Proceedings of the International Association for Shell and Spatial Structures (IASS) Symposium 2009, Valencia
Evolution and Trends in Design, Analysis and Construction of Shell and Spatial Structures
28 September – 2 October 2009, Universidad Politecnica de Valencia, Spain
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About the freedom of free forms

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Abstract

This paper deals with the arrival of freedom at the world of structures giving birth a new generation of forms: the free forms. Its purpose is to analyze, to discuss and to comment critically this singular fact as well as their implications on the designers' task. It is more a philosophical than a technical paper.

For centuries man has imagined new forms for their structures but he has not been always able to analyze and to build them. Before the arrival of the electronic calculus, the representation and analysis of structural forms could be limited to those ones belonging to the Euclidean Geometry. The computers broke those limitations and they gave wide freedom to the designers to conceive a new generation of forms; these new forms were called "free forms".

Nowadays any form imagined can be represented, it can be analyzed and it can be built. Nevertheless not any imagined form can become a structural free form. Perhaps it could be a beautiful sculptural form, but not necessarily a structural one. For being a structural form, the inescapable laws of the mechanics must be satisfied. Moreover a structural free form can become an architectural free form just only when aesthetical, functional, environmental and social requirements, among others, are accomplished.

Freedom has widened the horizons of creativity for the designers' task. Simultaneously new responsibilities have come altogether with this freedom. Today free form designers face permanent challenges; designers must be familiar with the menus of new and multiple tools created by the modern technology and they must be trained to make the right use of them. They must handle those wide menus in order to select the most appropriated options to generate, to model and to analyze the new free forms. At the same time they must select the most appropriated new materials and techniques to build these free forms. Finally, designer must be fully conscious of the high impact of their engineering and architectural works on the people and physical environment without forgetting their commitment to the society.

Keywords: free forms, morphology, morphogenesis, form design, structural analysis, technical requirements, social requirements.

> "*…And thus it is possible to build successfully forms so varied…that is only the announcement and proclamation of the* ***revolution*** *that is approaching in the field of architecture, whose vocabulary of plastic forms is opening and widening with rapidity and imaginative fecundity unknown in all the history of Construction." (*Translated from the Spanish original text, Torroja [1]).

The above words were written by EduardoTorroja in 1957; they are an expression of his visionary thought about the future of Construction. The purpose of this paper is to discuss from technical and social points of view that **revolution** anticipated by Torroja.

1. Introduction

For centuries man has imagined new forms for their structures but he has not had always the necessary skills and tools to analyze and to build them. The historical evolution of the creation of new structural forms was strongly and permanently linked to his ability to design and to analyze their conceptions.

On the other hand, design and analysis have not had always the same grade of development along history. At the beginning and from very remote times, man did not have more tools than his imagination, his audacity, his mind's eye and common sense to conceive and to build structures. At the same time "trial and error" was the most primitive and valuable tool to verify the safety of his works. By then his competence to conceive a work was superior to his capability to analyze it, that is to say, design had a higher level of development than analysis: man was able to conceive works that he was not able to analyze. Later the accumulated experience gave place to the development of empiricism which became a new tool for the design and construction of structural forms. Until this point, the analysis could offer no more than the "trial and error" method and the help of intuition for verifying the behaviour of structures. Nevertheless famous old structures were built thanks to the ingenuity and boldness of man. Many of those structures have lasted until our days and we admire them like real master pieces.

The capability of the analysis increased greatly in the XVIII century thanks to the development of the sciences and the birth of the Engineering as a professional activity. Mathematics and Physics became strong tools for better understanding and analyzing the behaviour of the structures. Man was able not only to design but also to analyze many structures than he could never do before. However there still were limitations: just only those structural forms belonging to the Euclidean Geometry could be analyzed; man could

conceive other new forms which he was not able to analyze. More recently we can point out new stages on the developments of structural forms as it will be shown in the following lines.

2. From A.M. Haas to the computer age

*"One **selects** the correct form (with the architectural draft) then half work is already done".*
(Translated from German original text, Haas [2])

More than thirty years ago I read the above slogan written by A. M. Haas, IASS past-president and very well known authority in the field of structural shells. I was impressed by his unquestionable truth and I have repeated this slogan for many years to illustrate the emphasis on the importance of the form for designing structural shells. It was just a few months ago when I read again the same text, but then a word caught my eye: ***selects.*** In fact, Haas used to *select* and not to *design* as we might say today. By the time when Haas wrote his slogan the designer was restricted to those forms included in the catalogue of the Euclidean Geometry because they and only they were able to be analyzed with the tools available by then. In the 60's a new tool was incorporated in the field of structural analysis: the computer. The arrival of this instrument made a break point in the history of construction as Ben Arroyo [3] pointed out: for the first time the capabilities of the analysis overcame those ones of the design. New roads began to be opened for the designers because the analysis was able to attack new forms not included in the catalogue of the classical Geometry. Designers were able to create a new variety of forms.

3. Morphogenesis

The arrival of the computer pushed the development of a new discipline in the structural field: the structural morphogenesis i.e. the generation of new structural forms. Before the computer age only very few forms not generated by Geometry were applied in the construction. For instance the funicular shapes, generated by mechanical principles, were used by A. Gaudí, perhaps the first, or at least, one of the first forerunners in the field of structural morphogenesis.

This advancement in the capability for generating new structural forms brings us to new considerations from the aesthetical and mechanical points of view.

Twenty years ago, for the 40th Anniversary IASS Congress (Madrid 1999), I wrote: "In Architecture as well as in Engineering, the concepts of *shape, space and structure* are strongly linked and connected with three different learning disciplines: *Geometry, Aesthetics and Mechanics*."(Andrés [4]). Now I wish to point out here a remarkable change: instead of "Geometry" I must say today "morphogenesis". In fact, instead of Geometry we must speak today of morphogenesis as a more extensive discipline which encloses

Geometry in the field of structures. Beyond Geometry, we have today many other ways to generate structural shapes: there are numerical models, physical models, hybrid models, biological models, etc. Some of these models not only generate the structural form, moreover simultaneously guarantees the fulfillment of mechanical laws as it is, for example, the homeostatic model technique (Andrés and Ortega [5]). Fig. 1 illustrates the famous project by Arch. F. Vivas for the Táchira Club of Caracas. It was one of the first free forms which structural analysis demanded great effort to E. Torroja in 1957, (Tarragó [6]); nowadays a similar project can be designed and analyzed with much less time and effort through the homeostatic model technique, Fig. 2.

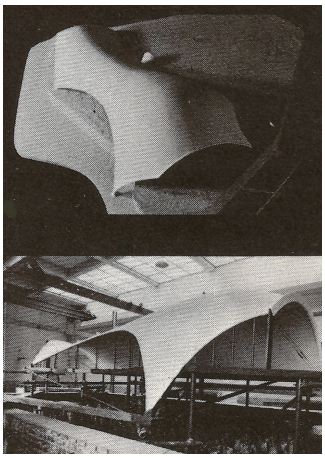

Fig.1. Vivas's and Torroja's Models (1957)

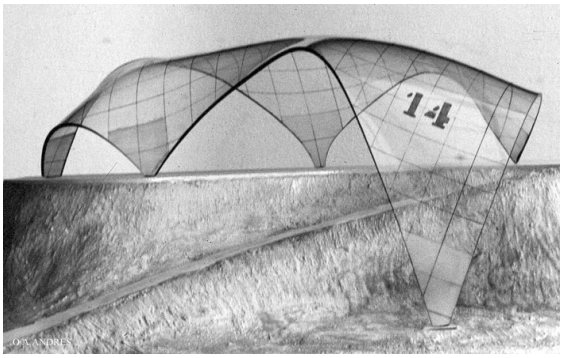

Fig. 2. Andrés's Homeostatic Model (1991)

Morphogenesis allows us to create new shapes and at the same time, shapes define limits in the space in such a way that they create an organization of this space; their visual perception impresses our spirit leading us to elaborate critical judgment about the aesthetic value of that organized space. On the other hand, when a shape is materialized as a piece of a building or construction it becomes a source of strength with great value in Structural Mechanics. All the above concepts and their relationships are synthesized in two triangles: Fig. 3 (according to the old conception, 1999) and Fig. 4 (according to the new conception).

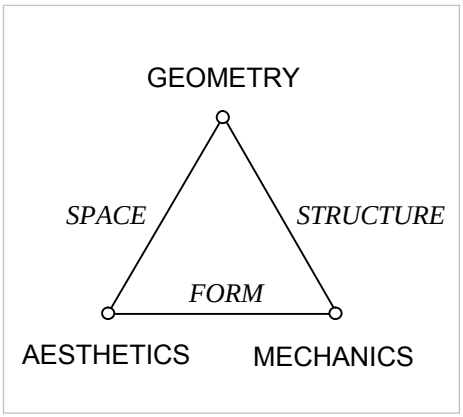

Fig. 3. Old Triangle (1999)

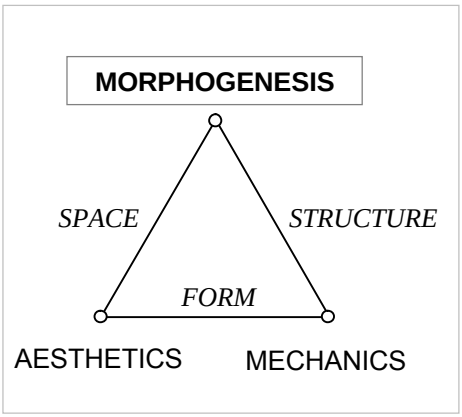

Fig. 4. New Triangle (2009)

4. Free forms

Nowadays, designers are no more constrained to the limits of geometric forms i.e. to select a form from the catalogue of Geometry; morphogenesis allows the designers to create an endless variety of new forms, taking advantage of the freedom that they have never had in the history of Construction and giving place to the birth of a new generation of forms: this new generation of forms is called today *free forms*. More than 50 years ago Eduardo Torroja foresaw this advancement as it is pointed out with the words which head this paper.

Sculptural forms are absolutely free as pure expression of their creators. In Architecture as well as in Engineering, structural forms are not absolutely free: their generation is independent of Geometry, but from a technical point of view they must respect the classical Vitruvius's [7] principles: "utililitas, firmitas et venustas" namely the fulfillment of function, structure and aesthetics. Of course, designers can perform the compatibility and priority of these principles according to their criteria which will remain reflected in their creations.

Free forms have called the attention of a great majority of designers; today they are widely known and so we can see them very often in technical publications and in the real world of construction. In the evolution of Architecture, free forms are a new landmark due mainly to the morphogenesis, as the introduction of the computer set a landmark in the evolution of Structural Engineering half a century ago.

5. Free forms in the present society

The morphogenesis has given new freedom to designers, but as every new freedom it claims for new responsibilities facing society. Technical responsibilities must be satisfied

without forgetting the social responsibilities: ethical, economic and environmental requirements which must be at all times considered and respected by current designers

Computers and morphology have given extraordinary potentiality to designer's task: from a technical point of view, today it is possible to represent, to analyze, and to build any kind of structural form, but from a social point of view not every form become necessarily a genuine architectural or engineering work. Sometimes very complicated designs look as a demonstration of the designer's skills to cope with sophisticated soft wares as well as an exhibition of their personal vanity, more than a sincere expression led to satisfy technical and social requirements.

This brings us to point out that an obsessive and exorbitant use of morphogenesis together with computer techniques could be negative for development of designer's imagination. At the same time, this could contribute to show an impression of indifference and insensitivity of those designers facing the society.

Finally we should not forget the words of F. Otto [8]: *"Structures cannot be designed arbitrary"*. Designers must always be very careful and reasonable regarding the use of materials and human work. Common sense should be always present in every design: from every point of view it is not suitable to waste natural resources and human efforts.

6. Concluding remarks

- Computer and morphogenesis techniques together with new building technologies and materials have given place to the birth and development of free form structures.
- Free forms are today an unquestionable landmark in the historical evolution of Architecture and Engineering.
- Let's architects and engineers be respectful and conscious about society's requirements, so as not be stigmatized by the hard words of Theodore Roszak: *"technologists look at the world with dead man's eyes"* (Florman [9])

References

[4] Andrés, O.A., On the aesthetics of homeostatic shell shapes, *in Proceedings of the IASS 40th Anniversary Congress Shell and spatial structures: from recent past to the next millennium*, Vol. II, F3-9, Astudillo and Madrid (ed), Madrid, 1999.

[5] Andrés, O.A., Ortega, N.F., The homeostatic model: its conception and development, *in Proceedings of the IASS-SLTE 2008 Symposium,* J.G.Oliva Salinas (ed), Acapulco, México, 2008.

[3] Ben Arroyo, A., Progress of Shell Structures in the last Ten years and its Future Development, *in IASS International Colloquium ,Progress of Shells Structures in the Last Ten Years and its Future Development*, Madrid, 1969.

[9] Florman, Samuel C., *Civilized Engineer*, p. 69, St. Martins Press, NYC. 1987.

[2] Haas, A. M., *Neure Forchung auf dem Gebiet de Schalenbau-weise fur Architekten und Ingenieure.* p.12*, Herausgegeben von Stefan Polónyi, Schalen in Beton und Kunststoff*, Bauverlag, Berlin, 1970.

[8] Otto, F., Shells and Membranes, *in Proceedings of World Conference on Shell Structures,* p.3, NAS-NRC, San Francisco, Oct. 1962.

[6] Tarragó, S., *La Modernidad en la obra de Eduardo Torroja, Colegio de Ingenieros de Caminos,* Canales y Puertos, Ediciones Turner, Madrid, 1979.

[1] Torroja, E., *Razón y Ser de los tipos estructurales*, Instituto de la Construcción y del Cemento, Madrid, 1960.

[7] Vitruvius, M., *The Ten books of Architecture*, (transl. Morris Hicky Morgan, 1960), Courier Dover Publications. ISBN 0486206459.