munich '72," in: Georg Vrachliotis et al., *Frei Otto. Thinking by Modelling*, (Spector Books: Leipzig, 2017): 41–53.

5 Cf. Daniela Fabricius, "The Spinner Experiment: Frei Otto and the Institute for Lightweight Structures," European Architectural History Network Meeting, Brussels, May 31 to June 3, 2012.

6 Rudolf Leonhardt, "Swinging Germany," *Die Zeit*, May 12, 1967.

7 "Frei Otto: Thoughts on the Construction of Grid Shells at Mannheim," in: *IL Bulletins of the Institute for Lightweight Structures (IL)* 13, University of Stuttgart (1978): 10.

8 Frei Otto, "Peter Strohmeyer: Frei Otto, Zelte," in: *Deutsche Bauzeitung* 7 (1960): 352.

9 See Gilbert Simondon, *Die Existenzweisen technischer Objekte* (Diaphanes: Zurich, 2012). See in particular, the section, "Die technische Erfindung: Grund und Form beim Lebewesen und im erfinderischen Denken," 52–55. Originally published in French as *Du mode d'existence des objets techniques* (Aubier: Paris, 1958).

10 Regarding the relationships of architecture and society, see for example: Frei Otto, "Wie werden wir weiterleben?," in: *Frei Otto: Schriften und Reden 1951–1983* (Vieweg +Teubner Verlag: Wiesbaden, 1984), 72–76, (originally published in *Dokumentation der Referate und Diskussion*, 42, Bundestag des BDA Hannover, 1967).

11 Frei Otto, "Phantasie und Architektur," *db deutsche bauzeitung* 69 (1964): 543–4; here p. 543 (French original: "Imagination et architecture: essai d'une vision d'avenir," *L'Architecture d'Aujourd'hui* 102 (1962): 89–93.

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The growing city, drawing, 1953

Social housing complex for the Alexandra Stiftung, Berlin, drawing, 1956

Two photo collages of social housing complex for the Alexandra Stiftung, Berlin, 1956

Wohnhäuser für New York (Housing for New York), *EL Bulletin* No. 6, Entwicklungsstätte für den Leichtbau EL (Development Center for Lightweight Construction), text, Berlin, March 1959

Model of the project Wohnhäuser für New York (Housing for New York), Institute for Lightweight Structures (IL) at the University of Stuttgart, contact sheets

GERMAN PAVILION EXPO 67 MONTREAL

Frei Otto and Rolf Gutbrod, competition model of the German Pavilion Expo 67, Montreal, ca. 1965

Carl Mertz and Rolf Gutbrod, model of the German Pavilion Expo 67, Montreal at the airport in Frankfurt, Germany (photograph: Frei Otto), ca. 1966

Construction of the measurement model, Institute for Lightweight Structures (IL) at the University of Stuttgart, ca. 1966

Rolf Gutbrod and Frei Otto, form-finding model of the German Pavilion Expo 67, Montreal, 1966

Two photographs of Frei Otto and Rolf Gutbrod, wooden model in the wind tunnel

Frei Otto and Rolf Gutbrod, construction of the German Pavilion Expo 67, Montreal, 1967

ARCTIC CITY

Five photographs of installing the dome for the pneumatic model of the Arctic City project, Atelier Warmbronn, 1971

Two photographs of Frei Otto working on the model of the Arctic City project, Atelier Warmbronn, ca. 1971

Frei Otto photographing the model of the Arctic City project, Atelier Warmbronn, ca. 1971

View into the model of the Arctic City project, Atelier Warmbronn, ca. 1971

Frei Otto with journalists in front of the model of the Arctic City project, Atelier Warmbronn, ca. 1971

MUNICH OLYMPIC PARK

Two photographs of Frei Otto and his team discussing the complete model of the Munich Olympic Park, Atelier Warmbronn, 1968

Three images of Frei Otto photographing a model for the Munich Olympic Park, Atelier Warmbronn, ca. 1968

Model with contour lines of the tent for the swimming pool in the Munich Olympic Park, Atelier Warmbronn, ca. 1970

Munich Olympic Park, 1972

MULTIHALLE MANNHEIM

Frei Otto's team conducting a photogrammetric measurement of the suspended model, Multihalle Mannheim, Atelier Warmbronn, 1973

Frei Otto's team conducting wind tunnel measurements on the model, Multihalle Mannheim, scale: 1:200, with Ove Arup & Partners, London, 1974

Construction of the wooden supporting frame and process of transferring the suspended form to a structure made from Plexiglas strips and brass supports, contact sheets, Institute for Lightweight Structures (IL) at the University of Stuttgart, ca. 1973

Frei Otto and Carlfried Mutschler, Multihalle Mannheim, 1975

PUBLICATIONS & RESEARCH DOCUMENTATIONS

Two contact sheets of modeling studies for the Dissertation Das hängende Dach, Entwicklungsstätte für den Leichtbau EL (Development Center for Lightweight Construction), contact sheet, Berlin, 1953

Das hängende Dach, Gestalt und Struktur, (Bauwelt Verlag: Berlin, 1954)

"The Congress Hall Debate," *Architectural Forum*, January 1958

Gibson A. Danes, letter, August 1963, courtesy of the Archive of the University Stuttgart

Protokoll über die Arbeiten des Instituts für Leichte Flächentragwerke an den Modellversuchen und Auswertungen am Projekt "Deutscher Pavillon," 1967, Weltausstellung Montreal, typescript, 1967

EL BULLETIN, BERLIN

EL Bulletin No. 2, Bauwerke mit senkrechten Bögen, die Seilnetze oder Membranen tragen und durch diese abgespannt werden, Entwicklungsstätte für den Leichtbau EL (Development Center for Lightweight Construction), Berlin, February 1958

EL Bulletin No. 3, Das Eingangsdach für die Bundesgartenschau m Köln 1957, Entwicklungsstätte für den Leichtbau EL (Development Center for Lightweight Construction), Berlin, March 1958

EL Bulletin No. 6, Entwicklungsstätte für den Leichtbau EL (Development Center for Lightweight Construction), Berlin, March 1959

IL BULLETIN, STUTTGART

No. 1, The Experimental Determination of Minimal Nets, 1969

No. 2, City in the Arctic, 1971

No. 3, Biology and Building, part 1, 1971

No. 4, Biology and Building, part 2, 1972

No. 5, Convertible Roofs, 1972

No. 6, Biology and Building 3, 1973

No. 7, Shadow in the Desert, 1972

No. 8, Nets in Nature and Technics, 1975

No. 9, Pneus in Nature and Technics, 1977

No 10, Gridshells, 1974

No. 11, Lightweight and Energy Technics, 1978

No. 12, Convertible Pneus, 1975

No. 13, Multihalle Mannheim, 1978

No. 14, Adaptable Architecture, 1975

No. 15, Air Hall Handbook, 1983

No. 16, Tents, 1976

No. 17, The work of Frei Otto and his Team 1955–1976, 1978

No. 18, Soap Bubbles, 1987

No. 19, Growing and Dividing Pneus, 1979

No. 20, Tasks, 1979

No. 21, Form-Force—Mass, Part 1 (Basis), 1979

No. 22, Form-Force—Mass, Part 2 (Form), 1988

No. 23, Form-Force—Mass, Part 3 (Construction), 1992

No. 24, Form-Force—Mass, Part 4 (Principle of Lightweight), 1998

No. 25, Form-Force—Mass, Part 5 (Experiments), 1990

No. 26, Youth Competition—Nature and Architecture, 1979

No. 27, Natural Building—Symposium Report, 1980

No. 28, Diatoms: Shells in Nature and Technics, Part 1, 1984

No. 29, The Tent Cities of the Hajj, 1980

No. 30, Awnings, Vela, Toldos and Sheet Metal Tents, 1984

No. 31, Bamboo Structures, 1985

No. 32, Lightweight Structures in Architecture and Nature, (Exhibition "Natural structures" Moscow, 1983), 1983

No. 33, Radiolarian, Stuttgart, 1990

No. 34, The Model, 1989

No. 35, Pneu and Bone, 1995

No. 36, Subjective Standpoints in Architecture and Science, 1984

No. 37, Ancient Architects, 1994

No. 38, Diatoms: Shells in Nature and Technics, Part 2, 2004

No. 39, Non-Planned Settlements, 1992

No. 40, Branches, 1995

No. 41, Building with Intelligence, 1995

PUBLICATIONS ABOUT OTTO

Architectural Design, Frei Otto at work, special issue, 1971

Ludwig Glaeser, *The Work of Frei Otto* (exhibition catalog), The Museum of Modern Art, New York, 1971