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AESTHETIC QUALITIES OF INDUSTRIAL BUILDINGS' STRUCTURE

BY

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Abstract. The industrial revolution was the major catalyst for the developing of new materials and building technologies which made possible the architecture of the XX century. The fundamental functional requirements of the industrial architecture – spatial flexibility, long spans, economy – determined a permanent research in the field of structure science in order to receive the optimal ratio between the material usage and built area.

Concurrently, following building economy reasons, the structure was left bare, and is a part of the image of the interior space, adding meaning to the architectural quality.

The paper presents an aesthetic approach of the evolution of industrial buildings' structure, starting from the pre-modern period, when decoration was attached to the structural elements, to the modern phase, in which their form became a result of mathematical calculations. The analysis follows the chronological developing of the building techniques and materials, underlining their plastic qualities.

With arguments from the domains of architectural and aesthetic theory, the paper points to the idea that structure is often one of the most important aesthetic elements of the industrial building.

Keywords: industrial architecture; structure aesthetics; aesthetics; building history.

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1. Introduction

When, at the beginning of the 20th century, the load-bearing structure was separated from the traditional tectonics of the wall or brick wall, as a consequence of the scientific and technical progress, the supporting frame became an independent element.

Nevertheless, in order to make the business profitable, the industrial building conformed to the demands of optimizing building costs, a reason why one of the specific characteristic for most industrial spaces has been the visible presence of the load-bearing structure.

This study highlighted the fact that the requirements imposed on the structure systems by the considerable sized spaces, flexible and free, adequate to the functional requirements specific to the production process led to the accomplishment of structures with the highest achieving and updated materials and technologies of the time.

Until the specific form of the new materials was definitely established, the adaptation to the aesthetic norms of the époque made use of the ornament.

2. Structure and Ornament

At the beginning, in the case of the civil engineering buildings, the metallic frame was hidden behind the plastered walls or ceilings. The iron frame elements, which were not formally integrated in the taste of the époque, were considered lacking expression and personality, as compared to the original materials, stone and brick. That is why, in case they were visible, they were adorned with typical elements for the traditional materials. Even so, the public did not remain inert; the examples of the Eiffel Tower as well as the Crystal Palace are famous.

The Eiffel Tower was enriched with well-known decorative elements, made also of iron and applied on the frame, aiming to please the tastes of the time. Despite these formal artifices, the building aroused an endless number of negative reactions at the time, some of them even violent (Fig. 1).

At Crystal Palace there were conceived chromatic compositions by means of finishing works and textile materials, having the role to diminish the visual effect of the metallic frame, unpleasant to the eye of the people (Fig. 2).

The industrial buildings from the 19th centuries, as the facades, presented attempts made to embellish the structure forms using the traditional adornments: capitals for the metal columns or decorations on the beams, the technology of forging or extrusion bringing the advantage of industrializing these elements and, consequently, accomplishing them without great technical or economical efforts (Figs. 3,…,6).

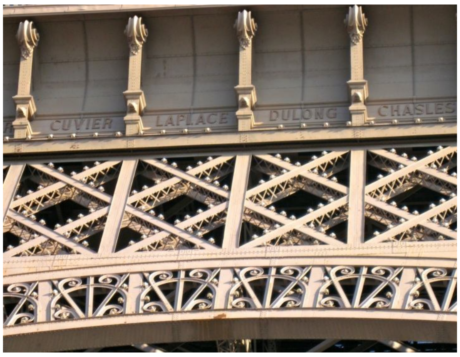

Fig. 1 – Decorative details on the Eiffel Tower.

Fig. 2 – Crystal Palace, London.

Fig. 3 – Temple mill, Holbeck, Leeds.

Fig. 4 – Menier Chocolate factory, Noisiel-sur-Marne.

Fig. 5 – 1818-30, Sayner Hutte, interior view.

Fig. 6 – Sayner Hutte, column base.

At the beginning of the 20th century, the necessity to quickly build on wider and wider surfaces entailed the simpler structure elements by reducing them to the mere functional shape, giving up any ornament. The result was a new, revolutionary system of shapes which will define a new style, based on a true use of materials, according to their technological specificity. ” [...] we faced creations which appeared in a shocking depriving of any ornament, in a surprising nudity of a rational and recurrent building [...]” (Lascu, 1989) as Henry van de Velde confesses when speaking about the buildings on metal frame: stations, warehouses, bridges. In his turn, Pier Luigi Nervi notices that ”these achievements have in common a structural essence, a necessary absence of all decoration, a purity of line and shape more than sufficient to define an authentic style, a style I have termed the truthful style. I realize how difficult it is to find the right words to express this concept.” (Nervi, 1965).

3. Functional Expressivity

Thus a new component of architectural expressivity appears – structure as an exclusive result of functional requirements, without any aesthetic additions, a true expression of practical conditioning. The impression given by the elements created after these principles determined both the aestheticians, in theory and in practice, to search for sources beyond the unexpected and new traits, deciphering some aesthetic qualities. Kant proposed the concept of „adherent beauty”, including in this category the successful architectural works. In their case, the satisfaction of contemplation is more complex, the beauty of the shape being doubled by the practical intelligence which makes it adequate to functionality. Kant considers adherent beauty as the ideal, leading the aesthetic judgment towards moral judgment. ”Adherent beauty, in its highest point, includes even a moral meaning.” (Gilbert & Kuhn, 1972).

Theorists later on found another explanation for this apparently paradoxical phenomenon of involuntary aesthetic investment to some artifacts of pure technical character and destination: to imitate nature. At the beginning, it had an intuitive character, by taking after natural shapes, accepted as harmonious, accompanied by principles of being adequate to functions.

Ruskin considers imitation of nature as an intrinsic process in the artistic creation. ”All the beautiful lines are adaptations of the most usual lines from the exterior creation.” ”The Roman arch is beautiful as an abstract line. Its model is […] the appearing arch of the sky and the horizon. The cylindrical column is always beautiful, as God created thus the trunks of all the trees beautiful to the eyes. The Gothic arch is beautiful, it represents the ending shape of any leaf which trembles in the summer breeze.” (Gilbert & Kuhn, 1972).

Ruskin was wrongly accused of minimizing the act of creation by supporting the idea of imitation of nature, but imitation ”in his sympathetic vision means in the end an insight in the law of the universe” and the artist is at the same time a viewer and an interpreter of nature, seeing in the appearing things ”parables of the deeper things and analogies of divinity” (Gilbert & Kuhn, 1972).

Hartmann shows ”what the significance of the real aesthetic feeling of shape is: there is nothing behind it from the category of «agreeable» or «easy to accomplish», but the objective contact with a fundamental inner issue, the nature of a law.” (Hartmann, 1974).

He proposes an interesting general statement on the aesthetic issue: ”a shape seen as beautiful is that which allows being seen in it a principle of formation.” (Hartmann, 1974) The examples given by the author are suggestive: the harmonious shape of a fish is so because it is hydrodynamic, the curved trajectory of a stone is the result of the interaction between the propelling force and gravity, phenomena perceived, felt by the receiver.

Henry van de Velde states that beauty supposes a great freedom in the creative approach, freedom limited only by the material to be used, in which the unseen natural laws act. Beauty is born from the correct intuition and expression of these laws. ”It is in the direct relationship with materials that beauty reaches the deepest pleasure of life; in them the revelation of all mysteries will be found; [...] Essential beauty, the most indispensable thing of a work of art consists of life manifested in the materials it is made of .” (Lascu, 1989).

The progress in sciences created the possibility to reach an agreement between estimations and structures. There were discovered the mathematic models of the natural laws which establish the characteristics of a supporting structure in a direct relationship with its function, the material and technologies to be used. Thus the refinement of the structural form appears, accompanied by an unexpected phenomenon – the increase of its aesthetic quality.

The Gestalt theory states that the aesthetic effect comes from the way in which nature creates an optimum relationship between contents and shape:”A harmonious configuration, with characteristics of equilibrium, rhythm, hierarchical organization is welcomed as nature should produce its shapes in an efficient way […]. Or efficiency means restraint, restraint means grace and grace is pleasant.” (Ghyka, 1981).

The scientific approach undertaken by Matila Ghyka highlights the impressive effect of applying mathematical models in solving structural problems:

”In their conflict with the well-defined problems when the demand was to restrain space, volumes and pressures, when the static design graphs, the differential equations of applied mechanics determined the directions and width of the steel poles, or they were revealed little by little, deprived of any paneling, there were standing out only the structural necessities, the engineers could see pure and open volumes spreading out from their hands, long-forgotten, harmonious profiles.” (Ghyka, 1981).

„Architecture, considered a major art, namely seen independently from its ornamental details or decorative character of its surfaces, acts on our aesthetic sense in a more abstract symbolic way […]. Let us remember, even from now that we often find in it, in almost the same form, the issues of the best task allocation, of the best profile, unconsciously solved by plants; […]" (Ghyka, 1981).

The functionalist aesthetic approach, better shaped in the third decade of the 20th century is also applied when conceiving and judging construction systems. According to it, one of the main issues for the aesthetic value of the structure is adapting it to the purpose it was created for by adapting it to the static function. This concept was born from the principles of saving material and applied by means of estimations. Le Corbusier appreciated the accomplishments of the modern building engineers. "Bound to the strict assignments of a rigid program, the engineers use form generators. They create plastic, clear and impressive things [...]" (Ghyka, 1981). Beyond the formal accomplishment, he highlights a philosophical principle: „The engineer, inspired by the law of economy and led by calculations, he renders us in agreement with the laws of the universe" (Ghyka, 1981).

Finding economical solutions has been a main objective in the research undertaken by the builders, engineers and architects who became aware that applying this principle, often found in nature (Figs. 7, 9, 13), has an aesthetic final result. Pier Luigi Nervi was preoccupied by this aspect from both the practical and theoretical point of view.

"When I approach a project, my first instinctive thought is to reject the solutions which, even at first glance, do not seem to me economically valid. To search for an economic solution in the structural field means to find the most natural and spontaneous solution, or, in other words, to find the method of bringing dead and live loads down to the foundations in the most direct way and with the minimum use of materials." (Nervi, 1965).

"[...] I have never found this relentless search for economy an obstacle to achieving the expressiveness of form I desired. On the contrary, the technical factor, like the static one, has often been a source of inspiration." (Nervi, 1965).

The structures from the industrial architecture, lacking any interference from other contents due to the technical and economical requirements, are the best example of transposing in the material the construction estimating forces diagrams (Figs. 8, 10, 11, 12, 14). Estimating the *felt forces* as Lance La Vine called them, has the role to direct the observer's cognition towards "the meaning of our existence in the middle of these forces": „Gravity as felt force is manifest in building frames as *the rooted order of the earth.* The frame translates the perceived qualities of gravity's regularity into conceptions of repetitive pattern and permanence. The architectural frame at once defines the structure of the world of natural force to be orderly and that of human residence to be the same." (La Vine, 2001).

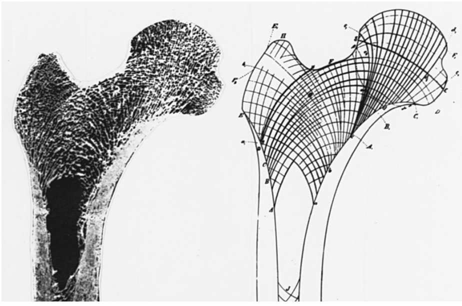

Fig. 7 – Thigh-bone.

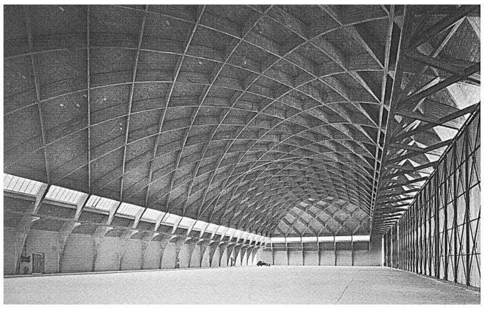

Fig. 8 – Aircraft shed, Orvieto, engineer Pier Luigi Nervi.

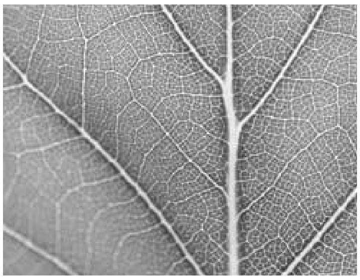

Fig. 9 – Leaf.

Fig. 10 – Lingottto factory, Torino – Car platform.

Fig. 11 – Tobacco shed, engineer Pier Luigi Nervi.

Fig. 12 – Gatti Wool factory, engineer Pier Luigi Nervi (1951).

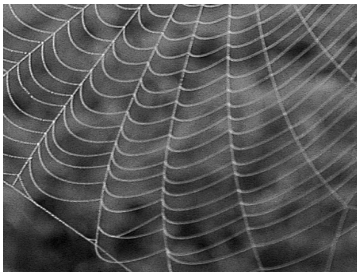

Fig. 13 – Spider web.

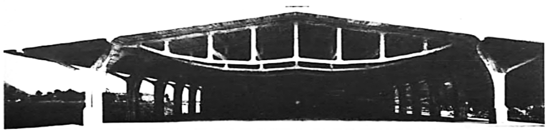

Fig. 14 – Warehouse Chiasso, Switzerland. engineer Robert Maillart (1924).

4. Expressivity of Metallic Structures

The analysis we have made showed that the metallic structures of industrial warehouses had a remarkable evolution from the technical point of view. Made of more and more successful alloys, allowing a convenient adaptation due to the new technologies in design and construction, the structural metallic elements are a faithful representation of the building charts and diagrams. Truly expressed in the space of the industrial warehouse, the metallic structures are impressive in their refined and complex geometry, highlighted by the zenithal lightning (Figs. 15,…, 19). The use of tensile structures represents a novelty in the field of expression. A significant aesthetic effect is the one given by the contrast between the almost immaterial delicacy of these structures and the wide volumes and open spaces of the industrial warehouses.

Fig. 15 –Electroputere Factory Craiova.

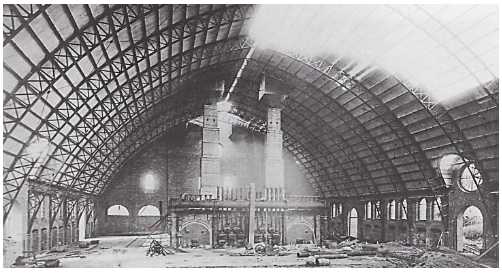

Fig. 16 – Coal storage building, Berlin, 1863.

Fig. 17 – Saltaire Mill, Bradford, attic.

Fig. 18 – Willow Run Airplane Factory.

Fig. 19 – Glenn Martin Assembly Plant.

5. Expressivity of the Reinforced Concrete Structures

Even if the first buildings in reinforced concrete followed the traditional tectonic formulas, the architects and engineers explored the potential of the new materials and obtained remarkable results. It offers the possibility to accomplish monumental plasticity, often in shape in the 20th century architecture. Next to the traditional solutions using poles and beams, the technology engaging reinforced concrete gave birth to a wide variety of original structural solutions which influenced the expression of the inner space, as well as the volumetric expression.

The system with the mushroom column eliminated the image of the beam network which fragmented the ceiling surface. The shapes of the structure elements were simple, stylized with a powerful visual impact. Alvar Aalto used this system in 1927-1929 at the paper shed from the printing house of the local newspaper in Turku (Fig. 20).

The use of this technology in 1932 at Boots Pure Drug Factory (Fig. 21) illustrates its architectural qualities. Placing the structural bracing in a withdrawn position in relation to the facade creates the impression of a building which takes off the ground, the massive character is diminished by the disappearance of the end beam and the smaller noticeable thickness of the floor – backed on the upper and lower part by transparent surfaces for the whole height of the level.

Another approach improves the system by the structural adaptation of the floor. At the wool factory in Gatti, Pier Luigi Nervi designed a structure of the ceiling which did not negate the Cartesian rhythm of the beams, but included it in an organic cubicle network, the result being an original plastic expression (Fig. 12). The improvement of the concrete structures in addition to the possibility to fill the material in any form allowed a more and more accurate adaptation of these structures to the static formulas. Thus there were saved significant quantities of material, at the same time the plastic vocabulary of the structures was diversified, which resulted in more and more spectacular expressions in shape. The scientific design of construction elements, stimulated by a great number of models from the animal and plant world (Figs. 7, 9, 13, 23) turned the structure from a pure functional object into an organism in which the laws of nature are applied.

Once the pre-stressed concrete was invented, the dimensions of the structure elements could be reduced even more. This fact led to decreased weights of the buildings and the road was open to an even wider freedom of shape. One of the most remarkable novelties was the thin shell structures. Engineers such as Pier Luigi Nervi, Candela or Eladio Dieste became famous for their innovations (Figs. 24,…,28). The cantilevers increased in dimension making possible to achieve structures of great plastic force (Figs. 22 and 27).

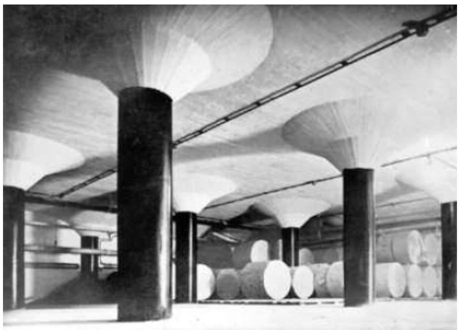

Fig. 20 – Paper shed, Turun Sanomat Printing House , Turku, 1927–9, architect Alvar Aalto.

Fig. 21 Boots factory (Pharmaceutical industry), Nottingam, 1932, , engineer Sir Owen Williams.

Fig. 22 – Heating plant, Civitavecchia, 1954, engineer Riccardo Morandi.

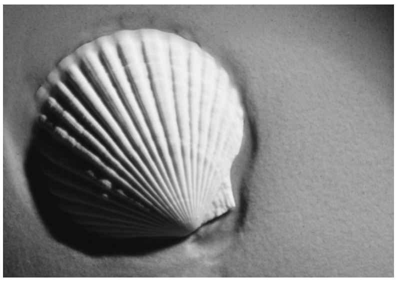
Fig. 23 – Sea shell (Pecten Raveneli).

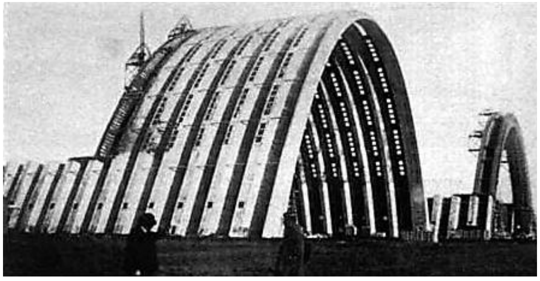
Fig. 24 –1921, Sheds, Orly, Aircraft industry, engineer Eugene Freysinnet.

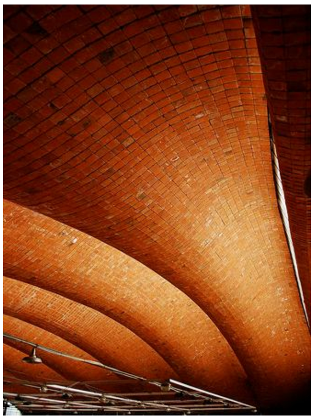
Fig. 25 – Julio Herrera & Obes Warehouse, Montevideo, engineer Eladio Dieste.


Fig. 26 – Bacardí Plant, Mexico City, 1958- 1961 architect Ludwig Mies van der Rohe, engineer Félix Candela.


Fig. 27 – Massaro Agroindustries, Montevideo.

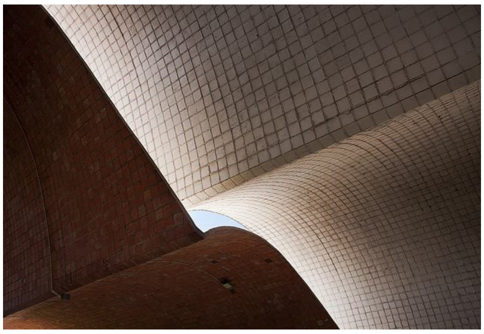
Fig. 28 – Massaro Agroindustries, Montevideo.

6. Conclusions

Conceived and built even from the beginnings and up to our days according to some simple functional principles and based on rapidly evolving technologies and building materials, the industrial space has gone through impressive development as in terms of technical aspects as well as formal expression.

The building structure of the industrial sites is characterized by the great support capacity, conceived to accommodate the load of heavy machines and equipment used in the production process, factors clearly reflected in space configuration. In order to have an efficient, economical investment, structural elements are often left bare and visible, and they are part of the industrial building image.

Apart from the technical efficiency, a lot of attention was paid to low investment costs and short execution deadlines. Fulfilling these objectives had as result a series of common characteristics for the enveloping planes and structure: modulation, individualization, space- saving.

In the case of production buildings, the inside lay-out requires structural solutions; hence there is a close link between the structure and the lay-out. Due to its rational character, industrial architecture reached and maintained a direct relationship between the outer building shape and structure on the one hand, and interior space on the other hand. No other architectural programme comes with the same conditionings, addressed and expressed so coherently and honestly.

The aesthetics of modern industrial architecture was based on a formal composition which was clearly seen and observed, an ethical concept in itself. Hence, modern theories encouraged the ideas related to reaching a new ideal in architecture, to reaching the truth by correlation in a sincere, genuine expression of its essential elements: function – structure – form.

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CALITĂŢI ESTETICE ALE STRUCTURII CLĂDIRILOR INDUSTRIALE

(Rezumat)

Revoluţia industrială a reprezentat factorul catalizator major în evoluţia tehnicilor şi materialelor de construcţie care a făcut posibilă arhitectura secolului XX. Cerinţele funcţionale de bază ale arhitecturii industriale – flexibilitatea spaţială, deschiderile mari, economicitatea – au determinat o căutare continuă în ştiinţa structurilor constructive pentru a obţine raportul optim între consumul de material şi volumul construit.

Totodată, din motive de economicitate a construcţiei, structura constructivă a fost lăsată vizibilă, participând nemijlocit la spaţiul interior şi adesea îmbogăţindu-i calitatea arhitecturală.

Lucrarea prezintă evoluţia structurilor clădirilor industriale dintr-o perspectivă estetică, pornind de la etapa pre-modernă, în care componentelor constructive le erau aplicate elemente decorative, până la etapa modernă, în care forma structurală este rezultatul unor calcule matematice. Analiza urmează linia istorică a dezvoltării tehnice şi ştiinţei materialelor subliniind calităţile lor plastice.

Aducând argumente din domeniul teoriei estetice şi arhitecturale, lucrarea demonstrează ideea conform căreia structura constructivă reprezintă unul din cei mai importanţi factori expresivi ai arhitecturii industriale.