# ICON

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# ICON

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Cover: Serial mass production of watches in Ruhla (GDR) with Swiss production technology. Photo taken by Ulrich Windoffer of Leipzig in 1967/68. Courtesy of Fördervereins Uhrentradition Ruhla e.V.

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Research Brief

# "MARSÁ" REINFORCED CONCRETE BEAMS AND THEIR APPLICATION IN SPANISH AGRICULTURAL INDUSTRIAL ARCHITECTURE

**Sheila Palomares Alarcón**

*Agustín Marsá Prat registered several patents between 1941 and 1956. These included a patent for a reinforced concrete roof-beam that he designed with the intention of replacing expensive iron beams which were so difficult to purchase at the time.*

*His concrete beams were proposed as a low-cost, lightweight reinforced concrete structural system, which required little skilled labour and had a striking aesthetic effect. Known today as "Marsá" truss beams or as reinforced concrete truss beams with braces, they were commonly used in industrial buildings related to the agri-food sector.*

## Introduction

Although the massive use of concrete dates back to the Roman Empire, it is thought that it was already used in a rudimentary way in northern Chile (3000 BC) and in ancient Babylon (7000 BC).[1] However, it was not until several centuries later that the first experiments involving reinforced concrete occurred. The English engineer William Boutland Wilkinson (1819–1902) is said to have been the first to patent reinforced concrete in 1854. He developed a coffered plaster stay-in-place formwork system and poured reinforced concrete; this system was used for the first time in 1865, in a villa in Newcastle. Soon after, in 1856, the French industrialist François Coignet (1814–88) patented a construction technique that combined iron and concrete. It used a 30 cm-thick slab of concrete that was reinforced with double-T iron beams placed underneath it. He used the construction to build the roof of his house, located in his factory in Saint Denis (Paris). In addition, Coignet patented the first reinforced concrete beams in 1889.

Between 1867 and 1886, the French gardener Joseph Monier (1823–1906) patented various systems in which he used reinforced concrete: from gardening products to prefabricated façade panels in 1869. He registered his patents in Spain in 1884 and improved them in 1886.

Joseph Monier is considered one of the first people to experiment with prefabricated reinforced concrete together with Josep Louis Lambot (1814–87), who presented a reinforced concrete boat in 1849 at the Universal Exposition in Paris.

1 López Vidal and Fernández-Ordoñez, "La construcción con prefabricados de concreto."



In 1890, the French engineer François Hennebique (1842–1921) founded a company to market the reinforced concrete systems he had patented in 1886. He registered his first patent in Spain in 1892.[2]

The first experiments with reinforced concrete were thus made in the mid-nineteenth century. Almost simultaneously, prefabricated concrete components started to be used in architecture, as in the case of Castle House (Bridgwater, Somerset). Castle House was built in 1842 by John Board, and recently restored by Ferguson Mann.[3] This house is considered a pioneering building that used reinforced concrete structures and components.

Experiments with reinforced concrete were followed by experiments with prefabricated reinforced concrete; however, this technique was only developed and used to a greater extent in the twentieth century. This was especially true after 1928, when Eugene Freyssinet submitted his patent for prestressed concrete, a new material that sped up the process of construction process and was used extensively after World War II.

The first patents for prestressed concrete in Spain and Latin America were registered in 1942 by Francisco Fernández Conde.[4] Subsequently, in 1944, the first company in Spain to build prestressed concrete components was founded in Rivas de Vaciamadrid. It was called the PACADAR company , S.A. ("Piezas Armadas con Acero de Altísima Resistencia" or, literally, Highly Resistant Steel-Reinforced Components). The first prestressed beam manufactured in Spain was made in 1945 and became known as "Viguetas Freyssi"; it measured 3.20 x 16 cm and it was reinforced with 8 rods with a diameter of 2 mm.

Since the beginnings of prestressed concrete beams in Spain, beams became a key element in the construction of slabs. They could be combined with concrete blocks or Catalan vaults and were used to build roofs on industrial buildings and gas stations. They were often combined with metal truss beams when there was the need to cover a long span.

The first prestressed slabs, double-T beams, and large components covering long spans, as well as other components such as gutters, tiered structures, utility poles, etc. were manufactured in Spain in the late 1950s. The 1960s were marked by the advent of the manufacturing of fully prefabricated industrial warehouses, and the 1970s by

2 " Hormigón Armado en España 1893-1936," Centro de Estudios Históricos de Obras Públicas y Urbanismo (CEHOPU), accessed 17 November 2020, http://www.cehopu.cedex.es/hormigon/temas/C34.php?id_tema=77.

3 "Castle-house," Ferguson Mann Architect, accessed 17 November 2020, https://www.fm-architects.co.uk/projects/castle-house/.

4 López Vidal and Fernández-Ordoñez, "La construcción con prefabricados de concreto."

the manufacturing of panel frames for heavy loads, lightweight slabs, large double-T slabs, lightweight coffered slabs and two-way struts, cladding panels, hollow-core beams and special components for latticework, all of which have been enhanced ever since.[5]

In the late twentieth century, the concrete industry in Spain grew exponentially, following improvements in dosing and curing techniques, quality control, finishes, raw materials, design. The best examples of this can be found in components for the frames of roofs. They used a growing number of prefabricated components, from traditional beam-and-block systems to hollow-core slabs. An increasing degree of automation in manufacturing units and the introduction of self-compacting concrete enabled a form of construction which stands out for satisfactorily meeting all the necessary technical and functional requirements.[6]

The wide range of uses and applications of prefabricated reinforced concrete and prestressed concrete were researched and analysed by Eduardo Torroja[7] and Miguel Fisac. The latter registered several patents,[8] including the "bone beams" he used to build the roof of the Centre for Hydrographic Studies (CEH) in Madrid in 1960. His solution, very original from the technological point of view, was patented and sold under the name HUECOS. He collaborated with Ricardo Barredo.

HUECOS was successfully used in the roofs of the leather factories in Vic and in Montmeló (1968), where it was impossible to use metallic structures due to the corrosion caused by the gases released by the chemical treatments used in leather tanning.[9]

## Agustín Marsá Prat's Patents

Little is known about Agustín Marsá Prat, except that he lived in Madrid. According to the Spanish Intellectual Property database, Prat registered several patents related to prefabricated building components between 1941 and 1956.[10] His first invention was reinforced concrete beam ES 5778, which was registered on 16 February 1941 (figs 1A and 1B) . It was widely used in the industrial warehouses built at the time; Prat patented different versions of this beam over the years.

His original proposal for ES 5778 consisted of "improvements to reinforced concrete beams, characterized by a longitudinal concrete core whose cross section had a square, rectangular or other shape, underpinned by two or more trusses joined by iron braces that are also attached to the ends of the beam."[11] A few years later, in 1944, he applied to register the patent ES 13192 (fig 1C), which was similar to ES 5778.[12] ES 13192 consisted of an industrial reinforced concrete beam model, ideally suited for mono-pitched roofs, which meant that it should be placed on an inclined plane.[13]

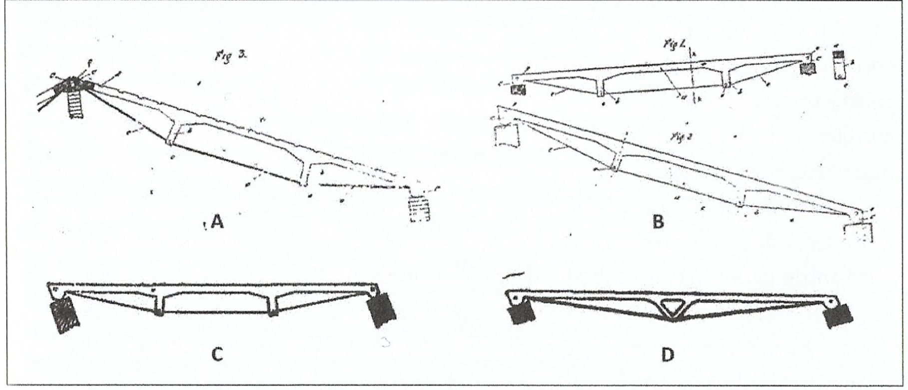



Figure 1. (A and B) ES 5778 . BOPI (Boletín Oficial de la Propiedad Industrial). N° 1290 al 1293, Año 1941, p. 138. (C) ES 13192. BOPI. N° 1383, Año 1944, p. 202. (D) ES 14733. BOPI . N° 1427, Año 1946, p. 141. (Source: Web de Historia de la Propiedad Industrial.)

5 Burón Maestro and Fernández-Ordoñez Hernández, "Evolución de la prefabricación para la edificación en España."

6 All translations were done by the author. López Vidal and Fernández-Ordoñez, "La construcción con prefabricados de concreto."

7 In 1958, the "Instituto Técnico de la Construcción" (Technical Construction Institute), chaired by Eduardo Torroja, designed a project for regulating prestressed concrete joists, which was announced in 1959 and cancelled in 1960. It was known as "Punto Azul" (Blue Dot) and consisted on printing a blueish logo on structural building components as a way to certify that they met the minimum quality and safety requirements. Camprubí, *Los ingenieros de Franco*, 74, 93.

8 His last patent was "Arquitectura Vertida," invented in 1997 (ES 2 1418 024) as a merge of previous ones. González-Blanco, "Gz/10," 526, 153-166, 154.

9 Arqués, "Miguel Fisac (1913-2006)," 6.

10 To read Agustín Marsá Prat's patents, please refer to: Boletín Oficial de la Propiedad Intelectual (henceforth BOPI). Histórico (retrieved from http://historico.oepm.es/bopi.php) and to Ministerio de Industria, Comercio, Turismo. Oficina Española de Patentes y Marcas, O.A. Archivo. Fondo Histórico, P7506 (MICT).

11 Marsá Prat, "Improvements to Reinforced Concrete Beams." BOPI, No 1290–1293, 138.

12 Marsá Prat, "Concrete Beam." BOPI, No 1407, 5100.

13 It is characterized by having a linear configuration, like all beams, but its ends are designed according to a specific shape in the area where they come into contact with the walls or points of contact of the building (hatched area of the figure), from where cables or a similar component come out and are embedded in the ends of two straight arms that divide the beam into three equal parts. The ends of the beams are rounded in the points of contact and the bases of the arms are reinforced for supporting purposes, forming two obtuse angles with the main body of the beam. Marsá Prat, "Concrete Beam." BOPI, No 1383, 9148.

The request for patent ES 14733[14] (fig 1D), another concrete beam for construction, was submitted on 17 August 1946. This beam has an essentially linear configuration, with two ends that are rounded in the areas where they come into contact with the partitions or walls (hatched area of the figure). In the middle of the beam there are two converging arms, cut in a straight line at their connections that form, with the body of the beam, a hollow protrusion shaped as an equilateral triangle with two slightly curved vertices. The two ends of the beams are joined by a tensioning cable that is embedded in the aforementioned arms.

A few years later, on 24 July 1948,[15] Prat submitted invention patent ES 184693 (fig 2A) for a twenty-year registration in Spain. It was for "an enhanced roofing system for buildings and industrial warehouses that allows building external slabs".

The purpose of this invention was to create a system that made it possible to cover buildings and warehouses with a horizontal slab, which simultaneously facilitated the construction of external slabs. Essentially, the patent consisted of adapting, with the consequent technical modifications, beams based on model 13192. Thanks to the fact that the slabs could be cast on the ground and were lightweight, they could be easily elevated into place. Placed at an angle or horizontally, the slabs can support a layer of thin bricks ("rasillas") and roof tiles.

On 30 June 1949,[16] Prat proposed patent ES 188854, an "Enhancement of roof construction systems for buildings" (fig 2B). The scarcity and shortage of iron used in the manufacturing of beams for the construction industry was a serious problem, which constructors sought to address by manufacturing reinforced concrete beams. But, despite the fact that reinforced concrete beams allowed one to replace iron beams, concrete beams were not entirely satisfactory because of their large size. In order to bear the necessary loads, they had to have a considerable size which made them inconvenient. The purpose of Prat's 1949 invention was to build flat and gabled roofs for industrial warehouses or factories, with excellent stability. At the same time, a lightweight design ensured that they were easy to assemble. They were very cost-effective, both in terms of materials and construction costs.

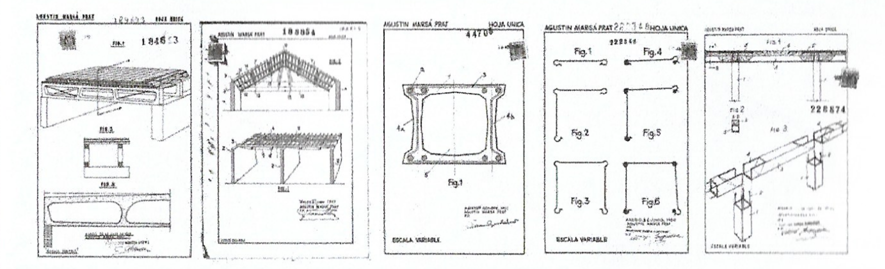
Based on the beams patented in ES 13291, Prat later completed a flat roof construction system for buildings. In the roof, the semi-circular ends of the beams are successively placed on the partitions or supporting walls; the top cordon or core of the beams supports compression, while extension is absorbed by the tensioning cable that connects the trusses or king posts to each other and to the ends of the beams.

14 Marsá Prat, "Concrete Beam for Construction." BOPI, No 1440, 1575.

15 Marsá Prat, "An enhanced roofing system for buildings and industrial warehouses that allows building external slabs." BOPI No 3236/47, 3524.

16 Marsá Prat, "Enhancement of roof construction systems for buildings." BOPI, 3687.





A B C D E

Figure 2. (A) ES 184693. (B) ES 188854. (C) ES 004 47 05. (D) ES 022 23 48 (E) ES 022 88 74. (Source: Ministerio de Industria, Comercio, Turismo. Oficina Española de Patentes y Marcas, O.A. Archivo. Fondo Histórico, P7506.)

On 8 July 1949,[17] Pratt proposed a "Roof construction system for buildings" that used his previous beam constructions: patent ES 188989 (fig 3A). The system eliminated the need for iron beams in roofs, which were expensive and difficult to acquire at that time. The system was based on the use of reinforced concrete beams with a polygonal metallic brace, which perfectly absorbs both compression and traction, enabling the construction of highly resistant, lightweight roofs with a graceful design and a striking aesthetic. Its production costs are minimal, because it allows for significant savings in terms of materials, both concrete and metal, it is simple and requires little unskilled labour.

On 7 November 1952[18], Prat proposed patent ES 020 61 81 (figs 3B, 3C and 3D). He had previously patented it in Switzerland, and asked that the Swiss patent of 26 December 1951 should secure priority for the Spanish claim. The patent was for "a construction system for gabled roofs." The framework consisted of reinforced concrete beams with trusses facing downwards and reinforced with braces (either a steel cable or a steel rod). Depending on the length of the beams, they had one or more trusses, one or more tensioners. The system was characterized by the fact that roofs were made from a series of consecutive frames consisting of two straight reinforced concrete beams placed at an angle, joined at the top vertex, and whose lower end rests on the building's walls; the lower ends are joined by a steel brace or rod with, at least, one tensioner. Because each beam has at least one truss facing downwards and the two ends of each of the two beams that form the framework are attached by braces that are also attached to the king post(s), they resist bending. At

17 Marsá Prat, "Roof construction system for buildings." BOPI, 3692.

18 Marsá Prat, "A Construction System for Gabled Roofs." Found in MICT.

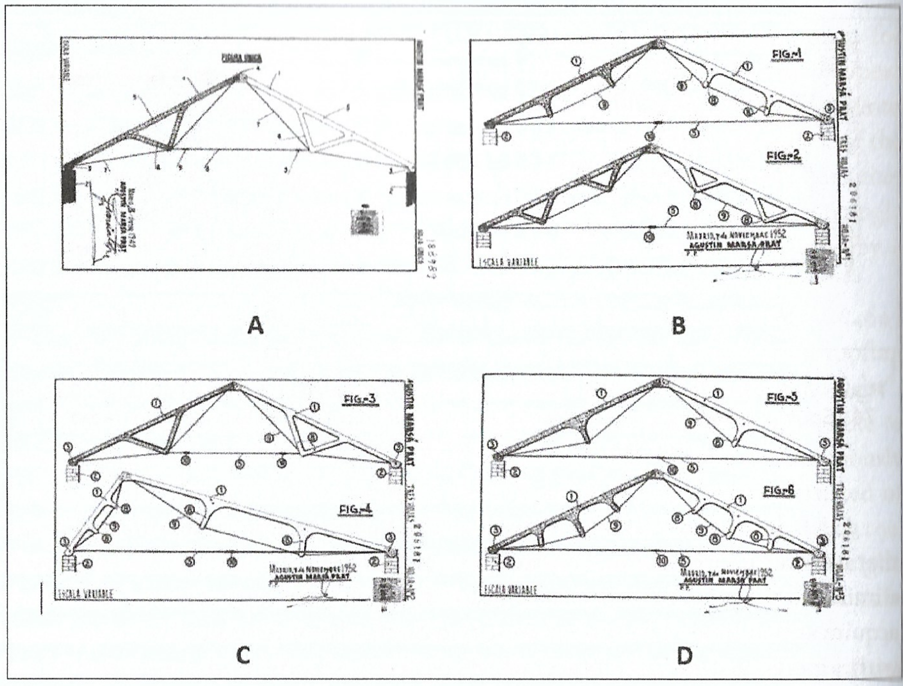


Figure 3. (A) ES 188989. (B) ES 020 61 81. (C) ES 020 61 81 (D) ES 020 61 81 (Source: Ministerio de Industria, Comercio, Turismo. Oficina Española de Patentes y Marcas, O.A. Archivo. Fondo Histórico, P7506.)

the same time, the horizontal brace that fastens the lower ends of the beams absorbs the load from the horizontal thrust of the framework's expansion that would otherwise be transferred to the walls.

On 29 October 1954, Agustín Marsá Prat proposed a new patent – ES 004 47 05 (fig 2C). In this case, the patent was for a hollow beam and thus different from all the other structures he had patented before. Presumably, it consisted of prestressed concrete (the first time he used this), because the expression "steel tensioners" is used in the text.

Hollow reinforced concrete beams are characterized by having two horizontal flat surfaces – top and bottom – and two vertical side walls formed by two double-T beams reinforced with steel tensioners. The four sides are connected by wire spirals that surround the four external tensioners, forming a rigid whole with a large central hole.[19]

Despite this attention to the beams, Prat was still working on reinforced concrete beam structures. On 10 June 1955, he requested patent ES 022 23 48 (fig 2D), which

19 Marsá Prat, "A Hollow Concrete Beam." Found in MICT.



was for a system for assembling frames used in reinforced concrete beams. The system was characterized by having elastic brackets with elastic eyelets that hold two bars together, joining them without the need for further fastenings.[20] This was advantageous because the system eliminated the need for handmade fastenings, which were labour-intensive.

Prat submitted his last patent, ES 022 88 74, on 30 May 1956. It was for an "enhancement of reinforced concrete structures", in this case also applicable to prefabricated concrete structures (fig 2E). Reinforced concrete structures here could use columns, main beams, beams or hollow beams (with an uneven interior cross section, which is smaller towards half of their length than at the two ends, in such a way that the nodes required to mould them have slightly conical shapes, with the tips to the inside and the bases to the ends).[21]

Prat's continued work on reinforced concrete beams and the improvements that were made to them over the years were an important technical innovation at the time, because the truss beams that were traditionally used in industrial warehouses were usually made of wood or metal. By figuring out how to replace them with concrete structures, Prat enabled "diaphanous spaces" to be built with a low-cost, lightweight reinforced concrete structural system, which required little skilled labour and had a striking aesthetic effect.

## The Innovativeness of the "Marsá" Reinforced Concrete Beam

In Spain, at the dawn of the twentieth century, traditional wooden roof-beams were gradually improved with metallic components. In the industrial architecture of the time it was common to find mixed roof-beams, i.e., roof-beams built with wooden truss beams and two connecting metal braces – a horizontal one, from end to end, and a vertical one connecting the middle of the truss to the ridge – and other solutions derived from this one. These structures could cover spans of up to 12 m and were widely used in the first half of the twentieth century.[22]

This building system evolved thanks to the introduction of a growing number of metallic components. Metallic roof-beams became increasingly common in the second half of the twentieth century. Ever since Baltard had built Les Halles (1851) in Paris, a new architectural and construction typology based on the use of iron and glass spread across Europe. In Spain, the first iron market buildings were inspired by Classical architecture and combined rounded metal arches with other materials such as stone and brick like in the old Linares market (fig 4).

20 Marsá Prat, "A System for Assembling Frames Used in Reinforced Concrete Beams." Found in MICT.

21 Marsá Prat, "Enhancement of Reinforced Concrete Structures." Found in MICT.

22 Castillo Martínez, "Sistemas constructivos de la industria azucarera granadina," 126.

Figure 4. Linares market (Jaén). Interior detail. (Photo by author.)

Braceless framework solutions started to be used by architects from the 1880s onwards: the Cebadas (1867–75) and Mostenses (1868–75) markets, built in Madrid by the architect Mariano Calvo Pereira, were inspired in the Parisian Les Halles building. Many markets were built in this period. Many have been destroyed, but fortunately, there are still some examples of markets with metallic roofs, including the "atarazanas" market in Málaga, the old Badajoz market, the Almería market, the San Miguel de Madrid market, or the old Born market in Barcelona.[23]

The new metal truss beams widely used in the industrial buildings designed in the late nineteenth and early twentieth century were initially reinforced with riveted plates. According to Castillo, this building solution was used for the first time in the Paris World's Fair in 1878.[24] The design of truss beams evolved with the introduction of angle brackets. Riveting was replaced by welding, and these components became increasingly common in new structures, especially among industrial buildings.

However, especially in the aftermath of the Spanish war years, which coincided with the post-World War II period, steel was difficult to obtain. This shortage was the driving force behind the search for new building solutions. Reinforced concrete, prefabricated reinforced concrete, and prestressed concrete were being increasingly used. In this context, it is worth highlighting the important work developed by

23 Palomares Alarcón, "Arquitectura, materiales y mercados en Andalucía (s.XIX)."

24 Castillo Martínez, "Sistemas constructivos de la industria azucarera granadina."



Agustín Marsá Prat and his patents for reinforced concrete beams, a mixed structural system in which, instead of using wood and steel, he used reinforced concrete and steel.

## The Use of "Marsá" Reinforced Concrete Beams In the Roofs of Industrial Buildings Related to the Agri-Food Sector

The "Marsá" reinforced concrete beam was widely used from the 1950s onwards in industrial buildings related to the agricultural sector[25] in Spain, especially in the network of silos and warhouses managed by the SENPA ("Servicio Nacional de Productos Agrarios", or National Agricultural Product Service)[26] and in the olive oil regulating warehouses managed by Patrimonio Comunal Olivarero.[27]

The network was developed after the creation of an entity called "Servicio National de Trigo" (National Wheat Service) in 1937, which was governed by the "Comisión de Agricultura y Trabajo Agrícola" (Agriculture and Agricultural Work Commission) of the "Junta Técnica del Estado" (Technical State Board). It was supposed to meet the following conditions: a) make it possible for farmers to purchase wheat and store it in warehouses built in strategic locations across the production areas, usually in the innermost regions of the peninsula; b) set aside a national reserve at the end of each campaign, storing the quantity deemed necessary to offset part of the initial shortages caused by a poor harvest in the following campaign.; and c) make it possible to receive imported wheat via our ports in years of shortage or to ship special types of wheat and even surpluses, in years in which harvest exceeds the existing consumption needs.[28]

The "Servicio Nacional de Trigo" (National Wheat Service) launched its first design competition for the construction of a Silo and Granary Network in 1941, but the General Plan for the National Silo and Granary Network was only prepared in 1945. It initially proposed the construction of 437 silos and 631 granaries[29]. Between the inauguration of the first silo in Cordoba, on 6 June 1951, and 1968, a total of 511 silos and 272 granaries were built across the entire Spanish territory in twenty different styles.

25 Ayuga Téllez, "Evolución de la edificación agraria en La Mancha," 39.

26 "Project for a grain silo with a capacity for 140 wagons in..." 1952, Fondo Español de Garantía Agraria. (F.E.G.A). General S.E.N.P.A. Archive.

27 Luis Patac de las Traviesas, "Standard project for an olive oil regulating warehouse with a capacity of 5,000,000 kg". January 1954. Fundación Patrimonio Comunal Olivarero - Sindicato Vertical del Olivo Archive.

28 España. Ministerio de Agricultura, Pesca y Alimentación, 'Reordenación y redimensionamiento de la red de silos del SENPA', Gabinete Técnico del Servicio Nacional de Productos Agrarios, Madrid, 1994.

29 Cavero Blecua, *Ponencia sobre la Red Nacional de Silos en España*, 5-6.

Different types of silos were designed and built in Spain: a) reception silos and warehouses, which were intended to quickly absorb the grain in production areas and store it until it was sold or transferred to transit or port silos; b) transit or reserve silos, which had more capacity than reception silos and were located in important railway hubs in production and consumption areas – these received large quantities of wheat, regulated the traffic along the main lines and accumulated wheat to form reserves; and c) port silos, which were located in port areas to allow unloading the grain from boats and storing it and transporting it by railway or truck to the innermost regions or vice-versa.[30]

These buildings were strategically located, taking into account the capacity of existing railway lines and road junctions and the location of the closest production areas.[31]

According to a design project amended in 1952, "for a grain silo with a capacity for 140 wagons," the first silos to be designed were reception silos (type A). Each silo consisted of a vertical warehouse with square cells (most of them elevated) with a variable capacity, i.e., a basic silo had a capacity of 950 Tm (A1), which could be expanded module by module up to a maximum of 3,950 Tm (A4). These silos were designed according to a standard adapted to different locations. Sometimes, the final blueprints were amended to include changes that had been made during the construction process.

Selection warehouses were built next to one of the sides of the silos. They were 11.50 m wide and used to accommodate selecting machines. Their roofs were mono pitched or gabled and made of solid bricks covered by half round tiles on a double layer of thin bricks ("rasillas") supported by "Marsá" truss beams,[32] mentioned explicitly in the design project. According to E. Rodón, these truss beams consisted of two prefabricated half truss beams that were joined at the ridge and "closed" with a bottom brace. They were placed parallel to each other, at short intervals of about 1.00 m, so there was no need to use purlins (horizontal beams that provide intermediate support for the rafter of a roof). They were also known as "concrete truss beams with braces" because the iron tensioners dealt with traction while concrete dealt with compression.[33]

This design is included in Spanish patent ES 020 61 81 and could be used to cover spans of up to 13 m. The beams called for in the specification had two arms coming out of them every 2.10 - 2.05 m and were usually placed one by one, although they could be placed in twos, as in the case of the Linares silo's selection warehouse.

30 Ministerio de Agricultura, *Servicio Nacional del Trigo.*

31 Salamanca Cascos, *Los gigantes del siglo XX.*

32 Palomares Alarcón, "Pan y aceite: Arquitectura industrial en la provincia de Jaén," 138.

33 Rodón, *Tratado de construcción: lo que debe saber el proyectista,* 176.



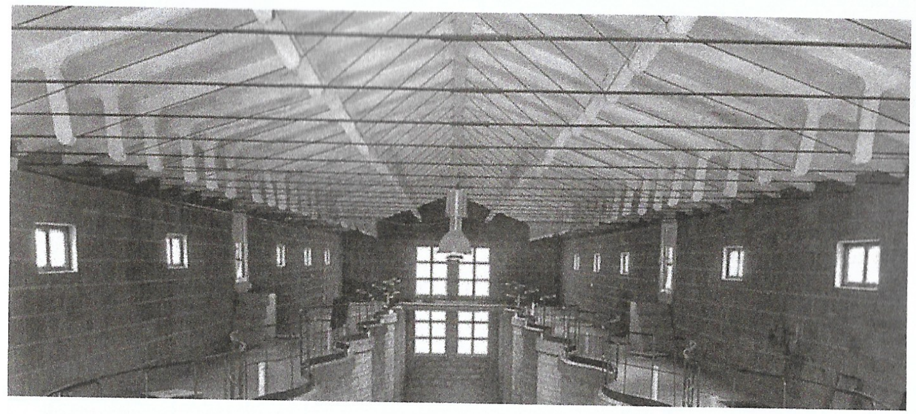


Figure 5. Beas de Segura olive oil regulating warehouse. (Jaén). Interior detail. (Photo by author.)

The "Patrimonio Comunal Olivarero" olive oil regulating warehouse network built 14 units between 1945, when the network was launched and the Lucena warehouse (Cordoba) was inaugurated, and 1969, when the Pinto warehouse was built.

It contained three types of warehouses: the ones built in the first phase, which had underground tanks; the ones built in the second phase, which had elevated tanks, and the ones built in the third phase, which had both metallic elevated tanks and half-buried tanks.

The elevated tanks used "Marsá" truss beams as part of their roofing system. (fig 5.) There were seven elevated olive oil tanks: Jaén (destroyed), Linares, Beas de Segura, Martos, Antequera, Atarfe and Villafranca de los Barros. Warehouses were designed by the agricultural engineer Luis Patac de las Traviesas in 1954, commissioned by "Junta del Patrimonio Comunal Olivarero."[34]

This engineer designed the "Standard design project for an olive oil regulating warehouse with a capacity of 5,000,000 kg to be built in towns across the province of Jaén." The configuration of the warehouses that were actually built depended on whether or not they were located in production areas, their proximity to the ports via which olive oil was usually received or delivered and the gravitational hubs of the consumption areas.[35] Initially, the tanks were designed to be arranged in two buildings, with a total of 108 tanks, but there were variants, for example, in the Linares warehouse, where the two elements were merged into a single building with 106 tanks.

The gabled roof of each industrial warehouse covered every two rows of nine cells; it had a slope of 19°18' and was clad with flat tiles. The walls that bore the load of the roofs were built along the axes of the cells and were three meters high.

34 Palomares Alarcón, "Arquitectura industrial agroalimentaria."

35 Palomares Alarcón, "Pan y aceite: Arquitectura industrial en la provincia de Jaén," 251.

The same truss beams (ES 020 61 81) were used in all the warehouses except for the Martos olive oil regulating warehouse. but in this case, it was designed to cover a span of 8.45 m.

Research was carried out using the documents associated with the patent requests submitted by A. Marsá and kept at "Ministerio de Industria, Comercio, Turismo. Oficina Española de Patentes y Marcas, O.A. Archivo. Fondo Histórico. P7506". The information did not detail specific construction-related aspects; it didn't say anything about the manufacturing process of the beams, whether the ES5778 and ES13192 were made of prestressed or poststressed concrete, or the maximum loads they could bear.

The architectural projects for SENPA silos or Patrimonio Comunal Olivarero olive oil regulating silos, include the representation of truss beams, but not the technical specifications that could give us more information about how they were manufactured.

## Conclusion

In short, prestressed concrete was a new material that offered architects specific advantages, particularly when combined with prefabrication, but also without it. The new material had undeniable advantages in certain well-defined fields of application areas. Yet this did not mean that it would necessarily replace reinforced concrete, which was always be the most appropriate material in certain cases, as steel, brick or masonry were in other cases. It is the same phenomenon that so often happens in the industry; cars have not eliminated carriages, and airplanes have not reduced the number of cars; but you can neither use carriages to move fast, nor cars to fly.[36]

Prat's reinforced concrete beams were an important technical innovation in the field of technique and construction, because they reinterpreted the traditional metal truss beams to create a new mixed structure that allowed saving steel, which was very difficult to obtain at the time in Spain. They had a specific aesthetic and were valuable for covering long spans.

In the last century, these innovative mixed truss beams were used in Spanish industrial buildings in a variety of different sectors, such as the mining industry, despite being more commonly associated with the agri-food sector. In the SENPA silos or in the Patrimonio Comunal Olivarero olive oil regulating silos, these designs have managed to last for more than sixty years.

Future research will shed light on the manufacturing process of the beams, as well as exploring why they went out of production.

36 Torroja, "El hormigón pretensado y sus campos específicos de aplicación," 25.



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