Pompidou Center: The structure of art – the art of the structure

Marta Gameiro
Civil Engineer, Partner and Technical Director at Gravidade International, ex-employee from RFR Ingénieurs.

1. Architectural landmark, a landmark of engineering

The Georges Pompidou Centre was an architectural landmark in Europe in the 70's, which was obvious in the article by Professor Vitor Murtinho published a year ago in this journal, in edition No. 40. In this article, we intend to show the impact this building had in the structural engineering of that decade as well as the landmark it became in the development of the use of steel in construction. We also highlight the intense collaboration between the two subjects, architecture and engineering, which allowed the completion of this exceptional building.

2. The competition

In early 1971 the French Government launches an international public competition for a project of a cultural center to be built in Paris, in the area known as Beaubourg. The main intention was to place at the disposal of the population a source of information and cultural dissemination, in a friendly environment, open to everyone and leaving aside any elitism or consideration of class.

In London, at Ove Arup & Partners, Structures 3 was a team led by engineer Ted Happold, dedicated to the exploration of new trends, such as the study of singular structures in textile membranes and cables, together with Engineer Frei Otto in Germany.

Peter Rice was then a young engineer at Structures 3 who stood out in the difficult mission of making the daring structure of the Sydney Opera of the architect Jorn Utzon, to which he devoted himself seven years after his graduation from Imperial College in London .

Structures 3 saw in the competition of the so-called Beaubourg Center, a clear, well organized process that offered a good opportunity for experimentation. He then challenged the newly formed pair of architects Richard Rogers and Renzo Piano to come up with a proposal together. After some hesitation, but yielded to Happold and Rice's insistence, the challenge was accepted.

The contest was very disputed, with 681 proposals being presented. It was not surprising that this would be the most emblematic and far-reaching work ever undertaken in Paris after the last war. The jury was composed of prominent figures of the architecture and engineering of the time, like Philip Johnson and Oscar Niemyer and presided by the remarkable engineer, inventor and French designer Jean Prouvé.

The spirit of the young team was, however, unpretentious. Knowing that winning this type of competition was as unlikely as winning the lottery, they approached it without commitments, seeking to explore new ideas that would respond to the central concept chosen for the project: designing a cultural information machine.

For the superstructure, a large-span steel solution was presented for the entire width of the building, with floors supported by flat truss beams resting on tubular pillars on the facades. The concept of flexibility was exploited

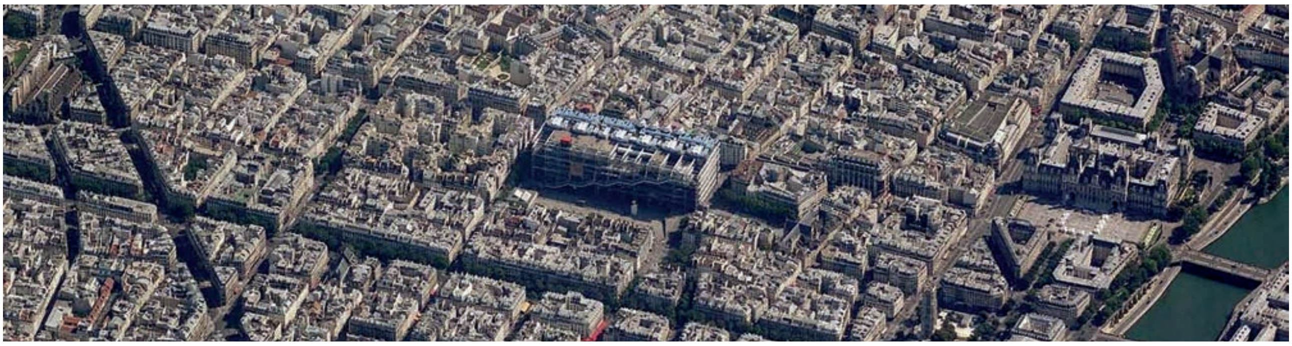

Figure 1. Aerial view of the Pompidou Center and the urban environment around it

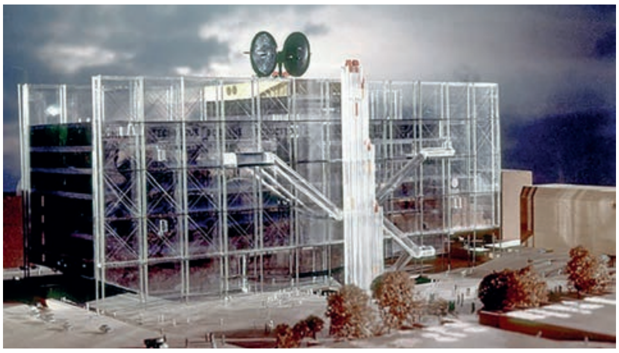

Figure 2. Model of the proposal submitted to competition

to the limit, proposing the possibility that floors, walls and partitions could be movable, that is, their position modified according to the needs of each moment. The connections between the various elements of the steel structure have since then become of central importance in the proposal.

Against the expectations of many, including themselves and especially of the French government, the selection of the jury went for the proposal of Piano, Rogers, Happold and Rice. The team's first major challenge was to ensure the exclusivity of project development from design to execution.

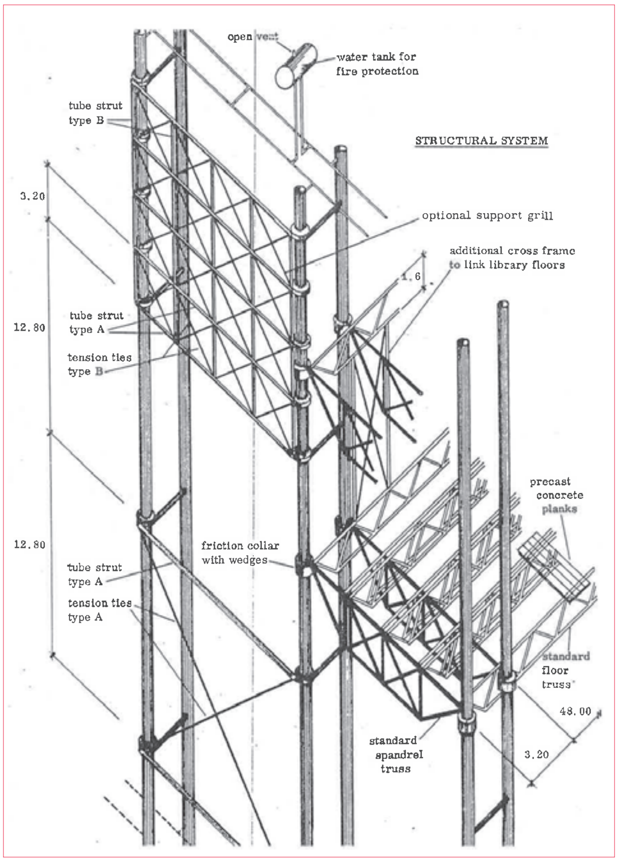

Figure 3. Structural System of the proposal submitted to competition

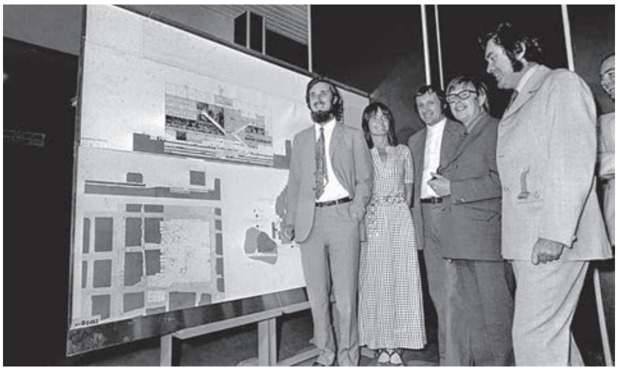

Figure 4. The winner team – from left to right: Renzo Piano, Richard Rogers and wife, Ted Happold e Peter Rice.

3. The challenges

Flexibility and versatility were one of the project's key points. The single span between front and rear façades, with 44.80m, met this requirement, allowing multiple and evolving uses of the building's interior space

In the façades the vertical circulations were concentrated and exposed: on the front facade, the circulation of the public, by means of escalators, in the posterior facade, the circulation of load and the technical infrastructures. The central 44.80m span thus had to extend at both ends to integrate the circulations.

Loads of great magnitude were to be considered, since an important part of the program consisted of a library and documentation center, which could work on any of the floors of the building.

On the other hand, the clearance was fixed at 28 m, maximum height of a fire escape car ladder. Should this height be exceeded, the building would be considered to be of great height and would have to meet numerous additional requirements regarding fire safety. The height between floors was therefore limited.

Finally, the "information machine" should, despite its large scale, have a human scale, be a popular place where the visitor feels welcome, not intimidated. The structure being largely visible, it was a decisive element in achieving that goal. It was in response to this challenge that Peter Rice printed his most significant personal mark on the project.

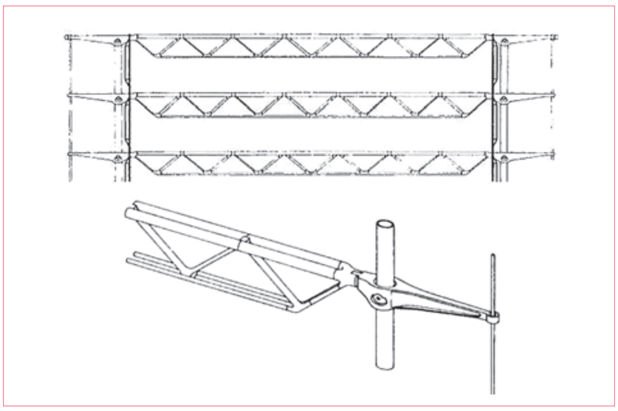

Figure 5. Cross-section model and detail showing the relationship between the main truss, the *gerberette*, the pillar and the tension rod

There were, as in all projects, cost and time constraints. It should be noted that the deadline for opening to the public was five years after the launch of the contest, which, today, seems like an eternity, but in the 70's it was a challenge.

4. The answers

The large span of 44.80m was overcome by flat tubular section trusses. The double strings, with a slight distance between the two tubes, gave a noticeable visual lightness to these elements about 3 meters high.

The trusses and pillars were made with tubular sections of steel, produced by centrifugation. The connections between the double chords and single diagonal bars, centered on the main trusses were materialized through cast steel parts. On the other hand, the vertical circulations next to the front and rear facades of the building were supported by pieces called *gerberettes*, also in cast steel.

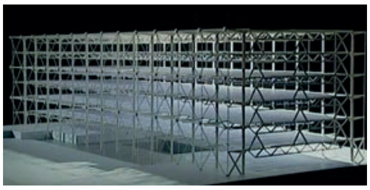

Figure 6. Model of the final structural system

Figure 7. Decorations in cast iron in the Paris metro

The term *gerberette* comes from the German engineer Heinrich Gerber who invented the gerber beam and used its patented system in the construction of numerous bridges from the second half of the nineteenth century. The *gerberettes* were in this case the parts in which they unloaded the main trusses, which transmitted these reactions to the tubular pillars of the facade and were locked at the opposite end by vertical tension rods. Each element thus had a perfectly defined function: truss beams working in flexion, tubular compression pillars, traction tension rods. The contact between the elements was made in a punctual, simple way (articulated supports) and ensured by cast steel parts.

The structural system showed a feature much appreciated and defended by Peter Rice: predictability. A perfectly established hierarchy, a well-defined function for each part, the ability to precisely control the efforts to which it will be subjected. An important factor of reliability.

The choice of cast steel came, in turn, to respond to the desire to confer human dimension, "tactile" quality to the structure.

In effect, Peter Rice had long wondered about what gave the great nineteenth-century structures their particular appealing character. Paris had numerous examples: the entrances to the *art noveau* metro stations, the plaftform of Lyon, the Eiffel Tower, the Grand Palais ... Its audacity did not explain everything. Numerous postwar structures were audacious but lacked the personality and warmth of their counterparts of the previous century. He concluded that what transpired in the latter was the commitment and care that the engineers had placed in his drawing. Just as the Gothic cathedrals, structures Peter Rice admired, manifested not only the functional choices but also the personal and subjective character of the masters and artisans who shaped them. Through the merged decorating elements and the iron connections, through the carved stones, each work expressed a personal mark, reminding us that it had been idealized and erected thanks to the work of the men who participated in it.

The cast steel could manifest these same qualities. The *gerberettes* were thus given every care during the development of the project. Its shape was studied in detail and refined for months. Obviously, the final result was the incarnation of the function of the part, faithfully

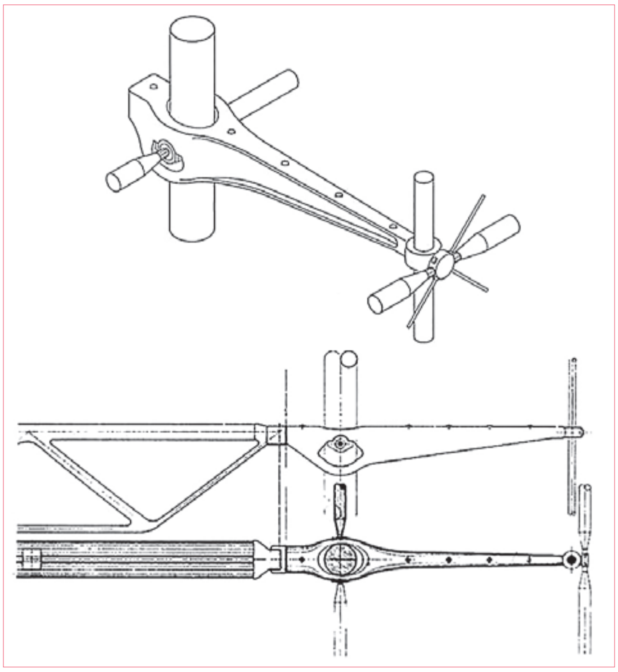

Figure 8. *Gerberette*

translating the diagram of moments in it installed. Thin at the support point of the trusses, high and wide in the connection to the pillars, again refitting to the connection

with the outer tension rods. The form also responded to the conditions of the casting and assembly process.

This is the symbol part of the structure, a product of the industry of the time, but an unmistakable witness to human intervention. The scale of the building would be perceived by the scale of the individual elements and not by the size of the whole.

5. The difficulties

The road to the realization of this important landmark of architecture and engineering was, however, tortuous.

The first barrier, present during the more than four years between the announcement of the winners of the competition and the inauguration, was the resistance found in the French entities involved in the process, with the exception of the Welding Institute. In fact, the government and the national engineering community did not expect that the victory of a competition of this nature would go to a foreign team. Rocovered from the shock, they tried to relegate the intervention of the team, and in particular of the engineers, to the mere follow up of the project, which would be developed by "excellent French engineers". However, Structures 3 showed that the heart of the project was precisely the detail, so its intervention had to be total from conception to execution.

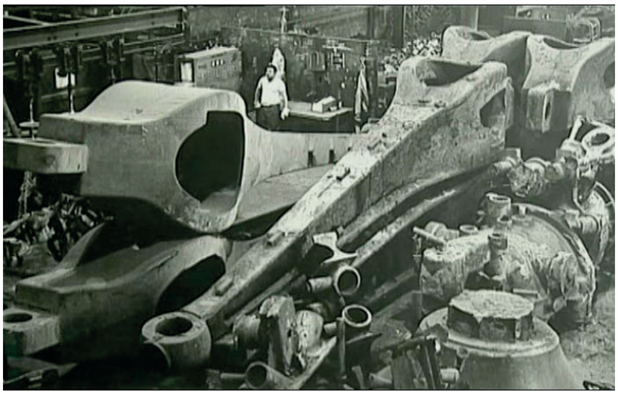

Figure 9. Gerberettes in the foundry Polig Heckel & Bleihart

Fortunately for Beaubourg, the competition defined the creation of an independent public entity to manage the whole process of installing the museum, from the project to the work, from the exhibition program to the acquisition of the art collections. Its president, Robert Bordaz, who reported directly to the President of the Republic Georges Pompidou, quickly grasped the point of view of the winning team, and has since then been his strong defender.

The competition also provided for the installation of the design team in Paris. Architects and engineers, the second led by Peter Rice, then undertook the work. The pressure was constant from the client, the consultants (experts and representatives of the French industry) from the project reviewer (Socotec). Fierce reviews were made about the feasibility of the steel structure. In particular on castings. Indeed, cast iron was then a technology of the past, abandoned for decades, and still produced in old and rare foundries of central Europe, with archaic methodologies. It was the antithesis of the modern steel industry, based on the industrial production of rolled parts, standardized, reliable. It was therefore necessary to modernize production and adapt it to current reliability requirements. The client stipulated that the castings be subject to a rigorous testing program to attest its suitability.

Here, as always, the responsibility of the engineer is very clear: to ensure that the structure is safe whatever the load conditions to which it is subjected. If in addition it is elegant and reflects the specific characteristics of the material from which it is made, the better.

Figure 10. Finishing of a *gerberette*

At the consultation stage of contractors, all foreign companies withdrew from the competition. The two main French companies agreed and presented an identical price that surpassed the established budget by fifty percent, both proposing in parallel alternative solutions that fit exactly in the available budget. The work owner declared the contest invalid and challenged the designers to find out who was available to build the project solution within the available amount and deadline.

At this point it is worth noting that the protectionism exercised by French engineering and industry is not unique to this country. It is a phenomenon common to other geographies. In general terms, companies tend to be conservative and dogmatic at home and to be open and flexible abroad. Globalization has blurred this way of acting, but in essence the rule remains valid.

Having found a German company that met the requirements, Krupps, the studies of the castings were completed and the first *gerberettes* were produced in the Polig Heckel & Bleihart foundry. Resistance tests revealed that the parts did not support more than half of the load for which they had been designed, fearing a tragic outcome of the whole process.

Figure 11. Operation of main beam attachment to the *gerberette*

A final difficulty was also present: President Georges Pompidou, final customer of the order, died in May 1974. His successor, Valéry Giscard d'Estaing, considered the project an unnecessary expense and required that two floors be removed from the building. Fortunately, the process was already too advanced to incorporate the amendment, so the project was implemented as initially planned.

Finally, the obstacle of communication, or, in fact, the lack of it. Communication failures that are the origin of many of the problems we face in countless situations of our daily lives. In this case, the main responsible for the failure of the first *gerberette* testing campaign, as will be seen below.

6. The solutions

The reader asks himself at this point how it was possible to carry out this undertaking.

Firstly, I would emphasize a decisive factor, without which all the competence and commitment of the project team and companies involved would be frustrated: the quality of the work owner. We have already mentioned the clairvoyance of the president of the public entity formed to manage the process and perseverance with which he ensured the conditions for the project to follow the course defined in the program of contest. In addition to the personal value of this figure, the system itself was also meritorious: the creation of a management body independent of political power and advised by individuals of recognized competence and exemption, including the aforementioned chair of the selection board, who allowed the public interest to prevail over other interests.

Secondly, but not less important, the competence, the critical and experimental spirit, the scientific and rigorous analysis with which the technical challenges that the project presented were tackled and solved. The most relevant among them consisted in the challenge of making cast steel a reliable material suitable for use in the modern construction industry. This was surpassed by the engineers integrating in the analysis a new methodology, coming from other industries. This was recent technology applied to metal production based on the fracture mechanics theory developed to meet the need to produce reliable steel platforms for nuclear reactors as well as for the North Sea oil structures. The fracture mechanics allowed to predict the behavior of the fragile materials submitted to stress states and their operation in the presence of internal defects, such as small cracks.

In the design phase, the calculation of the cast parts was carried out using this methodology and their specifications, stipulating the use of the recent English standard on cast steel, defined with precision the characteristics of the steels and procedures to be used in the casting.

Thus, in the manufacture of the first prototypes of the *gerberettes* and knots of the trusses, there was another problem mentioned above: communication lapses. Krupps engineers and casting technicians did not read the specifications, so laboriously prepared by designers. Written in French as stipulated in the competition, it was not easy to apprehend by the German-speaking. In their turn, the designers did not speak German and the communication was made through the precarious English of the Germans. Finally, they did not think twice about using the German standards to which they were accustomed, and which was, moreover, well known for being the most demanding and precise in Europe. Who would question the fairness of the prestigious DIN?

After the disastrous result of the first tests, Peter Rice and his team went to Germany to analyze the problem.

Figure 12. Construction site in the final phase of the work

They understood the origin of the error and explained it to the German engineers, who were still irreducible in their convictions. The search for a solution led them to the University of Stuttgart, the Institute of Materials, where they found Professor Kussmaul, who used the methodology of fracture mechanics. He was able to explain to his compatriots the problem in question and persuaded them to adapt the procedures to the English standard.

The second set of *gerberette* prototypes was thus produced and the tests were carried out without incidents, obtaining the resistances foreseen in the project.

From this point on, no further technical setbacks were found and, apart from the temporary panic set up at the time of Pompidou's death with the prospect of the project being disfigured by the removal of two floors, the work continued normally and was completed in time for the foressen date of inauguration, on 30 January 1976.

7. Peter Rice

After the completion of the Georges Pompidou Center, Peter Rice founded with Martin Francis and Ian Ritchie his own office in Paris, the RFR, responsible for the design of emblematic structures in France and around the world. He was a pioneer in the innovative use of various structural materials such as cast steel, glass and stone. He was a singular, brilliant engineer, respected by

Figure 13. The completed Machine of cultural information

Figure 14. The Structure of Art – The Art of the Structure

his peers, requested by the most outstanding architects of his time. Through his work, his legacy, he taught us a great deal about the role of the engineer in the profession and in society.

The Georges Pompidou Center, as well as many other projects in its curriculum, are a living example of how the intimate and collaborative work between architects and engineers produces exceptional results, which transcend both subjects.

Figure 15. Rogers, Piano e Rice on the *gerberette*

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