RAFAEL GUASTAVINO MORENO
Inventiveness in 19th century architecture

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In memory of my father, Pere Rosell i Millach

RAFAEL GUASTAVINO MORENO
València, 1842 – Black Mountains, North Carolina, 1908

Key words: architecture, industrial architecture, cement, construction, cohesive construction, iron, brick, flat brick masonry, master builders, *Modernisme*, fire resistance, vaults.

The contribution of Valencian Rafael Guastavino Moreno to Architecture was especially important in the technical area. He was the leading moderniser of an ancient building technique using flat brick masonry techniques, above all to erect vaults.

Guastavino would later transfer these techniques from Catalonia to the United States of America, where he founded a family company that built, over two generations, more than one thousand buildings, many of them of great importance.

These two accomplishments represent a notable contribution to contemporary Architecture: more so if we take into account a series of technological reflections and proposals that also constitute a contribution to the modernisation of construction, insofar as they entail an effort to understand the behaviour of and ways in which the new materials worked.

All this, which would come to fruition in America in the late 19th century, had begun twenty years earlier in Catalonia in the 1870s, such that when Guastavino arrived in New York he had already grasped the fundamental ideas and to a large extent put them into practice. Subsequently, the echo of his professional success and the fortune of the transferred technique would have, and today perhaps still have, an invigorating effect on Catalan architectural culture.

1. From València to Barcelona

Rafael Guastavino i Moreno was born in València on 1st of March 1842, the fourth of fourteen children of Pasquala Moreno and Rafael Guastavino i Buch. His father was a cabinetmaker and had moved to València from Barcelona. Half a century earlier, in the late 18th century, his grandfather, Davide Giuseppe Guastavino, had arrived in Barcelona from Italy (near Genoa), where he married and settled (Guastavino, 1970).

As a young man in València, Rafael wanted to be a musician and played the violin, but took an interest in Architecture after meeting the Inspector of Public Works, Josep Nadal, and joined his office as a draughtsman. Nonetheless, he retained his love of music, as can be seen in his later writings, where, from time to time, he draws

comparisons between music and construction. Upon the unexpected death of Josep Nadal he decided to move to Barcelona to pursue studies, living at the home of an uncle (Guastavino, 1970).

In Barcelona, in 1861 he enrolled in the *Escola Especial de Mestres d'Obres*, master builders' school, and while studying reportedly worked as an engineer's assistant at a foundry (Anonymous, 1898) and at the Granell & Robert architectural studio (Wight, 1901). Shortly thereafter he married Pilar Expósito, fathering three children in five years, and began working on his own (Guastavino, 1970).

At the end of the 1861-1862 academic year at the Master Builders' School of Barcelona, Professor Elies Rogent's students dedicated this photograph to him. Rafael Guastavino i Moreno, age 19, is sitting on the floor in the front row, the second from the left. [Source: Arxiu de la Càtedra Gaudí, Barcelona]

Guastavino continued his studies at the *Escola Especial de Mestres d'Obres* until 1864 (Guastavino, 1892) and during the 1863-64 academic year also attended classes in History and Theory of Fine Arts at the *Acadèmia Provincial*. The information we have about this time leads us to believe that he did not manage to complete his studies (Bassegoda, 1993), although he obtained his diploma, most likely taking advantage of the Royal Decree of 29 May 1871 (in response to the closing of schools at the time), given that we find him registered at the *Centre de Mestres d'Obres* of Barcelona, and that he worked as a builder.

The years of Guastavino's stay in Barcelona cover the entire period known as the *Sexenni Democràtic* (1868 to 1875) and early *Restauració Monàrquica*. Throughout those years his professional activity was notable, as evidenced by the commissions he received from prominent property owners: residential buildings he designed or built in elegant parts of the city, as well as the respectable number of industrial buildings he took part in –all told, a good indication of his integration in the social and economic fabric of Barcelona.

2. Works in Barcelona

Guastavino practiced his trade on two fronts: the more architectural tasks, commissions to design buildings and presenting projects for competitions; and his work as a builder, building the works designed by himself and by others, won through bidding. These two facets, architect and builder, were often combined.

Laid out systematically, following are the details we have been able to gather regarding the works by Rafael Guastavino during his period in Catalonia, in the certainty that in the future they will be completed and added to:

1866	4-storey residence in the Eixample district of Barcelona.
1868	5-storey residence for banker Victor Blajot, still standing in Passeig de Gràcia, current no. 32.
1868	Factory for the Batlló brothers in Les Corts de Sarrià, now part of the Escola Industrial complex.Two buildings, the taller one 4 storeys, called l'*Eix*, built with wooden beams and flat brick vaults, with a large stairway with pendentive vault; and the other, partially underground, one storey, the former loom room, with iron beams masked by brick arches supporting flat brick vaults. In addition, the 60m-tall octagonal brick chimney.
1868	Monument to "La Gloriosa", with notable lighting, in the Plaça Nacional (now Plaça Reial).
1871	Fàbrica Vidal i Fills. Factory with flat brick vaults over wooden beams.
1872	4-storey residence for himself, at the corner of carrer Llúria and carrer Aragó, with flat brick vault floors. Portland cement imported from England was used.
1872	Casa Camil Julià at Passeig de Gràcia, no. 150/2, rebuilt a few years ago.
1872	Casa Miquel Buxeda.
du	Casa Pau Montalt.
du	Palauet Llorenç Oliver in Passeig de Gràcia.

du	Mitjans i Cia. wool mill.
du	Fàbrica Martí i Rius, factory in carrer de la Lleialtat in the Sant Martí de Provençals district, two storeys, with 3m-span flat brick vaults over main beams.
1874	Competition for the monument to the Heroes of the African Campaign of 1860.
1875	Blanqueria Muntadas, Aparicio i Cia., tannery with flat brick vaults over wooden beams.
du	Modest Casademunt glass factory.
du	Florensa i Cia. porcelain factory.
1877	Magatzems Grau in Barcelona, warehouse with flat brick girders with 5.80m span and flat brick vaults.
1877	One-storey residence for Josepa Elias in carrer Nàpols, probably never built.
1878	Carreras i Fills wool mill, with iron beams and flat brick arches and vaults.
1878	Casa Modest Casademunt at carrer d'Aribau no. 3, still standing.
1878	Residence for the banker Andreu Anglada.
du	Fàbrica Rosic.
du	Saladrigues silk factory.
1879	Casa Edmond Sivatte in carrer d'Urgell.
1880	Theatre for the "La Massa" cultural centre in the town of Vilassar de Dalt, with a flattened dome nearly 17m in diameter. Cement from Dr Montestru de Tardienta was used.
1880	Casa Mumbrú in the district of Sarrià.

du Date unknown

Unless otherwise specified, all buildings are located in Barcelona.

Evidence of Guastavino's renown is found in the presence of his works alongside those of the top professionals of the time at expositions and competitions. We know, for example, of his participation at the Exposition of Agriculture, Industry and Fine Arts in 1871, held at the "new building" of the University of Barcelona (where he presented the Blajot, Julià, Montalt and Oliver buildings) (Catálogo, 1871). We also know that in 1873 Guastavino's work was on display at the World Exposition of Vienna (Exposition, 1873). In 1876 the *Centre de Mestres d'Obres*, the records of which show him as an "active member" from 1874 to 1877, held a large exposition including his works (Buxeda, Blajot and Oliver buildings, and "Casa del Jardinero"). And, finally, we know that in 1876 as well a sample of his works was shown at the Philadelphia Exposition commemorating the centennial of the United States (Bassegoda, 1976), an event to which we shall return later.

Rafael Guastavino's standing in Catalan society is evident in his being elected in 1873 to the jury that was to award the construction of the façade of the Barcelona cathedral (Bassegoda, 1993). And when the Economic Society of Friends of Catalonia awarded him the certificate of honour for his work as a member of the Organising Committee of the Spanish Maritime Exposition of 1872 (Bassegoda, 1993). As well, we should point out the inclusion of a number of the residences he built in architectural publications of the period (Nacente, 1888; Rogent/Domènech, 1897).

3. Catalan Architecture in the 1870s

The *Escola Especial de Mestres d'Obres*, where Guastavino had enrolled in 1861, was the only institution in Barcelona that offered degree studies in Architecture and building at that time, and had been established in 1850, along with the liked-named school in Madrid, as part of the modernisation programme for education in Spain (Montaner, 1983).

In fact, in the field of Architecture, this programme had already begun in 1844 with the founding of the *Escuela Especial de Arquitectura* in Madrid, along the same lines as the *École Polytechnique* of Paris, introducing the cultivation of building technologies and the study of history as the most notable additions with respect to the schools that had been granting diplomas in Architecture since the 18th century (Montaner, 1983).

Following this line of reform, and perhaps with a more practical intention, the master builders' schools were opened, of which Madrid was dependent upon the same school of Architecture, and Barcelona, given that there was no school of Architecture here, depended upon the *Acadèmia Provincial de Belles Arts*. Thus the majority of students in Barcelona became master builders and, those who wished to attain a degree in Architecture had to go to Madrid to complete their studies.

In the 1860s, burgeoning activity in Barcelona and, above all, new expectations in the building sector weighed upon the university environment that grew out of the reforms of the "Moyano Law". The old city had just torn down its walls and was poised to invade the surrounding agricultural land, as approved in the project by Ildefons Cerdà. The single-family dwelling, and above all residential property to let – which was emerging as a profitable business– called for a profound renovation of Architecture. By the same token new building techniques would be required, more modern, more rational, quicker and cheaper than those employed until then in the old city: techniques that would have to be based above all on the use of new materials: brick, cement and iron.

The renovation of Catalan Architecture was, then, to a large extent in the hands of the new graduating classes of master builders coming out of the *Escola*,

which in 1870 became a polytechnic school and later a school of Architecture (Montaner, 1983). Among the promoters of architectural renovation were two of Guastavino's professors, master builders themselves and architects with diplomas from Madrid. They were Elies Rogent i Amat (Hereu, 1987), one of the foremost figures in the Catalan Architecture of the second half of the 19th century, and Joan Torras i Guardiola (Cabana F./ Feliu, A. 1987), known as the "Catalan Eiffel", and a steadfast supporter of technological modernisation. Both were repeatedly recognised by Guastavino as inspirers of his ideas.

This will for change, seen inside and outside the *Escola*, found its ideological support in the faith in science as the generator of progress, in the assumption of the model of Nature as an object of imitation, and in the belief in invention: in discoveries that would lead to a new building tradition, one that would be useful in advancing along the "path of modernity". One chapter of this renovation is that which Guastavino foresaw, and to which he would devote, until the end, his work: the renovation of flat brick masonry techniques.

Flat brick masonry techniques, that is to say, all building solutions that the building worker executes on the basis of laying brick and tiles –always joined at the edge– had a long history in building in the Mediterranean area. The vault is the most spectacular and best know version of these techniques. In Catalonia, as early as medieval times, brick had replaced flat stone in the vaults of churches, perhaps for economic reasons (Bassegoda, 1936). Even if it could support only its own weight, given its lightness (generally two layers of tile called *senzillat* and *doblat*) the strength of the flat brick vault was an inexplicable phenomenon, a mystery.

Flat brick masonry techniques have always based their success on four factors: 1) Only common, low-cost materials are required; 2) In the case of vaults, centerings are not needed; 3) The execution process is extraordinarily simple for a craftsman who knows the trade; and 4) The technique is highly versatile and applicable to many building solutions.

In monumental buildings, flat brick vaults with minor loads had been used continuously since the Renaissance. In the 19th century, however, flat brick masonry was used mostly in places of low static risk: inter-beam barrel vaults, stairway vaults, floors. Flat brick masonry as a technique was associated with plaster, given that the difficulty of fixing the tiles in that manner required a conglomerate that would hold rapidly, immediately. But plaster, lacking the required strength, had no future and thus in flat brick masonry technique was part of the tradition in need of replacement.

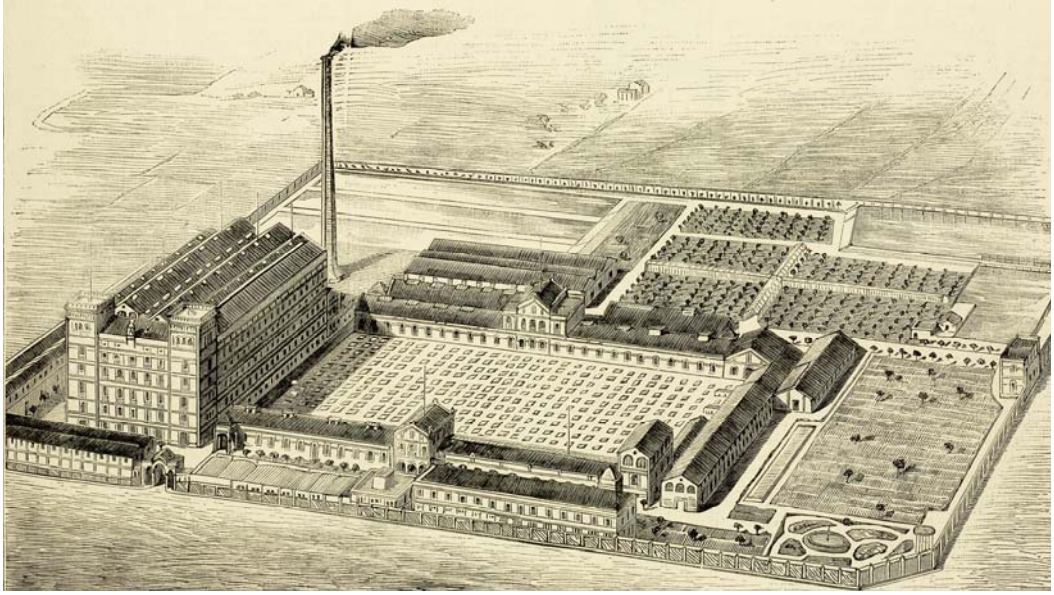
4. Guastavino's contribution

It was Guastavino's foresight to associate flat brick masonry with modern cement, available on the market since the 1850s, in order to combine the ease-of-handling of the technique with greatly increased strength, necessary for modern building. The tiles, solidly joined together with the new material, now possessed extraordinary strength just a few hours after being laid. In this way it would be possible to span easily large spaces and at the same time sustain the heavy loads required for modern residential and industrial buildings.

The testing ground for this intuition were the factories of Barcelona industry to be built in the 1860s. Indeed, in Barcelona many ageing industries found it necessary to abandon the confined spaces of Ciutat Vella, the old city, (Guastavino, 1892) and move to the districts of the Eixample or Sant Martí de Provençals. The floors of the new buildings were not made with wooden planks, but with masonry, imitating the English, in order to increase load-bearing capacity and fire resistance. The problem of fire was increasingly important, and insurance premiums rose considerably the more flammable the building materials. In this new way to build factories, the flat brick vault –and not with the bricks on edge as in England– in Guastavino's modernised form, played a major role, and thus Catalan factories became a genuine type of industrial Architecture. In just ten years, during the 1870s, 75% of the factories of Barcelona were modernised on the basis of flat brick masonry structures. In 80% of the cases these vaults were supported by wooden beams, and iron beams in the remaining 20%, the reason being that structural wood was considered a slow burning material, while an iron structure would collapse rapidly (Guastavino, 1892).

The construction of the Batlló factory, which caused quite a stir, was the beginning of this long and peculiar experience, still little known due to the lack of documents and buildings. At this point we can safely say that Guastavino also built with flat brick masonry: the Vidal i Fills factory, the Martí i Rius factory, the Muntadas, Aparicio i Cia. tannery, the Grau warehouse, the Carreras i Fills wool mill and the theatre of Vilassar de Dalt. Of the other factories and buildings we haven't the information to state in detail the characteristics of their construction, but we are convinced that in time we will be able to expand the list of works built with vaults, in the same way that we will be able to complete our knowledge of other aspects of Rafael Guastavino's endeavours in Catalonia. Then it would be necessary to add all those works of similar characteristics that he might have inspired.

Referring to the modern-day use of this traditional technique, Guastavino himself stated that 95% of the architects and 99% of the builders of his time had never heard of it (Guastavino, 1892). This confirms him as the originator of its renovation.



View of the Batlló factory complex as it was originally built in 1868. The 5•storey building at the left was the spinning mill and stands next to the sprawling semi underground weaving mill. [Source: print from the photo archive, Construccions Civils, Diputació de Barcelona]

Of course Rafael Guastavino was not alone in this endeavour. Evidently, given a traditional technique, a generalised will for modernisation and the historical opportunity presented by the renovation of the industrial building stock, we must assume that others were involved. As positive proof we might point out the similarity between the floor proposed by Guastavino –based on flat brick barrel vaults supported by a sort of flat brick membrane beams, in the shape of a superficial lune, over an iron plate (Guastavino, 1892)– and the floor that Joan Torras i Guardiola is said to have proposed around the same time (Bassegoda, 1910). Nonetheless no one can doubt that Guastavino, who devoted himself heart and soul to the system, was the driving force behind its popularisation. Indeed, the Batlló factory and what has been written about it later provide proof of his leading role as a moderniser of the flat brick masonry techniques.

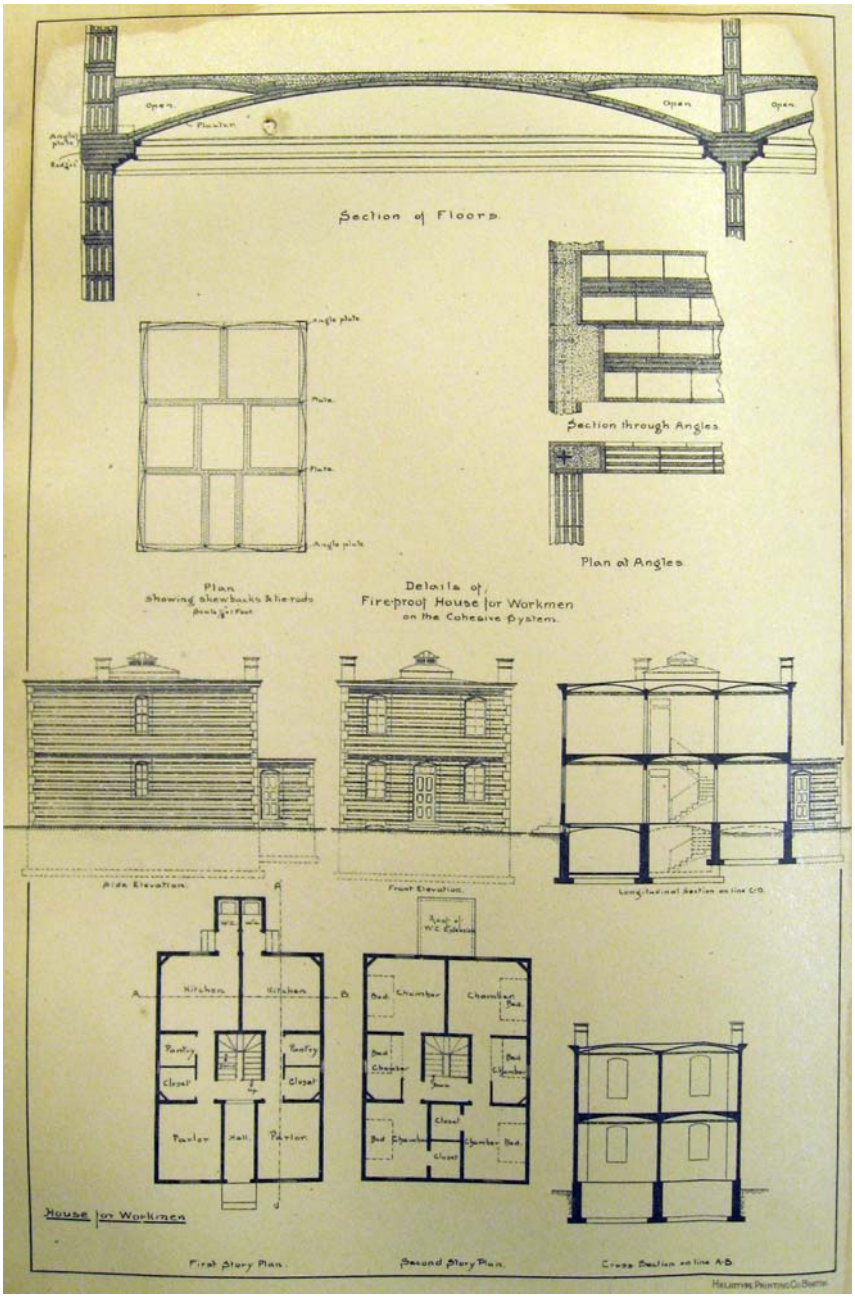
As Guastavino himself would later explain, on the visit he made in 1871 to the stone monastery of Muntadas he found himself before a great natural cavern –"of a single piece!"– carved out of the rock by the river Jalón. And that helped him understand the philosophy that he would call "Cohesive construction". Guastavino subscribed to Joan Torras's claim that the work of the architect of the future would be based on the imitation of nature. Finding support in history and wholly in keeping with organicist thought –two attitudes that took root strongly in 19th-century culture– he proceeded to formulate a theory and doctrine in defence of building with flat brick

masonry. His mind began to take wing and his great intuition would take him so far as to conceive of converting the technique employed in the vaults into a universal technique, into a new building system.

This brings us back to the Philadelphia Exposition. From Barcelona Guastavino sent there in 1876 a number of plans for his buildings to be displayed jointly with a special proposal entitled "Improvement in Public Health in Industrial Cities" and which represented the practical application of what Guastavino called "Tubular Construction". This tubular construction consisted in applying flat brick masonry technique to the walls of buildings, in addition to the floors, thus erecting hollow walls, which in addition to their lightness and strength, would ensure insulation and ventilation. Guastavino proposed Tubular Construction as a new system for building entire cities –like those theorised by the engineer Ildefons Cerdà, and which, in the same period, 1859, the latter had recently proposed for Barcelona: an idea in line with the more advanced currents in hygiene and public health, aimed at improving the quality of life for workers in industrial cities.

But time and again Guastavino complained of the lack both of the means to get his projects off the ground and of popular acceptance of the mystery of the vault. The quality of Spanish-made materials, above all the cement, was irregular, while it was impossible to establish acceptable means to establish a general theoretical framework for the system. There were no testing instruments. There was not, said Guastavino, even technical literature on building with flat brick masonry. An exception among the texts of the time was a booklet referring to the old brick masonry vault published in Madrid in 1776, a translation by Joaquín de Sotomayor of a work that Count de l'Espie had published in France in 1754. The contents of *Modo de hacer incombustibles los edificios sin aumentar el coste de su construcción* would lead us to believe that this text had likely lit the way. But nor are we talking about a scientific publication.

For his "Tubular Construction" proposal at the Philadelphia Exposition Rafael Guastavino received a bronze medal in absentia. His thoughts now turned to that vast, new country, the United States, at a time when "to do the Americas" was, in Catalonia, a rather popular alternative.



What Guastavino called "tubular construction" was system of brick frames and ceilings reinforced with iron, intended for large-scale building projects for new towns. The figure, which shows worker's dwellings, was part of a proposal. "Improving the Healthfulness of Industrial Towns", presented by Guastavino at the Philadelphia Exposition of 1876. [Source: *The American Architect and Building News,* Boston, 22 February 1890]

5. From Barcelona to New York

Throughout this time Rafael Guastavino's personal life had run into a number of difficulties. The first five years with Pilar Expósito had seen the birth of three sons, Josep, Manuel and Ramon, but their marital relations weren't going well and in the early 1870s the couple separated for the first time, for two years. Once they had overcome the crisis, Rafael and Pilar conceived their last son, Rafael, born in 1872. But the definitive failure of their marriage wasn't long in becoming evident. In February 1881 his wife and three elder children immigrated to Argentina; on the 26th Guastavino and young Rafael sailed from Marseille, for New York.

We don't know if the reasons behind his leaving were fundamentally personal, of which the marital problems were an example, or, as other sources have claimed (Goday, 1934), the reasons were financial, which would not have been surprising in a person devoted to business and with his head full of architectural ambitions. And why not a combination of the two? In any event we should add those reasons relating to the faith Guastavino had in the scientific and economic potential of the East Coast of the States, which was to permit him to realise his professional dream.

When he arrived in the United States, with his son, his housekeeper and her two daughters, Guastavino had forty dollars in his pocket and spoke barely a word of English (Collins, 1968). New York was a chaos, everything was under construction, the Brooklyn Bridge, Uptown... Manhattan, teeming with crisscrossing steam trains, was being transformed. The streets were flooded with people and a tangle of suspended wires darkened the sky. Local customs differed greatly from Europe: chew tobacco, drink whisky and gin, no wine or olive oil (Guastavino, 1970). Logically, his adaptation would not be easy.

6. The encounter with American Architecture

When Guastavino arrived in America, buildings, even in the cities, were mostly executed in wood, following the tradition begun with the *balloon frame* and *platform* systems, modern adaptations of the wooden construction brought to America by the European first colonists. Wooden buildings, however, had a large drawback in their flammability. It was only ten years since Chicago had burnt, and fires continued to be a fact of everyday life. And while just a few decades earlier iron –cast iron– had emerged as the great hope, by now it had been shown that, in the event of fire, iron buildings collapsed more quickly than wooden buildings.

On the other hand, in the 1870s the architect Henry Hobson Richardson had popularised in the US medieval revival, neo-Romanesque and neo-gothic Architecture

based on large vaults. These vaults, in the majority of cases, were made of plasterboard or plaster, similar to flat suspended ceilings, due to the lack of any tradition in stone or brick construction and the high cost of building in the traditional system with bricks laid on edge. St Patrick's Cathedral of New York, for instance, had been built with "vaults" of papier mâché. Later, after Richardson's death in 1886, when Guastavino set to work in earnest, medieval revival Architecture entered into decline: yet the need for vaults, rather than wane, grew, as a reaction emerged in favour of neoclassical Architecture. This tendency, which would be hegemonic until the outbreak of the First World War, meant a great demand for domes and required, all the more so, solid construction.

Guastavino saw in this conjuncture the great chance for America to adopt the European building system, using stone or brick, and, thus, to propose, as a real and competitive alternative, what he called Cohesive Construction. But, what was cohesive construction? The theoretical formulation that Rafael Guastavino set out over the years went more or less as follows:

Architecture is art and it is construction. Of course, when the theory is separated from the practice –as was occurring– the loss in quality was notable. Thus a reform was required of the training of both architects and building workers to bring them together in the same academic environment. The objective would be to build once again decoratively, that is to say that beauty should be the logical result of structure.

And he went on: The first Architecture was that of the Egyptians, which he called gravity because the material –the stone– performed in function of its weight. That Architecture had its heyday in the classical Greek period. Afterwards, the Romans invented a new Architecture, which is what Guastavino called "cohesive" because the materials –using mortar– performed in function of their capacity to remain intimately joined, like the conglomerates in nature; but the exterior covering in this Architecture was not authentic, rather it was borrowed from the Greeks, and therefore this Architecture was imperfect. Later on, Rome, and then Byzantium and above all Islam, would notably improve cohesive Architecture based to their use of brick. But then came the decadent period of the Renaissance and cohesive Architecture was never to reach its prime, as gravity Architecture had in Greek times. To bring cohesive Architecture to its prime, then, was the challenge of the times. (Guastavino, 1892).

Thus, following Guastavino's thinking, there are two forms of cohesive Architecture: that based on the use of mortar –Roman before Augustus– and that based on the use of brick and quality cement –also Roman, but after Augustus. The chronology and the importance of these events were based on the recent publication of *L'art de bâtir chez les romains* by Auguste Choisy, which, Guastavino said, filled in some of the gaps left by Viollet-le-Duc (one of the pillars of 19th-century architectural

culture). In sum, of the two types of cohesive Architecture, the one that needed to be developed was precisely that based on brick. And of the brick techniques it was flat brick masonry: more aesthetic, more rational, lighter, stronger, and, finally, cheaper (Guastavino, 1893).

As we can see, recourse to history is fundamental in Rafael Guastavino's thinking, logical in a man of the 19th century who sought to understand evolution as a means to identify what to rectify and what to adopt in order to advance.

But in that restless fin de siècle America there were two other building systems proposed as substitutes for wood, one based on iron –but, rather than cast iron, rolled steel– a technique closer to the wood tradition and which resolved the challenge of skyscrapers. The other system, at the time still incipient, was construction based on reinforced concrete, which opened eyes to the advantages of working without specialists, a factor that was in keeping with the structural changes in the American economy.

Guastavino criticised both these alternatives, arguing that concrete did not work because it was heavy, because the work was done by unqualified men, for all that he complained of the high cost of the labour he required (there is no doubt that this fuelled the insistent proposals for reform of building and Architecture education that accompanied his writings). On the other hand, iron had the obvious defect of its low resistance to fire. The ideal solution, then, was the combination of flat brick masonry cohesive construction with iron, which could give tile the same strength as bones and tendons give flesh in the human body (*summum* of the perfection found in Nature). This mixed brick-and-iron construction, which might be called "taut brick masonry", was the building system of the future, the technology that would bring cohesive Architecture into its prime (Guastavino, 1904).

Here, then, appears the other of Guastavino's two theoretical foundations mentioned above: faith in imitating the processes of Nature as a guarantee of success.

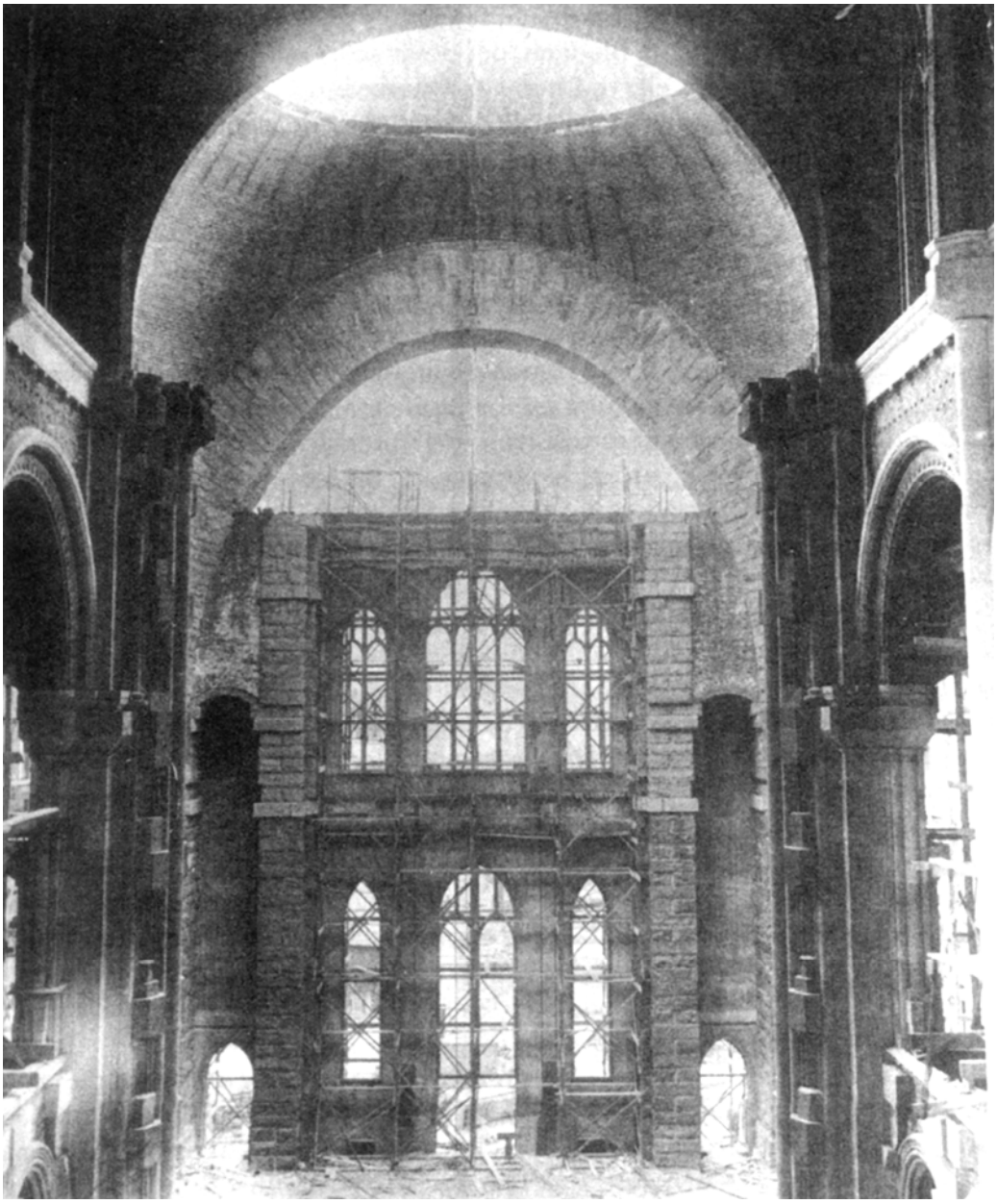
This, in broad terms, is what we might call the philosophical grounds upon which Guastavino would base his "crusade" in favour of cohesive Architecture. Moreover, though, there was a techno-scientific discourse that he would perfect meticulously on the basis of tests, calculation, hypothesis and demonstrations, and that would represent an extraordinarily profound study into the theory and practice of flat brick masonry techniques. But we shall speak more of that below, because these two discourses, the theoretic-philosophical and the techno-scientific, would first have to be validated by a tenacious sales campaign for the product before the system could be adopted in standard works and, above all, in the most important works of American Architecture.

7. The success of the "Guastavino system"

Despite the strength and lightness of cohesive construction and the fact that the savings in centerings and scaffolding was, from an economic point of view, quite significant in comparison with standard brick construction –that is, where the vaults were with the bricks on edge– its introduction into the American market proved difficult for a man without money and from so far away. Thus the beginnings were quite arduous. Having exhausted the letters of recommendation he brought from Barcelona, Guastavino realised that what seemed an obvious need foundered in the face of the scepticism of American architects, who did not believe the cohesive system to be transferable.

Thanks to his monthly contributions, lasting over a year, to the magazine *Decorator and Furnisher* (Guastavino 1882-83), where he published drawings and articles on Architecture and decoration, Guastavino got the chance to present a project for the Progress Club building in New York, for which he proposed the Arab style, practically unknown in the country. He won that competition, reporting his first earnings, which he put into the construction and sale of two row houses in Uptown Manhattan, naturally with flat brick vaults. Subsequently he also won part of the competition for the Arion Club of New York and a few other private works. After five years of difficulties and hard work he had got his system in the door (Collins, 1968).

It would be necessary to study in depth the network of relationships that, in conjunction with his efforts, allowed Rafael Guastavino to find success in such a difficult endeavour. It still seems impossible today. From then on, however, contracts began to arrive from up and down the East Coast, above all from the Boston and New York areas. By now his son Rafael was working at the company, which, in this period, adopted a very effective promotional campaign. Thus came about the collaboration with a number of renowned architects, including the foremost partnership in the United States, McKim, Mead & White, who commissioned him to build, among other works, the Boston Public Library, employing flat brick masonry in the floors. This was one of the most important buildings built in the decade and brought Guastavino great prestige. He opened an office in Boston, contracted an accountant, William Blodgett, to put his muddled finances in order, and, together they founded the Guastavino Fireproof Construction Company, which was to exploit a series of previously patented flat brick masonry techniques: the vault, the partition-wall, the staircase, etc. –up to 18 in Guastavino's time, later extended to 25 by his son. (Collins, 1968).



Rafael Guastavino had recently died when, in 1908, work was begun on Saint John's Cathedral of New York, by Columbia University, but he had already taken care of the technical and commercial preparations for the building work. The dome and pendentive were contracted for a total of 22.200 dollars and took a year to build, with the aid of tachymeters but without any centerings. Standing on the previous day's work, the workers completed de domes and vaults at the rate of three rings of brick a day. [Source: Guastavino Archive, Avery Architectural & Fine Arts Library, Columbia University, New York]

This business of patents was, both in America and in Catalonia, quite controversial, given that, in broad terms, they were patents on traditional techniques. Guastavino himself wrote a lengthy justification, explaining that the patents were conceded based on the use of new mortars (Guastavino, 1892). In America, a patent entailed the assumption of responsibility for and, to a certain extent, a guarantee of the quality of the product; but it also justified control over the competition. In Barcelona all of this was seen as an appropriation, with profit as the motive, of a technical legacy belonging to the people. Yet, as we have said, Guastavino, more than anyone else, had converted flat brick masonry into a modern technique, into another technique different from the tradition. Besides, America was another world.

Nonetheless, many of the patents were never developed. His work was based above all on the use of the vault in all its geometric variations. An in-depth study would be required to reach a firm conclusion, but it seems that the project to turn flat brick masonry technique into a comprehensive construction system did not succeed, and as far as walls were concerned, Guastavino continued to employ brick in the traditional manner.

1890 brought economic depression, which the Guastavino Fireproof Construction Company survived with great difficulty, to be reborn under the new name of Guastavino and Company. Then good times returned, contracts poured in once again and the collaboration with important architects continued. The time had come to build his own tile factory to allow for greater technical, artistic and market control over the material, given that American supplies could not meet the needs of so many commissions.

Tile production was tested at a 100-hectare estate that Guastavino had bought in the Black Mountains, near Ashville, North Carolina (where he had built himself a home – of wood, in this case– to share with Francisca Ramírez, a Mexican governess he had met years before and would eventually marry). The tests were satisfactory and the factory was finally opened in Woburn, Massachusetts, near Blodgett's home, producing structural and decorative tiles in vast quantities (Collins, 1968).

The business was already increasingly in the hands of his son when, in 1908, Guastavino, who was spending long periods at his home in North Carolina, lost the battle against lung disease and passed away. Death came at the age of 66, after having lived 27 years in the United States. By then he had achieved a large part of his aspirations and was about to start building the great dome of St John the Divine Cathedral, near Columbia University in New York, emblematic work in American Architecture: that dome, forty metres in diameter, would bring great prestige to the Guastavino firm (Guastavino, 1970).

By this time the number of important works built by the Company was already considerable. Later, a poster would be published with the most notable vaults erected

between 1897 and 1911, the majority therefore within Guastavino's lifetime, leaving not doubt at all as to the success of the "Guastavino vault". The list of these buildings, accompanied by the names of the architects who designed them, constitutes, as we can see, an inventory of the most important buildings Rafael Guastavino i Moreno built in the United States (Collins, 1968). Nonetheless, we should bear in mind that they represent only a selection from the total number of buildings he did, and a small sample of the total number of buildings by the company he founded.

Following is the list and in brackets the width or span of the corresponding vault:

1897 New York University. Bronx, New York, with McKim, Mead & White (17,07 m).
1897 Virginia University. Charlotesville, Virginia, with McKim, Mead & White (21,34 m).
1901 Institute of Arts & Sciences. Brooklyn, New York, with McKim, Mead & White (19,51 m).
1903 Bank of Montreal, Canada, with McKim, Mead & White and A.T.Taylor (21,03 m).
1904 Madison Square Presbiterian Church, New York, with McKim, Mead & White (14,02 m).
1905 St. Paul's Chapel, Columbia University, New York, with Howells & Stockes (15,85 m).
1905 Rodef Sholem Synagogue, Pittsburgh, Pennsylvania, with Palmer & Hornbostel (27,43 m).
1905 McKinley National Memorial, Canton, Ohio, with H. Van Buren Magonigle (17,07 m).
1906 Elephant House, Bronx Park, New York, with Heins & La Farge (10,36 m).
1906 Smithsonian Museum, Washington, D.C., with Hornblower & Marshall (24,38 m).
1907 Girard Trust Co., Philadelphia, Pennsylvania, with McKim, Mead & White and Allen Evans (30,78 m).
1908 St.Francis de Sales Church, Philadelphia, Pennsylvania, with Henry D. Dagit (18,59 m).
1908 Cathedral St. John the Divine, New York, with Heins & La Farge (41,15 m).
1909 St. Barbara Church, Brooklyn, New York, with Helmle & Huberty (13,11 m).
1909 J.J. Jermain Memorial Library, Sag Harbor, New York, with Augustus N. Allen (9,14 m).

Some domes constructed by the R. Guastavino Co. Between 1897 and 1911. Among them, 13 were built during the life of Rafael Guastavino the father, who died in 1908 when began the construction of the biggest one, the dome of Saint John the Divine, whit a diameter of 41,15 m: the highest building in the centre of the image. [Source: Guastavino Archive, Avery Architectural & Fine Arts Library, Columbia University, New York]

Indeed, after Guastavino's death, the company maintained its high profile. Directed by his son, it continued to build with flat brick vaults and specialised in the use of finishing materials manufactured at the tile factory in Woburn, materials that had great soundproofing properties, thanks to a fruitful collaboration with Professor Sabine of the Department of Acoustics of the Massachusetts Institute of Technology. During the construction boom of the 1920s the company did outstanding business. In 1929 crisis returned, which, once overcome, led to another period of prosperity. As Rafael Guastavino Expósito got on in years, the tile company passed into the hands of his daughter and Blodgett's son. Rafael Guastavino Expósito died in 1950. The Company wasn't liquidated until 1962 (Guastavino, 1970).

The record of buildings by the Company, including the first period of the Guastavino Fireproof Construction Company, contains over one thousand, mostly on the East Coast of the United States, but in the rest of the Union as well, in Canada, Mexico, and even India. In 1900, of the 10 buildings considered to be the most beautiful in the US, the majority had to do with Rafael Guastavino. Later, in 1967, when the American Institute of Architects listed the 38 most important buildings in Manhattan of the previous 30 years, of the 22 built before World War II over half had been built by the Guastavino Company (Collins, 1968).

Over time the use of flat brick masonry technique declined. Indeed, as Guastavino probably feared, it could not survive the increase in the cost of specialised labour. The spread of steel and, later, of reinforced concrete as building techniques was irreversible. Technological advances were not headed in the direction Guastavino would have liked because of the demand for greater capital intensiveness and less labour intensiveness. But, he had found his moment.

8. Publications and scientific work

The United States also satisfied a good part of Guastavino's scientific curiosity. Not only because there it was possible to set up an experimental process, but also because the competitiveness of American society demanded constant improvement of the work process and its results.

As soon as conditions permitted, he began tests to determine the working coefficients of the compression, tensile and shear stresses within the material section of the vault, in order to establish reliable hypotheses in laboratory conditions. With the collaboration of Professor A. V. Abbot, Guastavino performed a series of trials at the Department of Tests and Experiments of the Fairbanks Scale Company of New York, between May and June 1887.

With this series of tests it was then possible, by applying the classic formulas of gravity construction and with the aid of the static graphic analysis, to calculate

theoretically the material and formal conditions of flat brick vaults and domes. In addition Guastavino defined the optimum performance of domes compared with flattened barrel vaults, evidencing the advantages of the former.

But what Guastavino had sensed since the very beginning was the greater strength of cohesive construction compared with gravity construction. He had shown that, laid with Portland cement, layers of flat brick masonry performed like a homogeneous body that distributed superficially the pressures applied, which performed better and with less thrust than gravity construction. He explained and demonstrated, for example that inter-beam barrel vaults –in the case of floors with beams– work like a single unit and, thus, the more stilted they are the greater force they require from the support beams.

So, based on his on-site empirical tests, he corrected the existing theoretical apparatus –adequate for calculating gravity construction– taking care with the formulas used to calculate elements of homogeneous material, under the assumption that the vault was –differences in the material notwithstanding– like a sort of iron plate. In this way he obtained results closer to reality.

All these studies permitted the design, by Gaetano Lanza, professor of Applied Mechanics at the Massachusetts Institute of Technology in Cambridge, Mass., of a set of gauges that automatically indicated the different stresses produced in standard vaults with a deflection of 10% of the span, assuming a uniformly distributed load.

Although, in fact, the first theories on plates had been formulated by Navier and others circa 1828, the calculating systems that resulted from the application of those theories to thin vaults were not refined until the beginning of the 20th century. This shows Rafael Guastavino as a man of the 19th-century, intuitive and practical, who analysed scientifically the behaviour of technologies in order to induce a set of generally applicable laws, despite the lack of an exact theoretical apparatus that would make such possible.

But this process of refining the form and dimensions of vaults and domes also spurred reflection on the problems of their material execution. In his writings he had explained at length the difficulties caused by the lack of an American building tradition, which made it necessary to import skilled labour from Catalonia. In spite of these problems, Guastavino occupied himself with the most miniscule aspects of the execution of the work, and that led him to pose a series of questions regarding essential problems of building practices which, in Catalonia, routine had rendered, to a certain extent, irrelevant: about how cement and mortar perform, about hardening time and conditions, about the quantity of water to use, etc. And also about the abilities of the workforce for the actual construction work, and likewise of the architects for the design.

All these reflections, experiments, calculating procedures and results were made public at conferences and later published, first in specialised journals and then in

two books. At the same time Guastavino's proposals were included in a number of techno-scientific texts of the period (Berg 1889-90).

Rafael Guastavino Moreno in a photograph of the years of his greatest professional activity in the United States. [Source: Salvador Tarragó Archive]

The first book, *Cohesive Construction* (Guastavino, 1892), was based on two lectures: one given at the Society of Arts of the Massachusetts Institute of Technology in Cambridge in October 1889 (Guastavino, 1889) and the other at the Thursday Club in January 1890 (Guastavino, 1890). First published in the journal *The American Architect and Building News*, these lectures were later expanded upon and published in book-form in 1892.

This book covers the bulk of Guastavino's scientific thought. It explains what cohesive construction is, its theory and its advantages, and details the potential applications of the new construction system in all types of buildings. As well, it sets out the ideas regarding Tubular Construction, as exhibited at the Philadelphia Exposition of 1876.

In all likelihood the publishing of *Cohesive Construction* had to do with the World's Columbian Exposition in Chicago in 1892, occasion of the Second International Congress of Architects. The Ticknor publishing house also published the above-mentioned journal, and Guastavino probably had an interest in seeing to it that

those attending the congress should have further scientific information relating to the speech that he gave on his building system.

Guastavino's speech at that congress was entitled "Cohesive Construction: Its past, Its present; Its future?" (Guastavino, 1893). Directed at architects, it consisted basically in a historic exposition in support of current and future use of cohesive construction. The bulk of the text of the speech was published in Guastavino's second book, entitled *Function of Masonry* (Guastavino, 1904).

This second book comprises two parts, the first, *Prolegomenos*, was published in 1895 just after the Chicago Congress, and evidences the rivalry between cohesive construction, on the one hand, and iron and reinforced concrete, on the other.

The second part was published in 1905, undoubtedly based on a rewriting of a text, *Fonction de the maçonnerie dans les constructions modernes*, that Guastavino had sent to the International Congress of Architects of 1904, held in Madrid, and finally published in French in 1906 (Guastavino, 1906). This was a technical exposition of the advantages of cohesive construction, ever conscious of the competition from iron and reinforced concrete, and clearly sets out all his scientific reflections regarding the behaviour of the materials and their application in building.

In addition to the publications cited, we know of articles by Guastavino for *Decorator and Furnisher*, dealing with "revival" Architecture and decoration (Guastavino, 1884); and an article in *The American Architect and Building News* about his pavilion for the Chicago Exposition (Guastavino, 1893).

9. The echo in Spain and Catalonia

Although in this country the recognition of Rafael Guastavino never really became explicit, he did, from America, maintain a relationship with Catalonia and Spain. Thus he was commissioned to build the official pavilion for the Chicago Exposition of 1893. He co-authored this pavilion with the Valencian architect Enric Dupuy, the Spanish delegate to the Columbian Exposition. They built a replica of the Llotja of València, a colonial-age market, seemingly a very fitting idea to commemorate the fourth centennial of the Spanish landing in America, with which the Exposition coincided.

Among his contacts was Mariano Belmás, an architect and senator from Madrid dedicated to specialised press. Belmás represented Guastavino at the International Congress of Architects held in Madrid in 1904, to which Guastavino sent the above-mentioned speech. It appears that the latter was accompanied by an impressive album of photographs of his American works, some years later to come into the hands of the architect Luis Moya, who used it to write and illustrate his book *Bóvedas tabicadas*, published in 1947 (Collins, 1968; Moya, 1947).

At the Madrid Congress Puig i Cadafalch gave his famous speech on Catalan Architecture, in which he made mention of the Catalan building repertory and, naturally, of the flat brick masonry techniques that comprised a substantial part of that repertory and justified the name of "Catalan vault", as they had recently started calling the flat brick vault in Spain. In his speech Puig praised Guastavino's work.

In Barcelona professors and students at the School of Architecture had for years been visiting the Batlló factory as part of the academic programme. From the 1880s, flat brick masonry techniques, and above all the vault, came to form part of the new Catalan construction. The forty-year period spanning the late 19th and early 20th centuries saw the development of the so called "Modernista" Architecture, in which a number of outstanding architects designed with flat brick vaults, including Antoni Gaudí himself, or others as Lluís Domènech i Montaner, for instance, who were especially inclined to use the mixed iron-and-brick construction that Guastavino called "*l'obra de maó tibada*" (taut brick masonry). The "Modernists" took flat brick masonry to its highest point of expression. What in America were revival works of great scope and risk, here were works of great formal and structural creativity.

At the beginning of 20th century when the Catalans again took up theoretical studies of the vault –basically aimed at the clarifying the mystery, attempting to figure out why it sustained itself and how it could be calculated– they looked to Guastavino's publications as a starting point.

In 1900 Domènech i Estapà attempted to correct the classic calculation of the vault (Domènech i Estapà, 1900). Ten years later, Jeroni Martorell proposed to do the same, citing widely the works and writings of Guastavino (Martorell, 1910). Jaume Bayó applied the theory of elasticity and, following Guastavino, considered vaults as flexible plates (Bayó, 1910). Of the same mind too, considering the vault as an iron plate, was Fèlix Cardellach, who also spoke of cohesive construction in the terms set out by Guastavino (Cardellach, 1910). Although from a different standpoint, the reflections of Joan Rubió and the *Gaudinistes* can also be understood within the framework of the "feedback" derived from Guastavino's experience (Rubió, 1913). In 1923, Esteve Terradas based on Guastavino his studies that drew a comparison between the vault and a curved plate (Rosell; Serrà, 1989). Later, Josep Goday, in his opening speech at the *Acadèmia Catalana de Belles Arts de Sant Jordi*, recognised Guastavino as the pioneer of the modernisation of flat brick masonry techniques and commented on his theoretical contributions (Goday, 1934).

Even after the Spanish Civil War, with the re-emergence of the technique induced by autarchy, we should cite the booklet by Bonaventura Bassegoda i Musté and the above-mentioned book by Luis Moya, both from 1947, which make explicit reference to Guastavino's contribution, in the case of Moya publishing the photographs

of which we have spoken. We should also mention the book by Àngel Pereda Bacigalupi (1951) *Bóvedas Tabicadas*. And finally, Bergós (Bergós, 1965), now from 1965, again reproduces Guastavino's formulas that the author had published previously (Bergós, 1953).

There is yet another episode of great significance for the Catalan and Spanish building industry. We refer to the creation of the Asland cement company, the putting into practice of an idea, perhaps suggested by Rafael Guastavino, consisting in exploiting a Portland cement production industry, the first in Catalonia and one of the first in Spain, in 1901 at Castellar de N'Hug. Guastavino may well have even drawn up the architectural project for the factory, executed with flat brick vaults and metal structure. We know of the contacts, through the engineer Pedraza de la Pascua, that Count Güell, Asland's founder, had in North America, where the machinery and know-how were acquired. And we know that Guastavino stood at the centre of these relations (Palomar, 1968).

10. Historiography and archival sources

What we know about the work of Rafael Guastavino Moreno, and by the same token the possibilities we have to study them, we owe, to a large extent, to the efforts of Professor George Roseborough Collins (Massachusetts, USA, 1917-1993).

Professor Collins taught art history at Columbia University (New York) from 1946 until he retired in 1986, although he would continue to work until 1988, by then already evident the long illness that would lead to his death in 1993. In 1977 he was named Doctor Honoris Causa by the *Universitat Politècnica de Catalunya* and in 1991 associate member of the *Reial Acadèmia de Ciències i Arts of Barcelona*.

Interested in Antoni Gaudí's work, George R. Collins developed a close relationship with Catalonia and, from 1960, his research, publications and promotional efforts were fundamental in setting off the explosion in the popularity of the great architect' work –as well as that of the art and Architecture of Catalan *Modernisme*– in the English-speaking world and, consequently, its inclusion in contemporary cultural debate.

Details of George R. Collins's biography come to light in the speech, as of yet unpublished, given by the architect Jordi Bonet at the conference *Jornades d'Estudi Catalano-Americanes* held in Barcelona in May 1993. Jordi Bonet i Armengol established a long-term personal friendship with Professor Collins and is one of the circle of Catalan friends who helped broaden the American professor's knowledge of historical and contemporary Catalan culture (Collins, 1985).

In 1958 Collins founded Friends of Gaudí-USA and created the Archive of Catalan Art and Architecture (Collins, 1985), a documentary collection on Gaudí and the Modernist period that has been further endowed over the years and has served as a laboratory for a number of important studies.

A part of this archive also comprises the Guastavino Company documentation that Collins had rescued when the company was liquidated, acquiring it on behalf of Columbia University between 1962 and 1963.

In 1968 Collins published in the *Journal of the Society of Architectural Historians*, volume XXVII no. 3, the article "The Transfer of Thin Masonry Vaulting from Spain to America", which constitutes the principal source for the bulk of subsequent writings on the work of Rafael Guastavino.

It seems this article was written in the context of the progressive emergence of organicist positions in modern Architecture, which had in technological expressionism one its most attractive outlets. In the 1960s the importance of concrete membranes and shells (Torroja, Candela, Nervi, Saarinen) and indeed flat brick vaults (Dieste, Porro, Bonet in Catalonia, for example) aroused a new interest in Guastavino's historical applications. Professor Collins's specialisation in the Gaudí and Modernist Architecture (where the flat brick masonry techniques was a basic technical resort) also explains his interest in the subject that concerns us here.

George R. Collins's article of 1968 was perhaps premonitory of a series of publications regarding the work of Rafael Guastavino, in light of the large volume of existing material, of the importance of the builder in pre-WWI American Architecture, and of the then growing need in Catalonia to reveal the cultural hallmarks of the past. The immediate publication of a monograph, commissioned to Professor Collins by the Association Architects of Catalonia and the Balearic Islands, was announced, but never appeared.

In Catalonia, professors Joan Bassegoda and Salvador Tarragó have shed further light on the work and figure of the builder, with Professor Bassegoda contributing important data on Guastavino's period in Barcelona. Since then, from Catalan institutions a number of initiatives have emerged.

In 1987 the Ministry of Culture of the Catalan Regional Government funded a grant to inventory the documentation in the Catalan Archive; the above-mentioned *Jornades d'Estudi*, where, in addition to the lecture by Mr Bonet, Professor Joan Bassegoda gave another entitled "Rafael Guastavino in America"; and finally the exposition *Catalonia-Nova York*, which highlighted the figure of the builder.

Today Rafael Guastavino Moreno is widely known, and his works are studied and publicised in Germany, Italy and the United States.

In 1889 the bulk of the Catalan Archive was transferred from Columbia University to the Art Institute of Chicago (Ryerson and Burnham Library), where today it may be consulted under the name of the George R. Collins Archive of Catalan Art and Architecture. But the Guastavino Company archive has remained in New York, where at the time of writing it is being catalogued and filed in the Avery Library of Columbia University.

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