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## Bernard Laffaille, Nicolas Esquillan, Two French Pioneers

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### Abstract

Bernard Laffaille and Nicolas Esquillan were two main actors of shell and spatial structures design during the twentieth century. Their respective works crossed each other during the CNIT project for which they submitted two different solutions as mentioned in this paper. Pioneer of cable nets, Bernard Laffaille tried then to improve this innovative lightweight solution in his last projects. Nicolas Esquillan, who won the CNIT contest, can be doubtless considered as a pioneer of reinforced concrete shells, and contributed to the shell and spatial structures knowledge, working closely with Eduardo Torroja at the early years of the International Association for Shell and Spatial Structures.

**Keywords:** *Concrete and steel shells; pre stressed systems; double curvature; Esquillan; Laffaille.*

## 1. Introduction

Born at the very beginning of the twentieth century, Nicolas Esquillan and Bernard Laffaille can be considered as pioneers in the field of shell and spatial structures. They had a role of pioneers for reinforced concrete and metallic shells, designing “milestones” projects before and after the Second World War. Nicolas Esquillan was a very active member of the IASS, and Bernard Laffaille tried also to contribute to the development of innovative lightweight structures during the same decade as Eduardo Torroja. Only some aspects can be developed in this paper. Two main references can be underlined, even if other information can be found elsewhere. The impressive thesis written by Nicolas Nogue is an exhaustive study of Laffaille’s works [1]. Bernard Marrey gathered in his book devoted to Nicolas Esquillan important material describing his pioneer’s work [2]. Thanks to his work, we could organize the exhibition “Nicolas Esquillan” during the 2004 IASS Symposium in Montpellier. The two engineers applied for the “CNIT” project in Paris; it was a “crossing project” at the beginning of the second part of the twentieth century and played a major role in their careers. This role will be replaced in their respective sequence of structural designs.

## 2. The CNIT in Paris, a “crossing” project

### 2.1 The CNIT, a major challenge

After the Second World War, a need of great exhibition centers appeared in many countries in order to improve to economic activities. In a non referenced document found in “Maillart Archives” at Princeton University the project’s requirements are described by the architects as follows: In 1950, the “Societe civile du Centre de la mecanique” (the Automation centre company) was set up, on the initiative of the *Constructeurs Francais de Machines-Outils* (French machine tool producers). The Federation for engineering and metal processing industries thus set up for themselves the structure for creating an exhibition centre on an international level. The president, E.

Pouvreau, had a 30 000 m<sup>2</sup> triangular site at La Defense, and, very naturally addressed himself to the architects in charge of the master plan for the area (Bernard Zehrffuss and Jean de Mailly). The requirements of the brief were straightforward: *to provide the maximum exhibition area, both for heavy machinery to be set directly on the ground floor, and for lighter equipments at upper levels.*

## 2.2 A gathering of leading engineers for three main solutions

Pier Luigi Nervi, Jean Prouve, Bernard Laffaille and Nicolas Esquillan applied for this contest. Their respective contributions and the projects are described by the architect Zehrffuss [3]

Bernard Laffaille, a friend of the architect Robert Camelot who joined the architect's team, was consulted. A first curvilinear form enclosed by a hyperbolic parabola was adopted. Taking advantage of his experience of pres stressed steel structures, Laffaille submitted a solution based on a double negative curvature cable net (Figure 1), curiously looking like Nowicki proposal for Raleigh Arena (we do not know if Laffaille knew this project) [4]. This solution frightened the specialists of metallic structures. Pier Luigi Nervi and Jean Prouve were then called. Nervi began with a three points shell structure combining reinforced

concrete and steel structures with his "classical" rhombic morphologies. As quoted Camelot "Nervi made models; he couldn't calculate it, but he was quite sure it would work all the same !". In between Eugene Freyssinet produced a comparative study of concrete shells with pre stress[5].

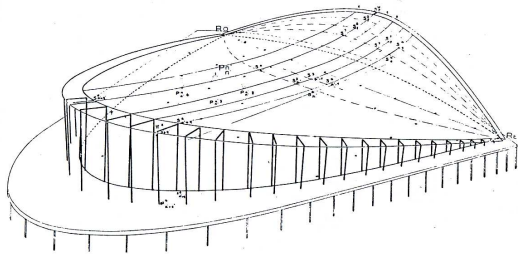


Fig. 1: Double negative curvature cable net – B. Laffaille

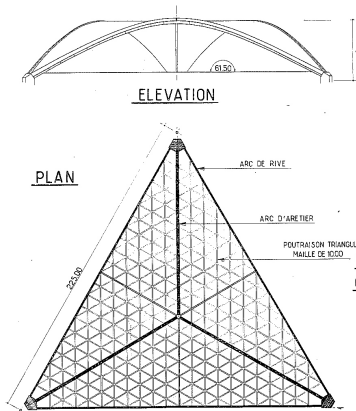


Fig. 2: Nervi's Proposal

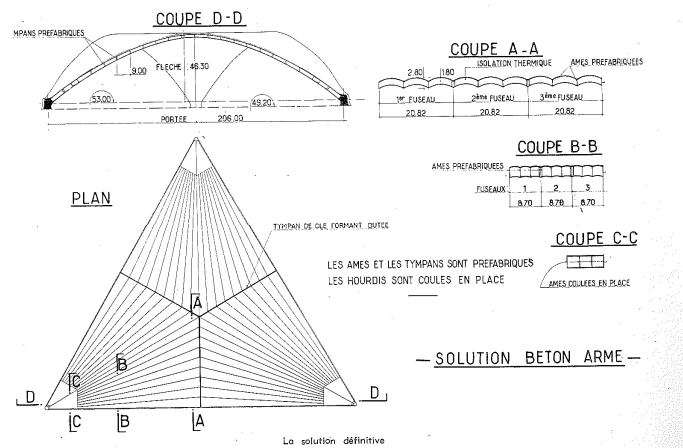


Fig. 3: Esquillan's Proposal

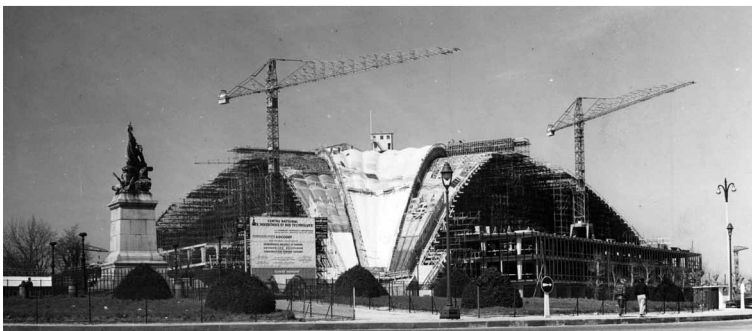


Fig 4. The CNIT under construction

The architects abandoned the metallic solution which needed intermediate supports. Nicolas Esquillan, consultant engineer for the Balency & Schuhl, Boussiron and Coignet group (BBC), provided a detailed design for a double skin three point shell structure (Figure 3). This solution was approved and built (Figure 4) as described by N. Esquillan [6].

### 3. Bernard Laffaille (1900-1955)

#### 3.1 Inventor and pioneer

The motto of Bernard Laffaille:

*“I have the absolute certainty that we can undertake everything and bring to a successful conclusion everything, on the condition of an intense will and carefree to benefit from it.”*

resounds as that of a researcher eager for action and realization.

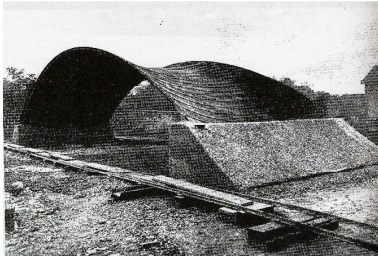


Fig 5. : Prototype of metallic thin shell. Laffaille 1935

Graduated from the Ecole Centrale (1923), he was a pioneer in the field of double curvature structures, beginning with metallic ones before the Second World War, continuing with reinforced concrete thin shells, and ending with pre stressed systems. Interested readers may consult the thesis by Nicolas Nogue [1], and this paper provides only some elements.

His patents list is impressive (at least thirty). Among them, his proposal for the improvement of vaults construction [7] was realized and experimentally tested (Figure 5). He carefully studied the economic constraints and was the author of a specific

mathematical method of cost evaluation [8].

His pioneer activity has been clearly recognized by the International Association of Shell Structures during the 1962 Colloquium hold in Paris[9]. The title of this meeting “Colloquium on hanging roofs, continuous metallic shells roofs and superficial lattice roofs” is not surprising, but the fact that Nicolas Esquillan organized this event is very important, as the testimony of french continuity. Laffaille died seven years before, and during his introductory talk A.M. Haas, as IASS president said:

“Perhaps some of you know that Bernard Laffaille attempted to organize such a conference in Paris, about eight years ago. However for various reasons, he did not succeed. Now a second effort has been made and we are glad that so many responded and especially that we have among us Dr. Frei Otto”

In the proceedings themselves, Frei Otto began his paper by the following words:

“Vor acht Jahren hatte Bernard Laffaille schon einmal versucht, ein solches Gespräch zustande zu bringen. Leider gelang es nicht mehr. Wir folgen nun der Einladung Eduardo Torroja. Beide, Torroja und Laffaille hatten nicht das Glück, die Verwirklichung zu erleben”

It is a matter of fact that Frei Otto considered also Bernard Laffaille as a pioneer. In one of his letter to him, he joined a table of main lightweight structures, including those of Laffaille (Figure 6) inside the red ellipse.

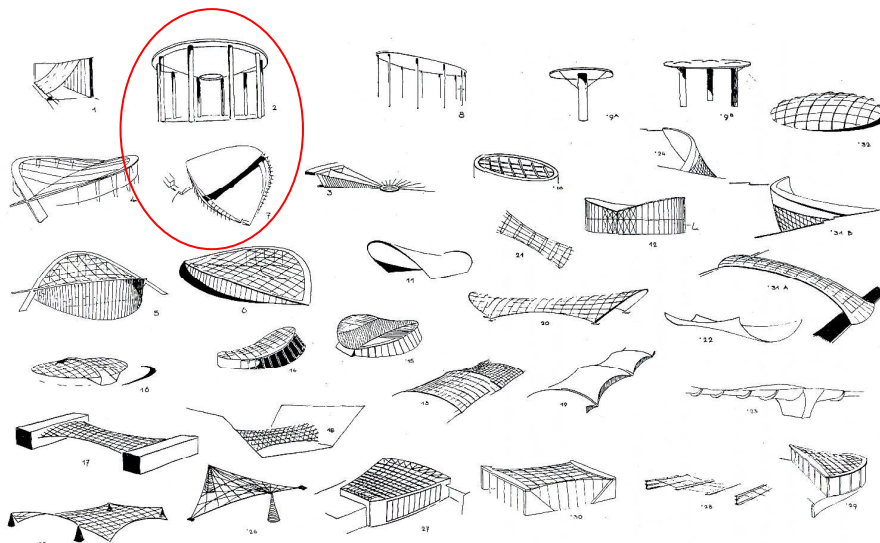


Fig. 6: Drawings sent by Otto to Laffaille January 1953 Cote IFA 49/1 [1]

### 3.2 Some iconic projects

#### 3.2.1 French Pavilion in Zagreb (1937)

Among ten years after the final patent for pre stressed concrete has been attributed to Eugene Freyssinet (1928), Bernard Laffaille applies a pretension for a metallic shell realized with the architect Robert Camelot for the international fair in Zagreb. The self weight of the lantern is sufficient for introducing the appropriate pre stress in the metallic shell (Figure 7, red arrows). He will apply the pre stress principle for many of his following projects.

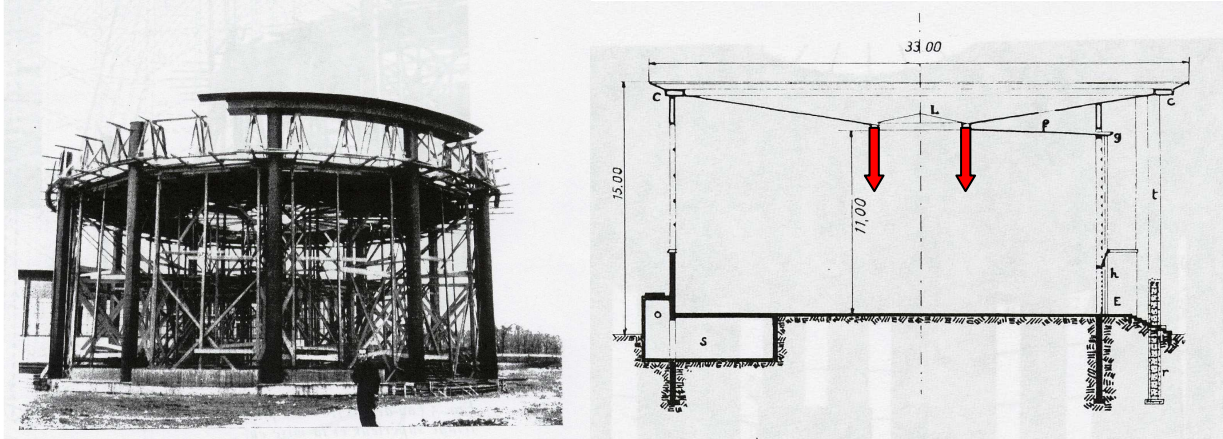


Fig. 7 : French Pavilion International fair in Zagreb 1937. R. Camelot arch. B. Laffaille eng.

#### 3.2.2 Circular sheds for railway engines

Just after the war a great demand of new technical buildings offered to Laffaille the opportunity to associate two of his inventions for circular sheds. He used concrete thin shells in association with so called “V” columns, named afterwards “V Laffaille”. This post in reinforced concrete in the shape of V, was invented by Bernard Laffaille to answer the economic necessities by a faster implementation, thanks to the prefabrication. Used completely during the construction of the circular sheds of the SNCF(French National Railway Company), in Avignon and in all France, V Laffaille returned his famous inventor. Between 1944 and 1950 Laffaille designed twenty circular sheds.

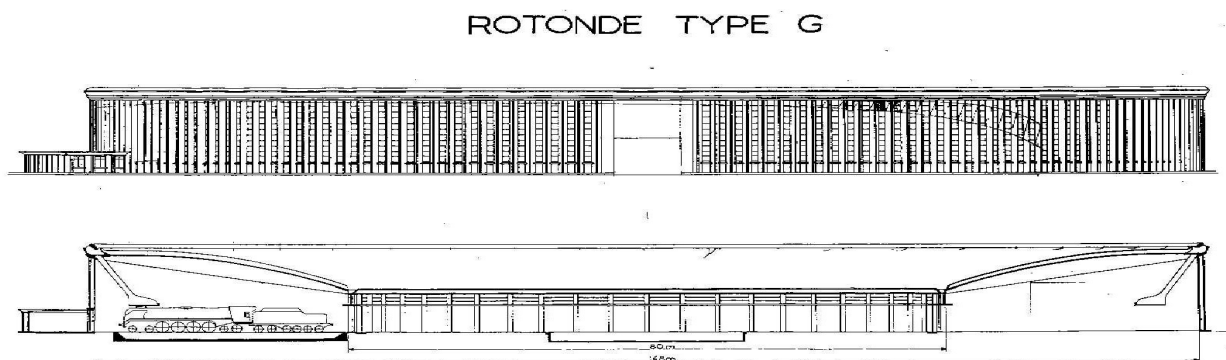


Fig. 8: Circular shed for railway engines.[1]

### 3.2.3 Centre Emetteur Europe 1

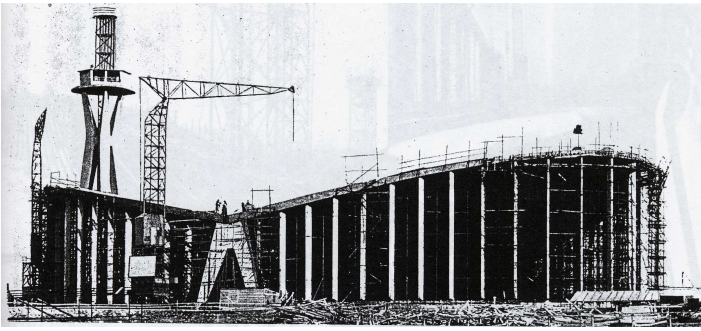


Fig. 9: Centre Emetteur Europe 1. Sarre

Keeping his idea of pre stressed cable nets, Bernard Laffaille designed a building for “Europe 1”, with Guedy as architect (Figure 9), in Sarre applying the design submitted for the CNIT. The cable net was inside concrete layers and cracks occurred during the pre stressing of ties.

Eugene Freyssinet was called in order to face the arisen disorders and did not accept the presence of Laffaille, who was deeply affected by this failure.

### 3.2.4 The last masterpieces

Bernard Laffaille died prematurely after this event, in June 1955. His last projects were achieved by Rene Sarger, who worked with him since 1946. One of them is a thin reinforced concrete shell with the same typology as Candela’s works (Figure 10 A). The second one is a church in the same town, Royan, France, and the design (signed by Gillet, Laffaille and Hebrard) associates several “V Laffaille” with a pre stress cable net roof (Figure 10 B).

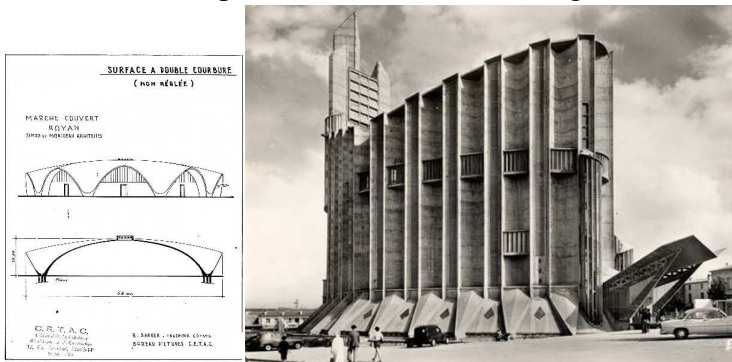


Fig. 10 : Royan A Covered market – B Church 1956

When “V” are used for churches, according to Guillaume Gillet, this will transcend the building by bringing him" a monumental and sacred dimension ".

## 4. Nicolas Esquillan (1902-1989)

### 4.1 A company engineer

Born in Fontainebleau, near Paris, Nicolas Esquillan attended courses at Chalons-sur-Marne Ecole des Arts et Metiers from 1919 to 1922. Appointed as head of structural research in 1936, at Boussiron company, Esquillan was appointed Vice Technical Director in 1939, then Technical Director from 1941 to 1971.

He won seven world records. The first was in 1934 with La Roche Guyon Bridge, spanning 161 m, a record length for a suspended deck bridge in reinforced concrete.

This record was to be followed by six others, with the bridges of Coudette (1943), Givors (1950), La Voulte (1953), Tancarville for the height of the piles in 1957, the Marignane hangars (1951) whose span of 100 m was soon surpassed by the CNIT vault which, with 206 m in length of facade and 238 m under the ridge valleys, still holds the world record for span and for the largest area (7500 m<sup>2</sup>) held up by supporting points.

## 4.2 The bridges

Only three of them are presented in this paper.

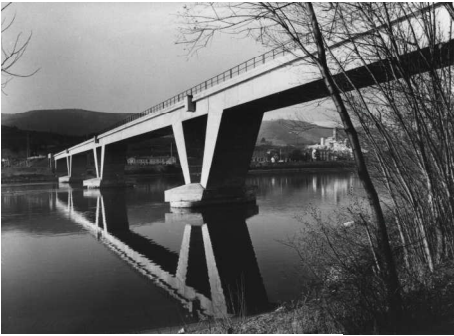


Fig. 11: La Voulte Bridge

Over the Rhône river, south of Lyon (1952-1955) this was the first great French railway bridge in pre stressed concrete; it crossed the Rhône in five 56 m spans. At 300 m, it was also the longest bridge in the world laid with railway track, and the first to be built as a corbelled construction. At the request of the SNCF, it was the site of a new cable-torsion prestressed process.



Fig. 12: Houphouët-Boigny bridge. (On the lagoon in Abidjan in Ivory Coast 1954-1957).

The bridge supports two railway tracks on the deck and a 14 m wide double lane for vehicles. It measures 361 m in length in eight 36.50 m spans. The main difficulty arose from the muddy terrain to an average depth of 40 m, below 10 m of water. Entirely prefabricated, it was built in thirty-one months.



Fig. 13: Moret viaduct.

This viaduct is situated on RN 5 highway (France), on the two arms of the Loing river and the canal (1956-1957). Stretching over 320 m, it was entirely prefabricated and took fourteen months to build.

## 4.3 Marignane Hangars

In January 1943, the firm Boussiron won the competition launched in 1942, for a double hangar at the airport of Marignane. The two units are covered by six 101.50 m waves, 9.80 m in width and 12.10 m for the sag. They comprise a concrete shell, 6 cm in thickness, with steel reinforcement at a ratio of 9 to 1000 per volume of concrete. A very important challenge was to construct on the ground and and to lift the shell in place.



Fig. 14: Marignane Hangars - Formwork for the test wave

This period of forced inactivity was put to good use in preparing the drawings and calculations. A test was achieved for a wave; the prototype was built on a 1/5<sup>th</sup> scale in 1943 in the Lot where the firm had taken up residence during the war (1943).

because of the thin shells, but more in the construction process itself that implies a correct lifting of very heavy parts. The first roof portion (100 m x 60 m, 4 200 t) was erected in 38 days; the second part was realized in 23 days (Figure 15). This structure is still in use.

This work is interesting not only



*Fig. 15: Marignane Hangars – First par lift – Completed hangars*



*Fig. 16: Removal of the formwork of a wave: the last section of the formwork is tipped out, and interior view of the roofing of a unit on the ground*

#### **4.4 The CNIT**

When looking at the interior view of Marignane Hangars (Figure 16), it is obvious that this realization was a kind of preview of the double layer thin shell of the CNIT soon evoked at the beginning of this paper.



*Fig. 17: CNIT interior and exterior views during construction*

### **5. Conclusion**

Bernard Laffaille and Nicolas Esquillan had an engineering career clearly inscribed in the twentieth



century. They were pioneers by their innovations, their inventions, their skills as builders aware of technical and economical constraints. They were informed of the mechanical problems like buckling for shells, they used freely the pre stress in their realizations, they were able to develop analysis and calculations without any computer ! They improved the field of double curvature systems on analytic bases. But they had a deep personal feeling of the mechanical behaviour of thin shells, and they could test their intuitions on scaled physical models. They both contributed to the development of lightweight structures. Nicolas Esquillan was clearly implied in the International Association for Shell and Spatial Structures , and Bernard Laffaille was recognized by the collectivity of lightweight structures engineers. His contribution was forgotten, and, hopefully, the work achieved by Nicolas Nogue is now an appropriate source of knowledge for young engineers.

## 6. Acknowledgments

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