

## Two Hybrid Structures by Pier Luigi Nervi

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### Abstract

In 1961 at the apex of his career, Pier Luigi Nervi constructed in Italy two of the largest buildings of his entire production: The Palace of Labour in Turin and the Burgo Paper Mill in Mantua. These two buildings may be regarded as the engineering version of the architectural category of the *Megastructures*, a theme which was developed by seminal architects like Archigram and Hans Hollein. Nervi, as an engineer, was more interested in the structural consequences of these large structures than their social and political impact. Indeed, in both these designs the complex structural issues determined not only the typological solutions and the architectural layout of these edifices but also the choice to make use of an unconventional material for the Italian engineer: Steel.

**Keywords:** Pier Luigi Nervi, Gino Covre, steel structures, reinforced concrete, hybrid structures, modern architecture.

### 1. The Palace of Labour, Turin 1961.

The First of May 1961 represents two important events in the contemporary Italian history. This is Labour Day, an international public holiday celebrated to remind all of the importance of working class struggles. This date is still very popular but its political significance in the Cold War era was much stronger than today. Moreover in 1961, the Italian Republic celebrated its first Centenary and therefore, on July 1959 the Italian Parliament, by means of a special organising commission - *Italia 61* - approved a series of cultural events organised across Italy to celebrate the Centenary. A national competition between a dozen leading practices for a large exhibition hall to be constructed in Turin, the city in which the Unity of Italy was first conceived. The brief indicated that the covered area should be approximately 25,000sqm.

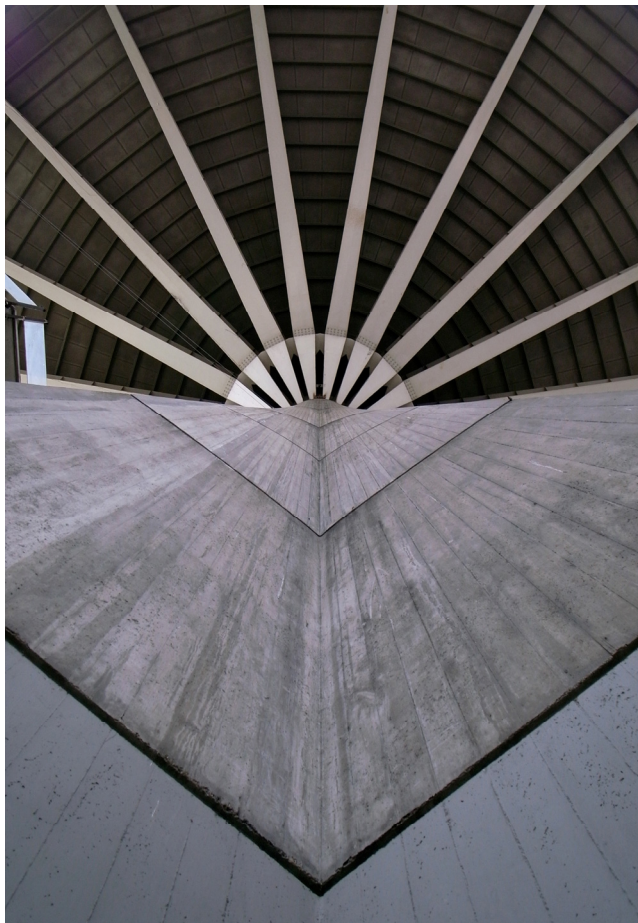
The difficulties were to find the best possible compromise between the political value of a building commemorating the Centenary of the Republic, its function afterwards and, above all, the feasibility of constructing it in such a short time. The competition brief was particularly strict on the following points:

- A detailed project, complete with structural calculations, had to be submitted before 7 October 1960.
- The main section of the Exhibition Italia 61 was to be hosted in the main hall, however this internal space had to be conceived to allow further uses.
- The plan of the building had to be symmetrical.
- The opening day was fixed as 1st May 1961.

On 20 October 1959 the panel concluded the examination of all the entries declaring that the only 'fully satisfying' project was Nervi's. Foundations were excavated on 1 February 1960. The final building was to be a square of 167m per side with an internal height of 25m.

In July 1960, the machine for the construction of the columns started to work. The roof and its supporting structure were the main concerns for Nervi. Initially, the temptation to design a dome over a circular was quite strong in the practice but it was soon realised that this solution would take too much construction time. Other possible solutions considered were either a vaulted structure or a continuous flat roof. All three options faced the same drawback of requiring excessive construction time. After some weeks, a suitable design had not yet emerged and Pier Luigi Nervi was at the point of withdrawing from the project, when his son Antonio, propounded a brilliant idea: instead of having one big roof, why not design a series of smaller, independent ones to cover the whole area? This new approach would simplify the roof design but more importantly, permitted the organisation of the building site as a 'work in progress'. In this way finishing works could begin in the areas where major structural work was complete while work continued in new areas.

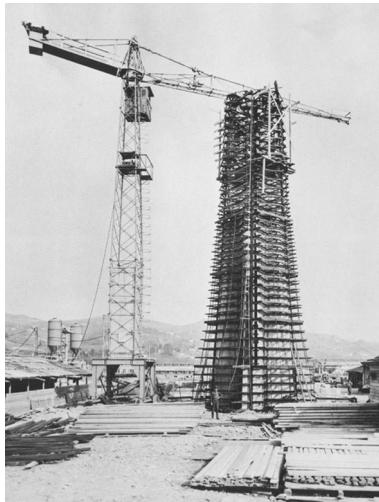
The large covering was planned to consist of sixteen square plates (40x40m) supported by a 20m high central pilaster. The connection between the plate and the pilaster was provided by a capital composed of radial shelves. Four perimeter beams would then stabilise the cantilevered elements. Between each plate a 2.5m wide glass strip was inserted to provide natural light. This initial layout needed transforming into a detailed design in which materials, technology and site management must be determined with absolute precision. The whole construction process of the huge structure could be reduced into the systematic construction and subsequent juxtaposition of sixteen identical structural elements: one pillar surmounted by one square plate: the 'mushrooms', nick-named by Nervi's office.



**Figure 1.** Detail of the column and the steel capitel in the Palace of Labour [MC]

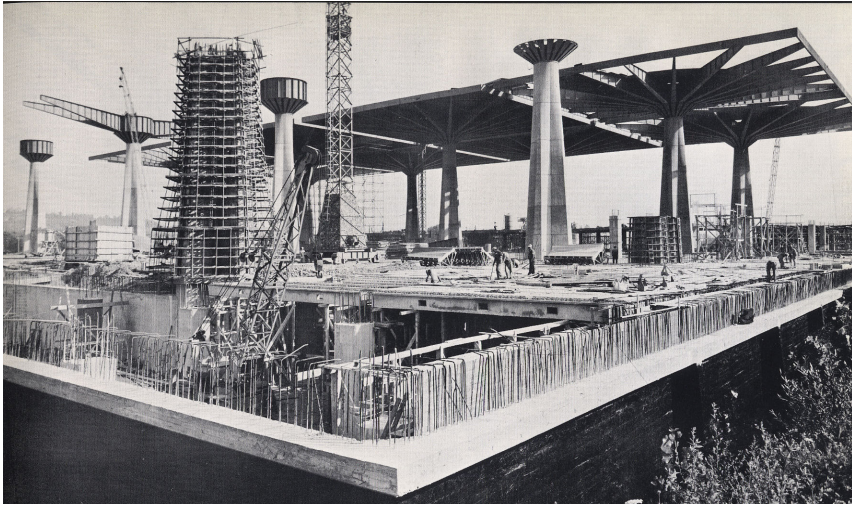
The simple ‘mushroom’ idea presented two major problems: the construction system for the erection of the huge pillars and the structure and material for the plates. Nervi and his team realised that to construct the horizontal element of the mushroom in reinforced concrete would take too long, especially considering the complication of two cold winters when the building process would slow down. So, for the first time in Nervi’s career, and purely because of the time constraint, steel was preferred to reinforced concrete. After planning the initial scheme, the detailed design of the structure was given to a firm which specialised in steel construction, the Badoni Company from Lecco in the North East Italy, which worked under the supervision of the steel engineer, Gino Covre, whom Nervi had first known during

the 1940 competition for a monumental arch at EUR in Rome. The construction of the columns in exposed reinforced concrete presented various issues. The main one was that it was crucial to have perfect vertical alignment of the columns, especially in the top part where the steel capital was to be placed. This is very difficult to achieve with normal timber forms. Even more importantly, it was difficult to provide a continuous surface between the cruciform base and the circular top of the columns. As there would be no time for corrections the columns had to be constructed perfectly from the very beginning. Finally, the forms for the columns had to be accurately placed by a crane and it had to have its own stability. The final solution was to build a single steel framework, composed of six parts bolted together which could be dismantled, with which to erect all sixteen columns; a huge machine: The giant lifting machine was also constructed by Badoni and costed 10 million ITL (approx. 83,000 EUR - May 2009).



**Figure 2.** The Bodoni' steel formwork to construct the columns [MAXXI]

The six pieces in which the tall column was made, were marked by a 2cm timber groove to avoid possible irregular separation between two consecutive pours. The complete cycle for the erection of one column was achieved in ten days. When a column was finished, the whole steel form was dismantled and its internal timber skin, formed by 12cm wide timber strips, was taken out, polished and re-installed within the machine, ready for another cycle. This process, repeated for all columns, allowed the finishing work to start where the structure was already complete.



**Figure 3.** The Palace of Labour on site, Turin 1961 [MAXXI]

On the 30 October 1959, after only four months, the construction of the sixteen mushroom-shaped columns were completed. At the same time the mezzanine floor, at the perimeter of the building, was finished. A system of movable forms in *ferrocemento* was employed to quickly build the structure of the floors. The final glass skin of the building was assembled and the whole building was ready in January 1961 for the exhibition organised by the architect Gio' Ponti, an architect and personal friend of Nervi.

The great hall was received with controversial comments. Many critics attacked Nervi's new direction towards gigantic structures and the scant attention to architecture. In particular, Bruno Zevi (Zevi, [3]) criticised the 'anonymous glass envelope'. Moreover, in addition to the negative comments of some critics, Nervi's design was fiercely contested by some other competitors. However, other critics admired Nervi's achievement: a postcard sent by Le Corbusier on 25 May 1961 described the venue as 'un magnifique palais'. Indeed the Palace of Labour in Turin demonstrated Nervi's ability to dominate the creation of a structural and technological object within strict building conditions.



**Figure 4.** The North elevation of the Palace of Labour [MAXXI]



**Figure 5.** The great hall within the Palace of Labour [MAXXI]

## **2. The Burgo Paper Mill, Mantua 1961.**

The Burgo Paper Mill represented, as did many of Nervi's works, a challenge.

In 1960, The Burgo Company was about to build a factory to accommodate new machinery for transforming wood pulp into newsprint, a process which needed an overall length of 100m. The building, envisaged purely as a container for the new machine, had therefore to be considerably longer. Furthermore, any future expansion would require additional space in order to place an identical machine adjacent and parallel to the original and this made the design even more challenging. A central space between the two machines would be required for personnel to work and control the process. This area had to be free from any vertical structural elements for at least 150m which meant that, after consideration of all utility spaces and working areas, the whole structure had to be approximately 250m long and 30m wide without internal columns, a gigantic, empty box.



**Figure 6.** The Burgo Paper Mill just after its completion in 1963 [BURGO]

In the first, preliminary, layout Nervi explored the option of a structure composed of two reinforced concrete arches, each 200m in length. The excessive cost of the foundations prompted the consideration of a flat roof solution and, indeed, Nervi opted for this. The horizontal roof element could not be supported by any columns inside the building and therefore, somehow, it had to be suspended. The flat covering of a rectangular edifice such as this, to be achieved without the use of columns, is an apposite analogy to the structure of a suspended bridge, a structure Pier Luigi Nervi had already designed but not yet built.

Initially, Nervi's practice proposed two variations in terms of materials. The first was a building made entirely in reinforced concrete, the second combined reinforced concrete with steel elements. Both provided a flat roof suspended by means of four external supports. Again, economic considerations and concerns regarding the speed of construction ensured that the steel-concrete option prevailed over the purely reinforced concrete solution. At the beginning of the 1960s, the price of steel was high but the convenience of using reinforced concrete began to be less apparent. This was mainly due to the necessary labour employed in this technology, which was considerably more expensive in the high wage society that Italy was becoming.

The Burgo Paper Mill project is straightforward, a quality of Nervi's design approach, especially with regard to large scale buildings. As Sergio Poretti noted (Poretti, [2]), the whole building can be separated into three distinct systems:

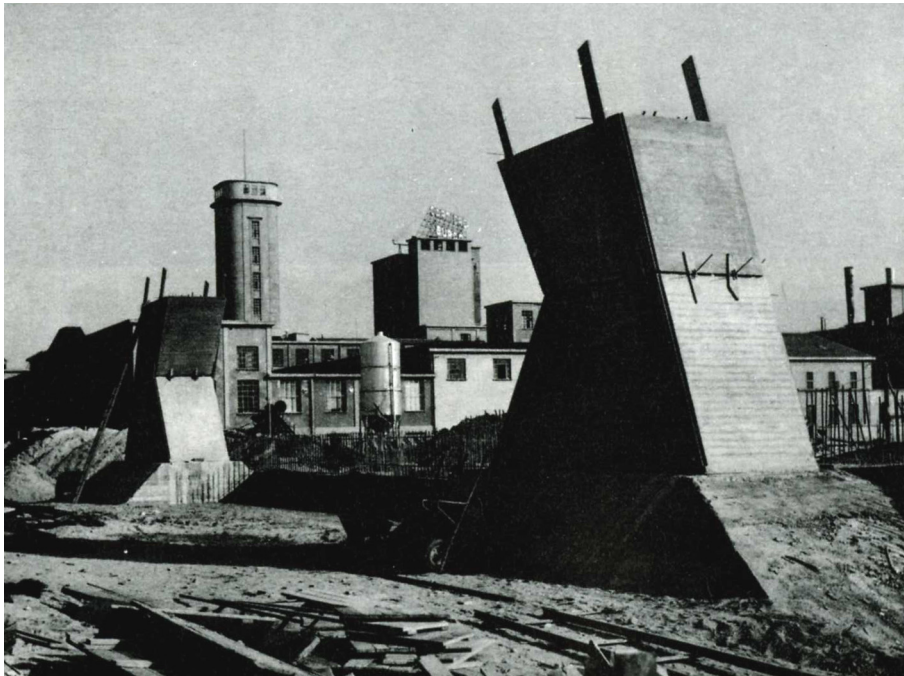
- The base - on two levels - which supports the continuous paper machine.
- The steel-glass curtain walls which enclose the whole building.
- The flat steel roof and its supportive, composite structure.



**Figure 7.** The Burgo Paper Mill in construction [MAXXI]



After setting up the construction site, the erection of the four pillars began in September 1961. The variable section of the pylons and the different inclinations of their parts are, as is usual in Nervi's structural elements, suggested by the line of stresses transmitted by the suspended ceiling to the ground. The main problem for this particular case, and also a central point in Nervi's ideas, was how to avoid the huge amount of carpentry required to assemble the wooden or metal cast forms for such a difficult shape and also their inevitable waste. These were typical building site issues for which Nervi proved to be an indefatigable innovator, here he applied a spectacularly simple but effective procedure. Initially, panels in reinforced concrete (7cm thick) were carefully prefabricated in-situ at ground level. These were reinforced concrete self-supporting box moulds which were then filled according to the sequence of the large poured sections, to which they remained as external 'skin'.

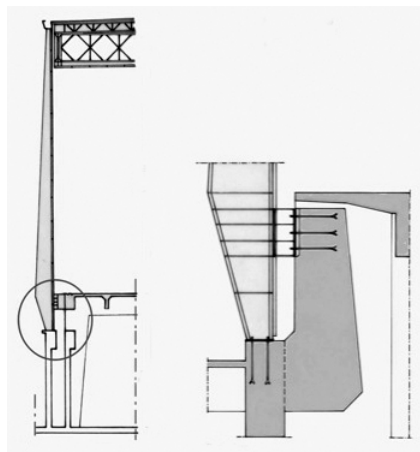


**Figure 8.** A detail of one external support [MAXXI]

A brilliant solution in its simplicity to avoid the wastage of materials, the final working of this 'skin' was rough but attained an aesthetic result. Once the four supports were erected, the involvement of the Antonio Badoni Company was requested in order to set the suspended roofing in Spring 1962.

The link between the steel roof and the external supports is the suspended chains, formed by independent rigid jointed bars. The connection between the chain and the reinforced concrete pylons is provided by four steel elements placed in the cross beam at the summit of the four supports. At intervals of 10m, corresponding with the joints, 92 vertical rods of 45mm diameter support the four lattice steel beams which is the main structure of the roof; cross-beams ensure the overall stability of the roof, which has an overall thickness of 2m. The Badoni Company, already in charge of the roof was also responsible for the steelwork of the lateral curtain-walls. The four vertical partitions, which enclose the heterogeneous system formed by the basement and the suspended roof, are a very sensible element in this work. It is purely a technical consideration, but it is important to understand that Nervi focused on designing every part of his work in the most suitable way, no component could be conceived outside a more complex system.

In a large structure like the paper mill, static stresses and temperature variations can create considerable deformations due to the Joule effect of the paper machine, the internal temperature can reach 50 degree Celsius. In the suspended steel structure, the range of thermal deformation was calculated to be more than 20cm, this made quite problematic to link the wall to the roof. Nervi's solution cleverly reversed the usual procedure. Generally, the curtain-wall is hung from above; in contrast, in the Burgo Paper Mill, the wall is conceived as a large vertical cantilevered element set into the foundation and left free at the top. The framework is composed as a series of vertical box-beams blocked by the foundation. At the top of these, a waterproof membrane protects the steel structure and avoids rigid connections between the two parts (roof and walls), rain water is carried off by gutters placed in one of every three of the cavities of the upright box beams.



**Figure 9.** Details of the curtain wall [BURGO]

A machine within a machine, this summarises the entire work of the Burgo Paper Mill. A different, synergetic product designed by Nervi in comparison to his more typical works like the sports arenae. The huge box invented by Nervi is inevitably heterogeneous as it is composed by three different structural episodes (basement, roof and curtain-wall

The Burgo paper mill however lacks the ambition of similar contemporary projects, in which social and political issues were part of the design values. The political orientation and social commitment of designers such as H. Hollein and Archigram, or in Italy of M. Fiorentino, V. Gregotti, G. De Carlo, and A. Rossi, favoured a global re-thinking of the relationship between public and private spaces, of which a factory is a evocative example. The lack of Nervi's political and social commitment made of this building a missing opportunity from the *Architettura Sociale* perspective; on the other hand Burgo remains surely one of Nervi's most complex challenges from a structural point of view.

### **3. Current State of the Buildings**

After surviving a huge fire in 1974 which caused sever damage to the paper machine and to the structures of the roof, the Burgo Paper mill was promptly repaired it is now fully operative. The miraculous recovery of the Burgo was due both to the resilient structures that Nervi conceived and buit and to the modularity of its design which allowed a quick substitution of the damaged parts. The Burgo Papaer mill works only with recycled paper and currently provides the paper for some of the major newspaper in Italy such as the *Corriere della Sera* and *Il Sole Ventriquattrore*.

The fate of the Palace of Labour is, conversely, quite different. This building is now reduced to a semi-dereliction place, partly used by the Faculty of Economics at the University of Turin. The beautiful structure, still in a 'good state of conservation both for the columns in reinforced concrete and the steel roof' (Ruggieri, [2]). The huge internal hall, however, is now used merely as a stocking area with limited access. Health conditions are poor and maintenance is almost non-existent. In the areas occupied by the University, the elegant and famous ribbed ceiling originally designed by Nervi is now hidden by a mundane false ceiling.

### **4. Conclusions**

In many respects the Palace of Labour/Burgo Paper Mill's cycle represented a unique experience in Nervi's career. The obvious reason is the massive use of steel.

Indeed Nervi used steel elements in other works and projects, as in an early project for a circular aeroplane hangars in 1935, however, he had never used it before with such great structural relevance. Arguably this is the reason why he called Gino Covre to design the steel structures. Despite the use of steel proved to be effective and, considering the particular constraints of the design of these two buildings, probably a necessary choice, Nervi never used again steel in any of his project, with the only exception of the cables for the Messina bridge.

Reinforced concrete remained Nervi's favorite material also in the years to come, triumphally ending his career in the structures for the Vatican hall, where the metamorphosis of the 'Melted Stones' was finally completed.

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## **Photographic sources and credits**

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- [MAXXI] MAXXI Architettura - Archivio Nervi - Via P. S. Mancini 18-20, Rome (IT)
- [MC] M. Cresciani Private Archive - info: m.cresciani at leeds.ac.uk