GEOMETRÍA, ESTRUCTURA Y FORMA. CENTRO GEORGE POMPIDOU

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RESUMEN:

Sin duda gran parte de la historia de la arquitectura y la ingeniería de construcción del s.XX y s.XXI, está ligada con el desarrollo y evolución de las superficies funcionales de grandes luces estructurales. La implantación de nuevas tecnologías y materiales de construcción en la segunda mitad del siglo XX, es también contemporánea, con las exigencias de aplicación de nuevos programas y la necesidad de desarrollar tipos de construcciones en altura, grandes luces, superficies de exigencias tecnológicas variables y características tipológicas no experimentadas hasta ese momento en el ámbito de la ingeniería y la arquitectura. Los ingenieros y arquitectos se han visto obligados a afrontar la resolución de tales retos, con nuevos conocimientos científicos, técnicos que se desarrollarán paralelamente a la evolución de las nuevas técnicas constructivas, revolucionado así las técnicas de producción de la propia Arquitectura.

El Centro George Pompidou (1971-1976) de los arquitectos Richard Rogers, Renzo Piano y los ingenieros Ted Happold, y Peter Rice, abre una innovadora visión de las superficies continuas de de amplia repercusión arquitectónica y social. La propia arquitectura se convierte en sí misma en el principal modelo experimental para ir definiendo y perfilando los más innovadores métodos de diseño de superficies continuas (Espacio flexible, transformable funcionalmente), cálculo y comprobación de estructuras (Mecánica de rotura), como los métodos de control y fabricación (Moldeo, fundición y centrifugación de precisión de grandes y pequeñas piezas de acero)

Esta ponencia aborda el estudio analítico del conjunto de soluciones estructurales y constructivas que han servido de base técnica y científica a los ingenieros y arquitectos de finales del siglo XX y principios del siglo XXI, que han acometido el profundo cambio de las bases de producción de la arquitectura, incorporando con el uso de un amplio catálogo de soluciones técnicas, nuevas caracterizaciones espaciales, que identificarán y significarán a tales estructuras como condiciones básicas y principio generador de la forma arquitectónica contemporánea.

Palabras clave: Centros Culturales, Grandes Luces, Estructura Acero, Moldeo, Tecnologías Avanzadas

GEOMETRY, STRUCTURE AND SHAPE. CENTRE GEORGES POMPIDOU

ABSTRACT:

There is no doubt that a great part of the history of architecture and construction engineering of the XX and XXI centuries is linked to the development and evolution of functional surfaces of great structural spans. The introduction of new technologies and construction materials in the second part of the XX century is also contemporary with the demands of applying new programs and with the need of developing new types of high-rise structures, great spans, surfaces of variable technological demands and typological characteristics not experienced until that moment in the fields of engineering and architecture. The engineers and architects have been obliged to face the resolution of those challenges with new scientific and technical knowledge that will be developed in

line with the new constructive techniques, hence revolutionizing the production techniques of Architecture.

The George Pompidou Center (1971-1976) made by the architects Richard Rogers, Renzo Piano and the engineers Ted Happold and Peter Rice, opens an innovative vision of the continuous surfaces with great architectural and social impact. Architecture itself becomes the main experimental model with which the most innovative methods of continuous surface design is defined and outlined (flexible space, which can be functionally convertible) calculation and checking of structures (fracture mechanics), like the control and manufacture methods (casting, smelting and precision spin of big and small steel pieces)

This paper tackles the analytic study of the collection of structural and constructive solutions that have been the technical and scientific base for the engineers and architects by the end of the 20th century and at the beginning of the 21st century. They have undertaken a deep change in the production bases of architecture, adding new spatial characterizations with the use of a broad catalog of technical solutions, which will identify and signify those structures as basic conditions and a generating principle of the contemporary architectural shape.

Key Words: Cultural Centers, Great Spans, Steel Structure, Casting, Advanced Technologies.

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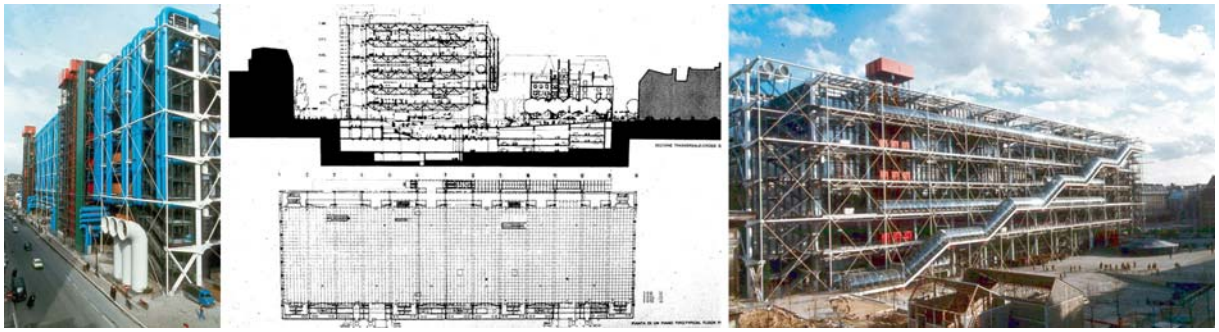


1. Introduction

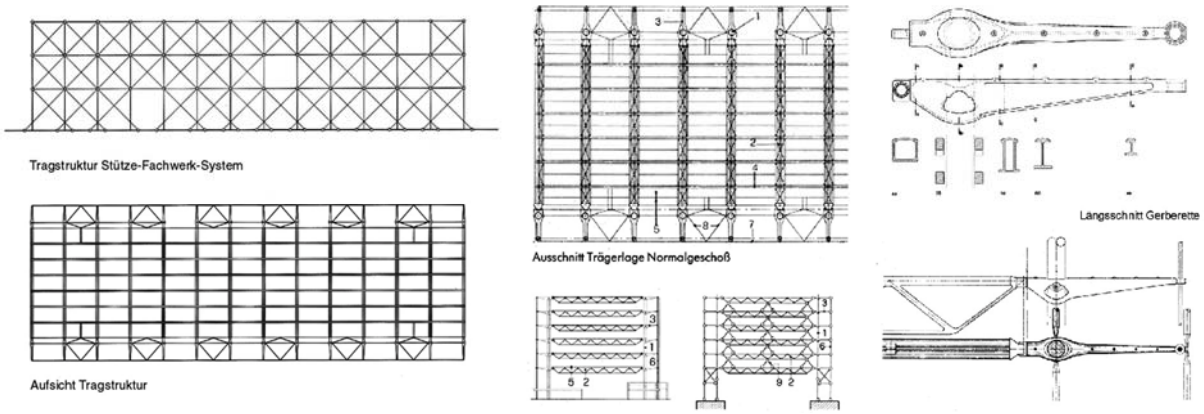
In the summer of 1971 a competition for the construction of a large cultural centre was about to be solved in the city of Paris. The centre had to include the creation of a public library, the transfer and reorganization of the National Museum of Modern Art, space for exhibitions, archives and research MAN and CNAC, the construction of the centre of industrial creation and the opening of polyvalent halls for theatre, music, cinema as well as the fitting out for the research of contemporary music. The centre should be able to take in 10000 people every day in a surface of 65000 m²

The jury, chaired by Jean Prouvé and with the presence of Philip Johnson and the architect Oscar Niemeyer, awarded the team formed by Renzo Piano, Richard Rogers and Gianfranco Franchini. The proposal stood completely aside from a monumental solution for the cultural centre. The winner project summarized a large part of the trends that had been inspiring the contemporary architecture, in contrast with the standards of the architecture of the modern movement. The adjustment to the design with an industrial base praised by Jean Prouvé, will see itself casted in the decision of the winner of the competition.

The references to projects such as the Pravda Building designed by the Vesnine brothers in 1921, as well as the more direct evocation to the Fun Palace by Cedric Price, 1961, collected the light metallic structures with which these projects are shown, identifying large structural scales, as well as a spatial transparency that would allow defining a flexible and continuous space. In the same style, we can also recognize the influence of the projects of Archigram and specifically the Plug-in-

city by Peter Cook, 1964, the Walking city by Ron Herron, 1964, the Instant City by Jhoana Mayer, firstly designed in 1950 but fixed in 1969; and finally the project Bournemouth-Steps by Archigram, 1970. These projects enact the idea of a new mobile and convertible city, constituted of solutions of habitable capsules, volumes of changeable dimensions depending on its functionality, which can be plugged in or exchanged on different supports.

From the point of view of the built works, the Centre Georges Pompidou summarizes the solutions developed by Albert Khan for the design of his factories in the United States, especially in the Glenn Martin Company's Factory, Middle River 1937, where he employed large lattice metallic beams. The solution of employing all the services, stairs elements, elevators, sanitary facilities and air conditioning plants on the outside and separate from the building (Ackermann 1985) will be an inheritance of the project of the architect Egon Eiermann "Neckermann Distribution Centre", in Frankfurt, 1970.



These ideological influences in the field of the functional criteria will be interpreted starting from the structural solution in which the engineer Peter Rice will work together with the architects. This solution will be based on the work for large structures developed by Kenzo Tange in the construction of the Reception Pavillion for the Universal Exhibition of Osaka, 1970. He constructively solved both the problems of the large scale knots by means of the elements casting process (Rice 1977). The other interpretation added by the engineer to his solution will be the one derived from the instruction that Rice received while working with Frei Otto and who had applied to the Olympic Stadium of Munich (1967) the researches in the field of the definition of solutions of lath knots. All of these lines of research are parallel to the work developed in the 50's by Buckminster Fuller. That will culminate in the design and execution of bar structures, and its stability will be solved by means of simple structural works.

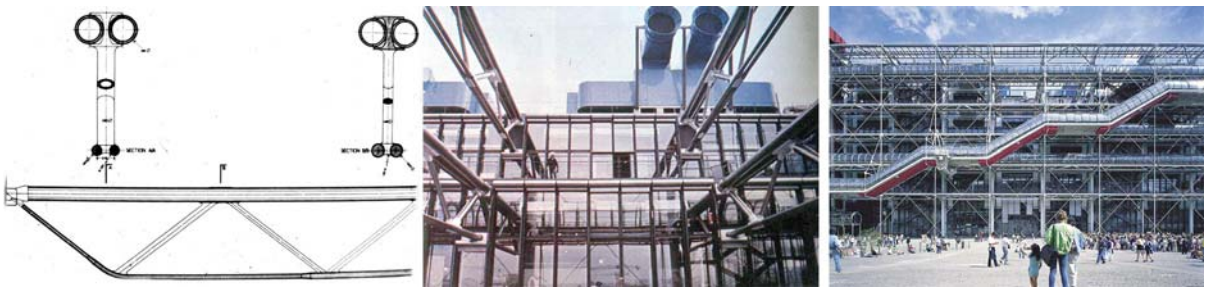
The inheritance of Buckminster Fuller can be recognized in the degree of importance set out by the architect, in the definition of the line of force of the building, similar to the structures of the Gothic (Colquhoun 1978). The reference to the similarity between the ideas of Fuller and the structure of Renzo Piano and Richard Rogers was focused in the value of the ideal lattice lines which enclosed a volume, similar to the Gothic. The lattice defines the shape of the building and shapes its figure with the establishment of the directions of the forces, that is to say, the architectural shape.

The outlining process of the shapes is spatially summarized in the Centre Pompidou, in a uniform weave with an undifferentiated shape with its own structure. As an inheritance of past ideas, figures are inserted. As an example we find the Dymaxion House by Fuller or the Environment-Bubble by François Dallegret (Banham 1977). We need to remember that in the Pompidou project, the finishing of the roofs of the last floors where curved on the edges and transparent.

The building is completely glazed, but its appearance hides this reality. The vision of a continuous space cannot be perceived from the outside, from where we can only see a uniform structure with a spatially uniform triangular framework, it identifies an attempt of obtaining an isotropic space (Curtis, 1982). The transformation of the flexible and continuous space will have a bearing on the reconsideration of the wall as a technical shape. The coincidence between the resistant structure

and the structure of installations is quite significant, whether we consider the solutions of the equipment of the east front or the solution of the inclusion of the elements of circulation of the Place Beabourg.

The idea of separating the installation structures from the resistant structures had been developed in the early 60's with the construction of buildings of large scale. We must remember that the Knights of Columbus (New Haven 1961), a project by the architects Kevin Roche and John Dinkeloo, planned precisely a strict differentiation between the behavior of the resistant structure and the environmental control equipment. It combined the possible movements of the general structure with the one of the installations.



The requirements of flexibility of the space also derived from the designs of the 60's regarding the building typologies for industry and situated the attempts of a solution for the complexity of the structures of large scale that could release the floor, in order to establish an isotropic space for work and which could therefore admit a spatial and variable layout according to the functional requirements. This situation that will be represented by means of a set of structural solutions solved starting from lighten deep beams, lattices or solutions of spatial tightened and hanging structures, implied the environmental control of the liberated space in which the placing of the structure will be specifically the description of itself.

2. The problem of scale.

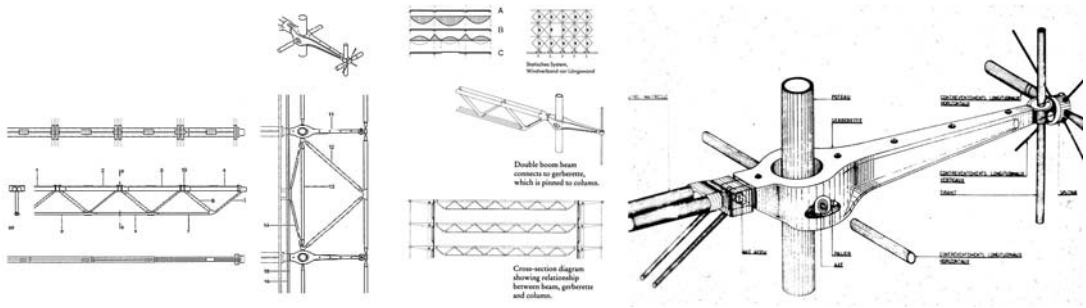
The interpretation carried out over the structure designed by Peter Rice, on the definition of the simple structural work and therefore on the behavior of the pieces exclusively under tensile or compressive stress will be a decisive step in the design of the structure of the Plateau Beaubourg. The most significant characteristic of large scale structures is the criterion of the control of the forces and the criterion of the control of the structural work. Therefore, the elements designed by Rice must not be interpreted as structural solutions with an improvement of the work performance- Instead, the control of forces and their layout will imply an improvement of the resistant section of the structural elements that can be adjusted to the resistant characteristics of the material. That explains the solution of the engineer defining hollow pipes as elements under compressive stress and solid bars under tensile stress.

Significantly, the structural analysis that will interpret these simple solutions of work could be described as a turn back on the development and design of structures. Since the XIXth century, the structural solutions on steel have set out formulas of isostatic behavior and, therefore, the recognition of simple forces due to the difficulty of interpreting the efforts produced on the components. The subsequent developments, especially the solutions provided by new joint methods (such as the welding after II World War), will facilitate the design of lighter and technically more complex steel solutions, that engineers will understand thanks to computational calculus systems.

Since the 60's, this development for large scales had had a specific formulation, fracture mechanics. This theory had been applied by Peter Rice, with Ove Arup & Partners, in the resolution of the models and the analysis of the wind behavior of the Sydney Opera House, created by the architect Jörn Uzton. The solutions provided by fracture mechanics are placed in the field of the ignorance of the processes of deformability of the structural elements, subject to extraordinary great loads or tensions.

ISBN: 84-7293-402-4

Fracture mechanics let us find a solution consisting on establishing the final fracture on a model, that is to say, the physical-material gap after a state of continuous and high load and therefore to recognize the flaw lines as the principal directions of the final efforts, taken as one of the possible solutions in order to recognize the resistant behavior of the material in certain areas of the structure. Despite that, the behavior of the great possible bending efforts prevents establishing the deformability conditions equivalent to the Saint Venant criteria for local effects.



Fracture mechanics was employed in the wind models of the first solutions by Ove Arup for the Sydney Opera House structure. The identification of the shells as surfaces of a parabolic ellipsoid made it difficult to calculate the structural behavior and its behavior in front of the horizontal forces, which is why they carried out analysis on its deformability with physical models in a wind tunnel. It is meaningful that Arup ideas (which changed from solving constructively the shells with a simple surface to a triple surface, composed of two big concrete plates, joined with a spatial and metallic structure that lightened it) couldn't solve the complexity of the scale problem.

This means that great spans induce moments, demanding mass in order to dispel energy. At the same time, that starts great moments and as a consequence of the cyclical process, it produces a structural failure. The final result began with the architect's solution of the geometric definition of the shape, remote from the engineering answer, which had employed more than 300000 hours of engineers calculus. The final shape will behave with a simple structural work under compression. Using a technique of control of the force lines, the prestressed, they will develop a technology able to control the geometry of the shape.

Peter Rice employs again in the centre Georges Pompidou the fracture mechanics, in order to establish the quality conditions of the molten steel units. The analysis put the units under big loads as well as under fatigue effects of the material. This way, it was possible to determine the relation between the local efforts practiced in a fracture point, the dimension of the initial flaw and the force applied. The tests over big pieces finally allowed establishing the nature of all the factors affecting the units: dimensional precision, geometric shape, fault detection, nature of the efforts and fracture load.

As a supplementary precaution, all the essential units were tested at the 120% of its maximal payload. This matter was also imposed because there was no concord between the French, German and British regulations for metallic structures. The one finally employed was the British one, because it had developed widely the analysis and systems of steel structure testing.

3. The structural solution.

The structure of the centre Georges Pompidou contradicts the model that modern architecture had sponsored as a prototype, that is to say, the grid. The concept of lattice, whose patronymic model, the rigid knot, constituted the definition of the geometric base of the shape of the modern movement, disappears in front of a conception in the line of the structures of the engineering of great spans, such as the one of the bridges, on which they employ solutions such as the Gerber beam (by the German engineer from the XIXth century), the articulated and tightened solutions. In conclusion, structures with a stabilization of variable geometry (a mast tightened by winds).

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The idea of functional freedom set out by the model of the floor grid, will be substituted for a recovery of the structure in the edges- It is significant the fact that the relation between the inside and the outside, which had also been associated to the flexibility and the freedom of the floor of the modern movement, will be confronted at the centre Georges Pompidou with the presence on the front of a structure characterized by the architectural shape. If the formal base of the architecture of the modern movement employed in the solution of Piano and Rogers is the geometry and the volume derived from the use of lattice, the structure will envelop the space and therefore will interpret again the nature of the front leaving it in an internal plane necessary to keep its freedom of definition. That is why when we say that the front is completely glazed; we understand that the glass plane is a condition restricting the internal space except from the ends (that is to say, on the outside, where we find the structural mechanism).

The identification of the main structure in the project shows a solution of supports different from the one of the execution. On one hand the pillars where made up of a lattice of two pipes apparently welded, forming a Vierendeel beam. That solution had been introduced in the development of the pillar in the suspension bridges by Steinman. On the other hand, the unfolded pillar permits leaning a deep beam that will have its meeting point on one of the ends of those lattices. It is obvious that the solution would have forced to interpret the structural behavior of the pillar as a solution with flexocompression work due to the eccentricity of the point of support on the pillars. The behavior of that structure with the bending had probably been solved by combining the compression effect of the internal pillar of the lattice and the tension of the external one. We must not forget that the lattice pillar would play as a Vierendeel beam, and that therefore the moments produced in its knots would have lead general moments in the lattice pillar and in the end the effect of flexocompression of the support.

Peter Rice will develop again the approach to the pre-compression in the solution of the pillars of the Centre Georges Pompidou, simplifying the lattice or the Vierendeel beam of flexocompression leaning, in a single pillar of 80 cm of diameter, with a centrifugated steel pipe with variable thickness (from 40 to 85 mm). The support will be precompressed by the Gerber beams of molten steel of 10t. (Rice 1978). This mechanism of wide span portico with the Gerber's 6.0 m. articulated in the support of the pillar, receiving the beam of 48.5m of span over the support cuboid-cylindrical console, will be balanced thanks to the stressed anchorage to earth, by means of solid steel bars of 220 mm, from an element, from molten steel in a mould, the satellite, fundamental in the design of Beabourg. This mechanism, fixed at the end of the Gerber, will expand the system of superficial stabilization of the plane of the portico to the three spatial directions, shaping by means of triangulation the system of transmission of loads and of spatial bridging of the set by means of 45º bars working in tension.

The steel and glass super-structure as a whole, 166x76.45x42 m. is articulated over 14 porticos with a distance of 12.0 m. between them. The floor structure pans lean on the porticos, releasing a space of 7.0 m. over the hollow pillars, loaded with water as a system of protection against fire and structural refrigeration. This prevention is improved with the transformation of the isostatic system into a temporary hyper-static one, given the predictable collapse of ties, putting the cuboid-cylindrical support between Gerber and the pillar, shooting the water tanks and refrigerating the structure without putting in contact the equipments and the electric installations isolated on the outside.

4. A laboratory of new technological experiences

The value of the Centre Georges Pompidou as a structural milestone, is that it has significantly interpreted the value of the architectural shape through the development of its constructive elements. In that sense, the establishment of a new value of the architectural production will be the precision, a characteristic that will consolidate the new capacities of manufacture of new and complex shapes, logics of industrial manufacture where the geometries of a high degree of indetermination will start being validated with the impulse of the new computational systems.

ISBN: 84-7293-402-4

The new interpretation of the relation between structure and shape, that the Beabourg inaugurates introducing concepts such as the structural hierarchy, that is to say the structural control, starting from the constructive design of its parts and constructive details, will prepare architects and engineers to experiment innovative relations and structural and constructive appreciation of materials, that will summarize the character of the new shapes in architecture. Some projects heirs of that milestone are the pyramid of the Louvre, by I.M. Pei, the Museum of Science and Technique at la Villete, by A. Faisenbilder and in general all the new crystalline shapes which have taken in the structural glass as the master material at the origin of the shape.

The work of Piano, Rogers and Rice means a significant advance in the development of the definition of the architectural shapes as logics of force fields, placing themselves in the direction of the structural shapes as an aspiration, which in our century is recognized as something natural, for the solution of the shapes at large scale, of digital production.

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