

## Frei Otto and the debate about the genesis of architectural form

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Fig. 1. Pavilion for the Federal Garden Exposition in Mannheim, Germany, 1975.

The concept of arbitrariness has drawn the attention of the critics in the contemporary debate about the genesis and the reasons of architectural form, to point out one aspect that, being always present in the history of architecture, has to a greater or lesser extent remained subdued. The reason for this quietness may be found in the need to justify form always from the point of view of the theory of architecture and rationality. The presence of arbitrariness in architecture is being observed as increasingly relevant, especially in the last quarter of the twentieth century, within the context of a paradoxical thought which questions coherence as belonging to the substance of architecture<sup>1</sup>.

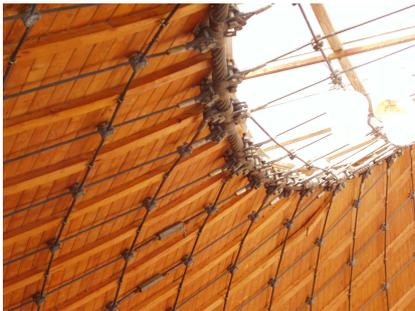


Fig. 2. Institute of Lightweight Structures in Stuttgart.

If the approach of arbitrariness assumes that any form, known or invented, can become architecture, we would have in contrast the concept of causality as the origin of architectural form. Moneo<sup>2</sup>, in his documented survey about arbitrariness in architecture, shows two examples to illustrate both positions. So, John Hejduk's exercise for his students at Cooper Union asking them to design a house taking as a starting point a painting by Juan Gris, is mentioned as a precedent of the use of arbitrariness as a concept underlying the work of many architects of the last quarter of the twentieth century. Gaudí would be an example of the opposite approach, although with a wealth of fantastic forms which, at first sight, could be described as arbitrary. However, behind these Gaudian forms you can trace a geometry and a building process explaining its genesis. They are surprising, new, unexpected forms which have not been imposed from outside, but have arisen by inventing a generating process. As Moneo puts it, "the invention of form coincides with the invention of the building process", in such a way that "Gaudí does not invent forms; he discovers them"<sup>3</sup>.



Fig. 3. Convertible roof for a big multimedia space. Project model made by Frei Otto and the Institute of Lightweight Structures in Stuttgart.

It is really amazing to discover the countless possibilities implicit in Gaudí's exploratory approach of architectural form. Many of them have become explicit thanks to the work and experiments of the German architect Frei Otto. Not for nothing is he held to be a pioneer of new forms by the historiography of architecture of the second half of the twentieth century. They have usually been exemplified by the German Pavilion for the Universal Exposition in Montreal (1967) and the Olympic



Fig. 4. Undulating surface made up of parallel axes alternating ridges and valleys. Model made with soap film at the Institute of Lightweight Structures in Stuttgart.

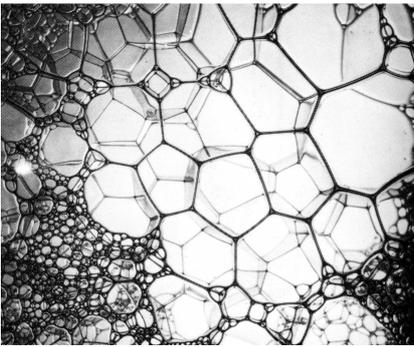


Fig. 5. Experiment with soap foam making up three-dimensional bubble aggregates.



Fig. 6. Hanging model producing a branching geometry and branching supports.



Fig. 7. Hanging chain net producing the antifunicular form of a grid shell supported all around its perimeter.

Stadium of Munich (1972). He is best known through these works, and even linked to the beginnings of High Tech, but they are not enough to reveal all his plentiful and rich contribution. His grid shells (Fig. 1), his cable net structures (Fig. 2), his pneumatic structures, his convertible roofs (Fig. 3), and so many other inventions that came from his workshop in Berlin, and later in Stuttgart, are the result of observing attentively physical phenomena giving rise to self-generating form processes.

His experiments with soap bubbles (Fig. 4 and 5), with grain heaps or with viscous liquid membranes, or his tests to investigate branching structures (Fig. 6), folds or antifunicular forms (Fig. 7) are some of the natural processes which have drawn Frei Otto's attention, with the aim of observing the forms that were generating and unravel their own logic. All this has revealed in this architect a marvellous capacity to discover the unknown and the unheard of in the everyday, the extraordinary in the ordinary, in the most common natural phenomena.

Two issues are outlining here, both of them highly topical in the contemporary debate about the genesis of architectural form. On the one hand the controversy between digital design and physical experimentation, between computer and analogical processes, and on the other hand the relationship between nature and architecture. In Frei Otto's view form generation through physical processes and the observation of these natural phenomena's logic has a differential value in relation to computers, as computers are governed by a logic devised by man, whereas physical phenomena are ruled by a logic, on which much remains to be discovered and become known. Physical experiments with models would thus become a privileged tool for invention, to find the unsearched, in contrast with the computer, where, according to Frei Otto, you can only find what you are searching for, what conceptually is already there. This experimental methodology involves a thorough knowledge of physical processes, both qualitatively and perceptually, which lets Frei Otto invent methods and experiments in accordance with the issue raised in each case, always considering countless possibilities. Moneo's assertion about Gaudí could also be applied here: "the invention of form coincides with the invention of the building process".

The relationship between architecture and nature involved in this methodology of the genesis of

architectural form is consequently not based on imitation or on formal analogies, but on the analysis and observation of self-generating form processes. Nature is not considered as a model to imitate, and its phenomena are investigated without prior intentions or any pre-established aspirations of immediate application to architecture, just for the purpose of understanding its processes. Architecture, on the other hand, is considered as natural science, within the context of a holistic approach in accordance with nature, with a backdrop of an ideal of economy in a cosmic sense, which assumes agreement with the universe, and which makes Otto one of the precursors of sustainability in the field of architecture.

This consideration of form as the result of a search process belongs to the German tradition of the "organic" ideal, according to which, as Alan Colquhoun puts it, "the external form of the work of art, similarly as in the case of plants and animals, ought to be the result of an internal force or essence, instead of being mechanically imposed from outside"<sup>5</sup>. Goethe himself claimed the organic nature of poetic work. In his view the production process of the work of art does not proceed from the parts to the whole nor from outside into inside, but from inside into outside and from the whole to the parts. This assumes that the whole exists from the very beginning, although in an embryonic form, and that each part grows jointly with the others, being the external the expression of its internal vitality. There is in this idea a clear parallel between artistic creation and natural processes, whereby art is considered to be deeply rooted in nature, its source of fecundity. In Goethe's view art behaves like nature, and, precisely because of this, art does not imitate nature, but prolongs it, creating a new reality, purely artistic, with an

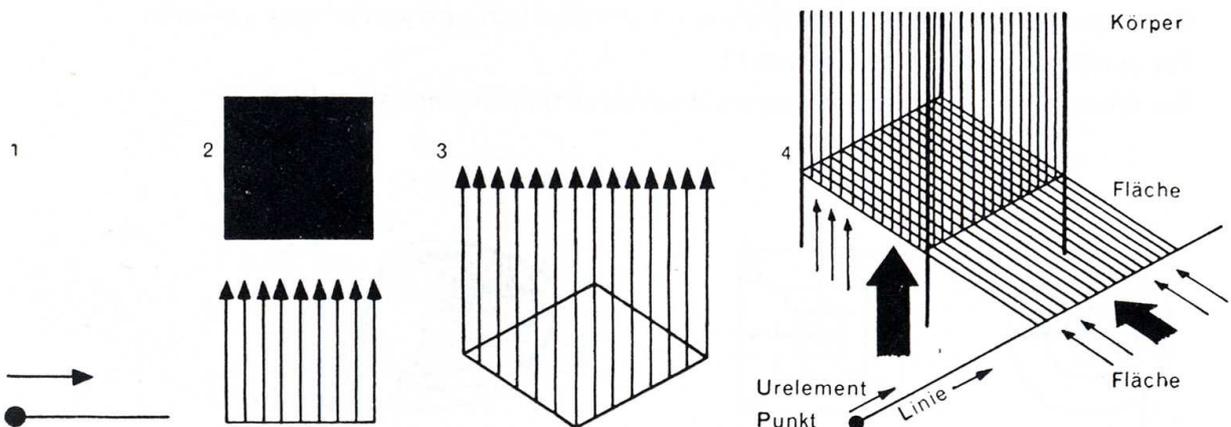
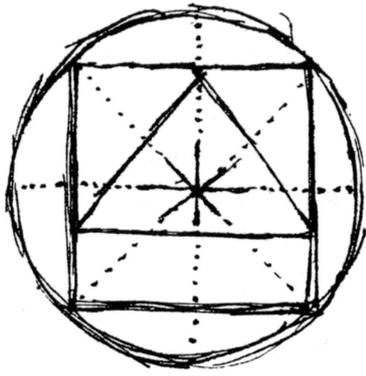


Fig. 8. Dimensional dynamics from dot to line, from line to plane and from plane to body. Sketch by Paul Klee.



autonomous life ruled by its own laws. The main purpose of art would thus not be to represent natural reality, but to set up a new and independent reality. In this way, we could link the concept of "organism" with that of "abstraction", as, according to this, artistic creation becomes production of autonomous objects which are endowed with an organization of its own, where anything not belonging to the internal economy of its form is removed.

So, the debate between naturalism and abstraction, so recurrent along the twentieth century, becomes less confrontational if we realize that in both positions we are closer to the logic of causality than that of arbitrariness. Indeed, we can see how those more closely linked to the abstract approach, like Kandinsky or Moholy-Nagy, are in fact determined to explore the internal logic of form, trying to set up "an analytical inventory of our perception of form", and "to organize, starting from categories of perception and Gestalt psychology, a system with a clear didactic purpose"<sup>6</sup>, which may be useful as an introductory course for any form handler. This abstract discourse of form, aiming at achieving a well-organized inventory of form effects, where its most specific elements and relationships are clearly identified, is actually searching to reveal the order of the inner structure of form, or, as previously said, the specific laws of that "organism" or new reality with a life of its own, as a result of artistic creation.

John Hejduk himself would provide us with a good example of these explorations when he asked his students to investigate the design possibilities of a geometric structure made up by a nine square net. But two of the most paradigmatic examples of form systematizations based on abstract art discoveries are to be found in two artists linked with the Bauhaus and Russian Constructivism respectively: Paul Klee and Iakov Chernikhov, two figures of key importance in the field of theory of form.

The systematizations that we can find in Paul Klee<sup>7</sup>'s pedagogical writings and texts of lessons given at the Bauhaus correspond to an idea of form as a process, to a dynamic conception of form generation, starting from basic elements of geometry: dot, line, plane, space (Fig. 8). One of the first epigraphs of these writings says: "Forming is connected with movement". There we can see an attempt to identify vectors, focal points, axes and main directions providing the clues of visual dynamics,

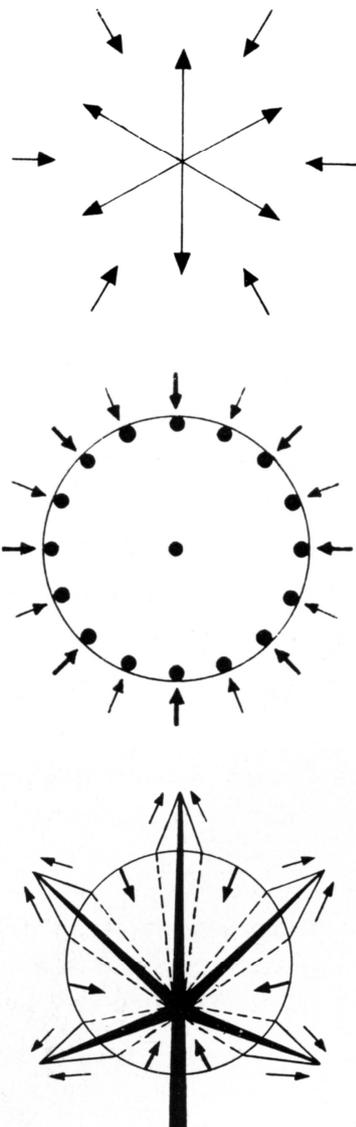


Fig. 9. Focal points, axes, vectors and geometric stresses regarding the circle. Sketches by Paul Klee.

and the essential parameters of geometric stresses active in the genesis of form (Fig. 9). We are not far from a conception of form as an “organism”, which grows and develops from an internal force or geometric essence.

On the other hand, the systematizations that we can find in Chernikhov's texts<sup>8</sup>, also written with a didactic purpose, reflect the influence of abstract art, most particularly of Suprematism, and of the machine aesthetics, as one would normally expect. They show an effort to make an inventory of the elements of form on a plane and in space (Fig. 10), and to investigate specially the relationships or fundamental operations with these basic elements of form, such as penetration, embracing, clamping, interlacing, mounting, or coupling. One can easily detect in Chernikhov's systematizations an outstanding interest in exploring thoroughly the possibilities that the combinations of different elements of form can generate in these operations (Fig. 11). The characteristics of each category are examined so as to assess its potentialities as raw material for the genesis of form. We find ourselves again confronted with a search process of the internal forces or essence of form.

Frei Otto also faced, for educational purposes, the task to make up a system of categories that should account for form. His target was both ambitious and utopian<sup>9</sup>. The point was to find a method that should be valid for all known objects, in order to cast some light on the wholeness of the infinite diversity of forms of objects surrounding us, trying to establish a certain order and a common ground in the universe of forms. In spite of being aware about the impossibility both to reach a conclusive

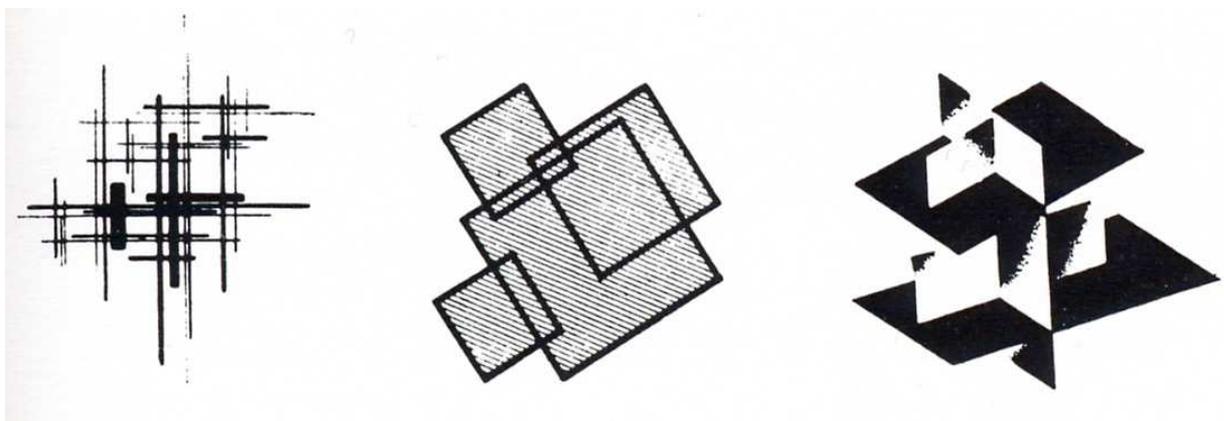


Fig. 10. Compositions of linear and plane elements on a plane and in space. Systematizations of form by Iakov Chernikhov.

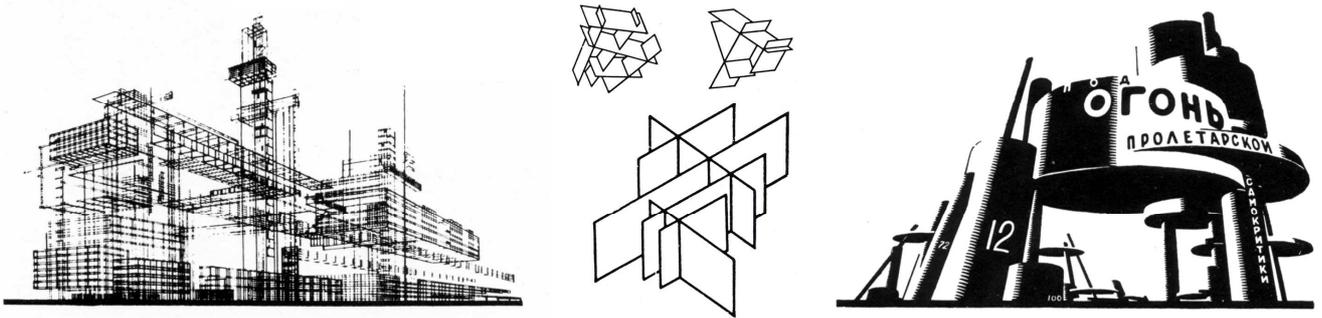


Fig. 11. Combinations of linear, plane and solid elements to make up three-dimensional compositions. Studies about form generation made by Iakov Chernikhov.

systematization and to set up a comprehensive order on the infinite, the intention was to include in this systematization of form not only the objects created by man through technology and art, but also the objects of inanimate nature, animate nature and dead nature (Fig. 12), embracing all scales and drawing common principles.

This comprehensive approach regarding forms and objects reflects Frei Otto's interest fields and research targets, where we can find, on the one hand, the search for common principles between objects from nature and objects created by man, and, on the other hand, a vision of man and architecture in accordance with the

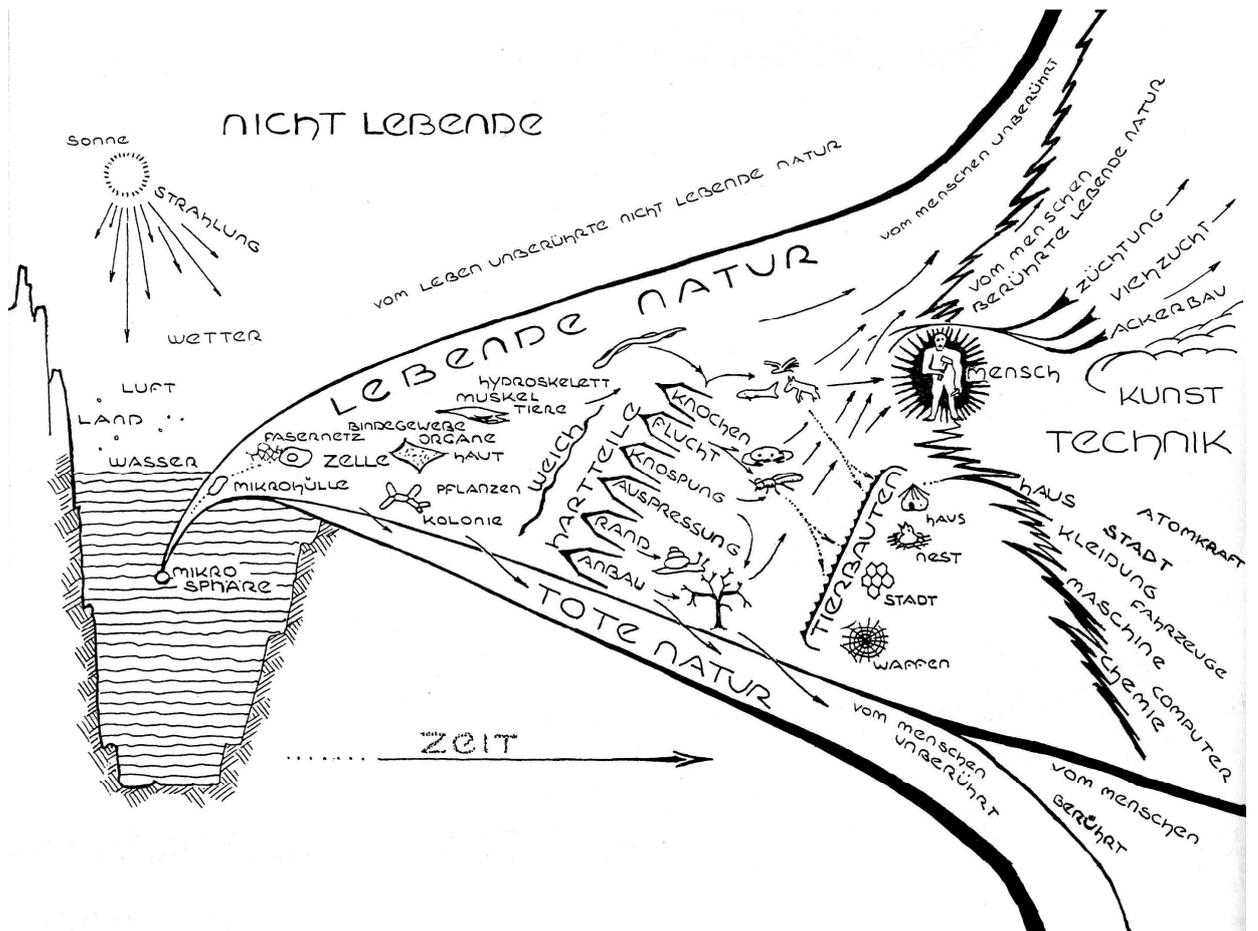


Fig. 12. Evolutionary synopsis on the genesis of form along time, and on different groups or worlds of forms.

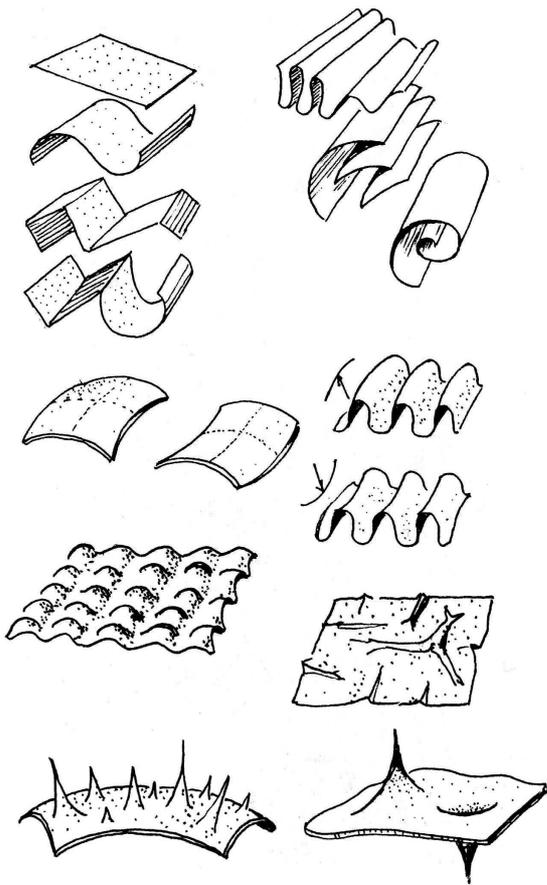


Fig. 13. Classifications of possible forms with two-dimensional elements. Drawing by Frei Otto.

surrounding ecological system so as to make up with it a whole unity, an inseparable part in compliance with the whole. The categories shown in this systematization of form easily conjure up the processes of self-generation of form active in Frei Otto's experiments and structures. So, the categories "positive form" / "negative form" and "cavities" / "hollow bodies" make you think of pneumatic structures, whereas the categories "high and low points", "edges" and "corners" naturally remind us of his experiences with nets or membranes (Fig. 13 and 14).

If the forces generating form in Klee's or Chernikhov's systematizations were more geometric, abstract or conceptual, in Frei Otto's systematizations they are more visible, perceptible and physical. Here the relationship between stress and form is more evident. The form itself reveals the stresses going through it. It becomes channel and expression of the flow of stresses. Nonetheless, it is not difficult to find a common ground in these two ways of exploring form. Josef Albers, for example, a colleague of Paul Klee at the Bauhaus, set in his preliminary course exercises to explore the relationship between form and material through physical experimentation with workshop materials such as newspapers or corrugated cardboard. Walter Gropius himself, founder of the Bauhaus, acknowledged Frei Otto as a follower of his principles<sup>10</sup>, and as a true successor of the philosophy and methodology that pervaded the foundation of the Bauhaus, as he does not start from any prior formal approach, but rather considers form as a result of a search process.

Perhaps one common element in these two ways of exploring form would be one principle that can be detected in those works which are most widely recognized, irrespective of their aesthetic tendencies or stylistic options, a principle of economy of expression, referred to as "the principle of parsimony" by Joaquim Español<sup>11</sup>, which actually retrieves the conceptual richness of Mies' well known aphorism suggesting us to reach the most through the least. As a matter of fact, and in contrast with Venturi's ideas, "less is more" does not necessarily mean to deplore complexity or to suggest exclusion, but, as Joaquim Español says, "this expression is fruitful if we redefine it as a process, asserting that any movement going from fewer means to better results is a positive one"<sup>12</sup>, or, as Mies wrote in 1923: "The greatest effect with the most concise means". This "search for a maximum formal and conceptual tension with a restricted use of

geometrical forms", taking J. M. Montaner<sup>13</sup>'s words, "does not refer to any fashion or any new tendency", but can be recognized as one of the identifying features of twentieth century architecture, and we could also say, as Joaquim Español, not only of that century.

In contrast with the concept of arbitrariness, apparently so far away now at this point of our speech, Moneo proposes the concept of "formativity", as presented by Luigi Pareyson, to embrace in it both arbitrary form and law-abiding form<sup>14</sup>. It is a concept attempting to explain the work of art from its own inner

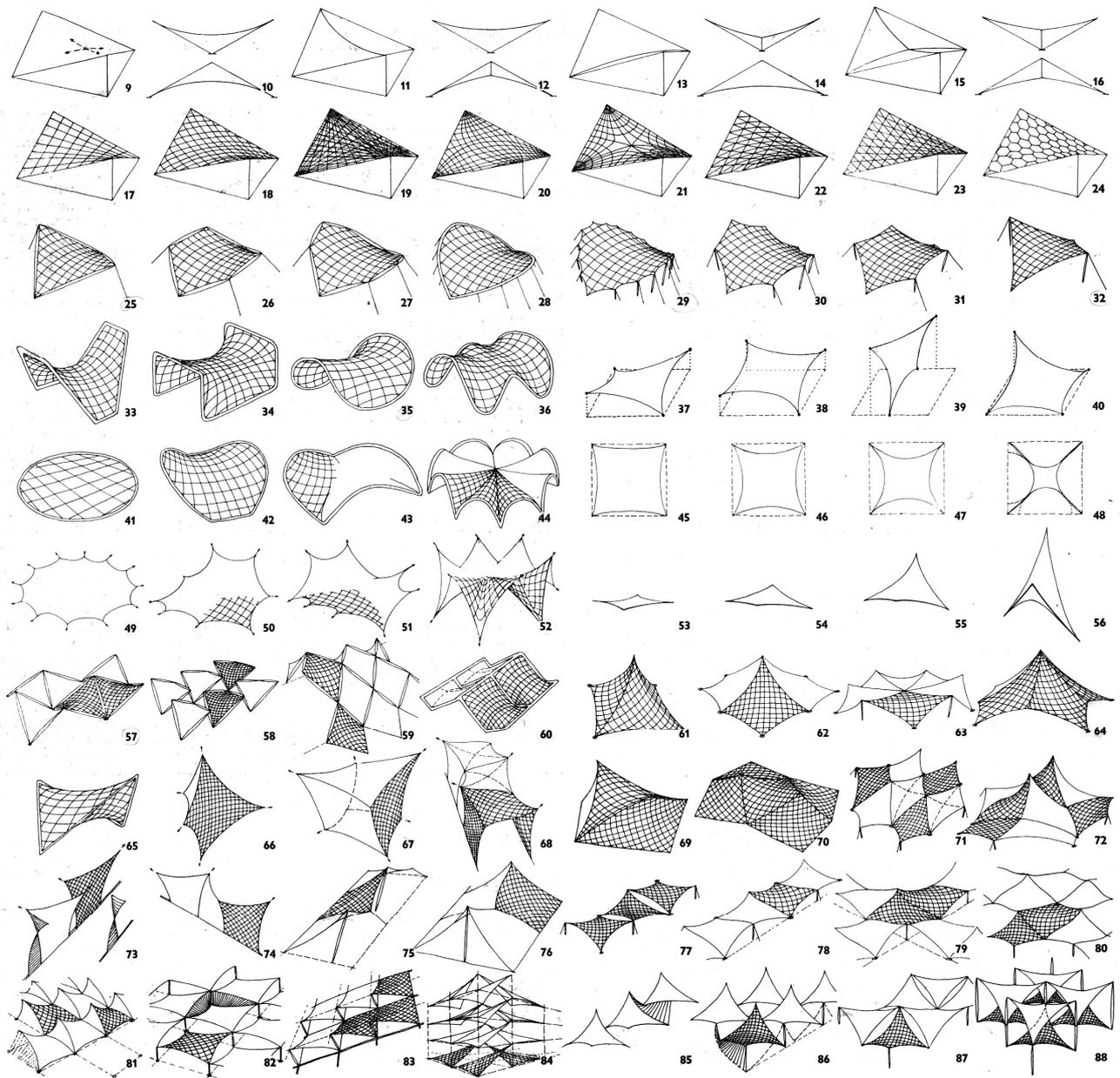


Fig. 14. Variations, additions and combinations of net structures with warped forms. Graphic systematizations by Frei Otto.

being, and focusing attention on its creation process. Formativity accounts for the process of artistic creation considering both invention and realization simultaneously: "to form means to invent the work and at the same time the way to make it"<sup>15</sup>. So, the artist invents not only the work but also its laws, and he must abide by the internal coherence of the work he is creating. "If it is true that the artist does not succeed if he does not do the work's will, it is not less true that he himself creates that will. [...] Therefore, there is a dialectic polarity between the artist's activity and the work's intentionality, between the person's free initiative and the immanent teleology of form"<sup>16</sup>. The artistic activity thus appears both as "freedom and need, artist's work and work's will, adventure and determination: in one word, trial and orderly realization"<sup>17</sup>.

In the context of this dialectic, where the work is both the law and the result of its implementation, "forma formata" and "forma formans" at the same time, we find the conciliation of two distant terms: on the one hand, arbitrariness in the election of the numerous courses that come up to the artist facing his work at the beginning of its creation process, and on the other hand, causality coming up once the work is finished, when the artist realizes how, among trials, hesitations and corrections, one single way has actually been followed, "and the very unmodifiability of the work arises as a sign of the univocity of the followed route"<sup>18</sup>. Two different viewpoints over one single activity: the viewpoint of the artist facing the work he intends to carry out and the viewpoint of the work once its completion is fulfilled. When confronting "this organic development of the work, indeterminate and unforeseeable *a parte ante*, and univocal and necessary *a parte post*,"<sup>19</sup> experiences and contributions like Frei Otto's maintain their validity and pertinence in the ever up-to-date debate about the relationship between form and architecture.

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<sup>1</sup> A sample to prove this presence of the concept of arbitrariness in contemporary architectural debate would be the well documented survey carried out by José Rafael Moneo in his speech of acceptance as a full member at the Real Academia de Bellas Artes de San Fernando in Madrid, dated in January 2005 and titled "*Sobre el concepto de arbitrariedad en arquitectura*", as well as the article by Luis Rojo de Castro "*De la coherencia a la contradicción, y de la contradicción a la paradoja, o qué hacer con la arbitrariedad en la arquitectura*", published in *Arquitectura* no. 326, COAM. Madrid, 2003.

<sup>2</sup> Moneo, José Rafael: op. cit. p. 34-35, and p. 29-31.

<sup>3</sup> Moneo, José Rafael: op. cit. p. 29 and 30.

<sup>4</sup> To know more about Frei Otto's experience and thought, cf. the author's Ph. D. dissertation: "*Frei Otto y el Instituto de Estructuras Ligeras de Stuttgart. Una experiencia de metodología, investigación y sistematización en la búsqueda de la forma resistente*", Universidad Politécnica de Valencia. Valencia, 2005, and most particularly a conversation held with him, published in *A Conversation with Frei Otto / Juan María Songel*. Princeton Architectural Press. New York, 2010.

<sup>5</sup> Colquhoun, Alan: "*La arquitectura moderna: una historia desapasionada*". G. Gili. Barcelona, 2005 (2002). p. 41.

<sup>6</sup> de Solà-Morales, Ignasi: "*Exploraciones para un tratado de composición*", en Fonatti, Franco: "*Principios elementales de la forma en arquitectura*". G. Gili. Barcelona, 1988 (1985). p. 7.

<sup>7</sup> Cf. Klee, Paul: "*Das bildnerische Denken. Form- und Gestaltungslehre*". Schwabe. Basel, 1990 (1956). Edited by Jürg Spiller.

<sup>8</sup> Cf. Cooke, Catherine: "*Chernikhov. Fantasy and construction*". *Architectural Design Profile* 55. A.D. Volume 54. London, 9/10-1984.

<sup>9</sup> Cf. Chapter IV of the above mentioned author's Ph. D. dissertation: "*Cap. IV. Frei Otto y la sistematización de la forma*". pp. 167-194.

<sup>10</sup> Cf. *A Conversation with Frei Otto / Juan María Songel*. Princeton Architectural Press. New York, 2010. p. 27-28.

<sup>11</sup> Español, Joaquim: "*El orden frágil de la arquitectura*". Fundación Caja de Arquitectos. Barcelona, 2001. p. 197-199.

<sup>12</sup> Español, Joaquim: op. cit. p. 198.

<sup>13</sup> Montaner, J.M.: "*Taxonomía de minimalismos*", in Savi, V. Y Montaner, J.M.: "*Less is more. Minimalismos en arquitectura y otras artes*". COAC y ACTAR. Barcelona, 1996.

<sup>14</sup> Moneo, José Rafael: op. cit. p. 55.

<sup>15</sup> Pareyson, Luigi: "*Conversaciones de estética*". Visor. Madrid, 1988 (1966). p. 31.

<sup>16</sup> Op. cit. p. 30 and 33.

<sup>17</sup> Op. cit. p. 31.

<sup>18</sup> Op. cit. p. 32.

<sup>19</sup> *Ibíd.*

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Cooke, Catherine: "*Chernikhov. Fantasy and construction*": Fig. 10, 11

Klee, Paul: "*Das bildnerische Denken*": Fig. 8, 9

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