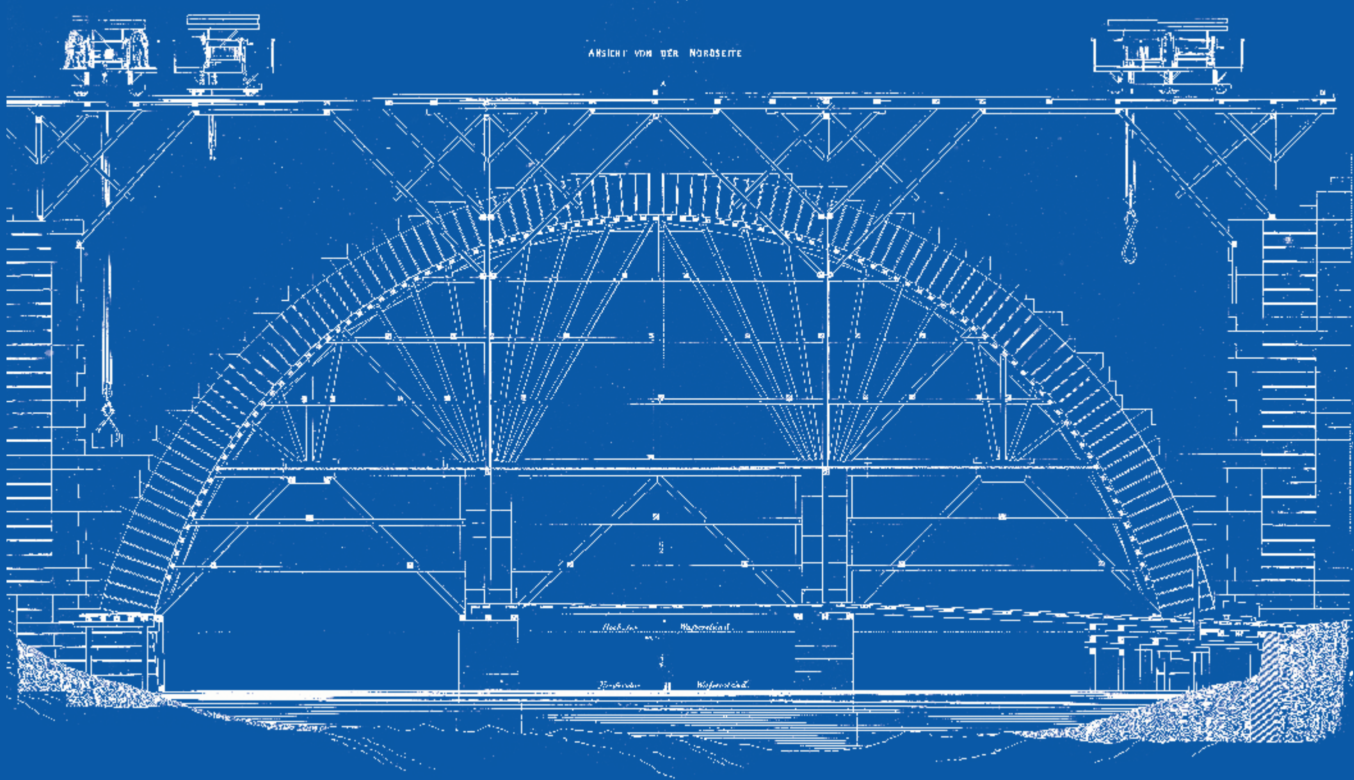
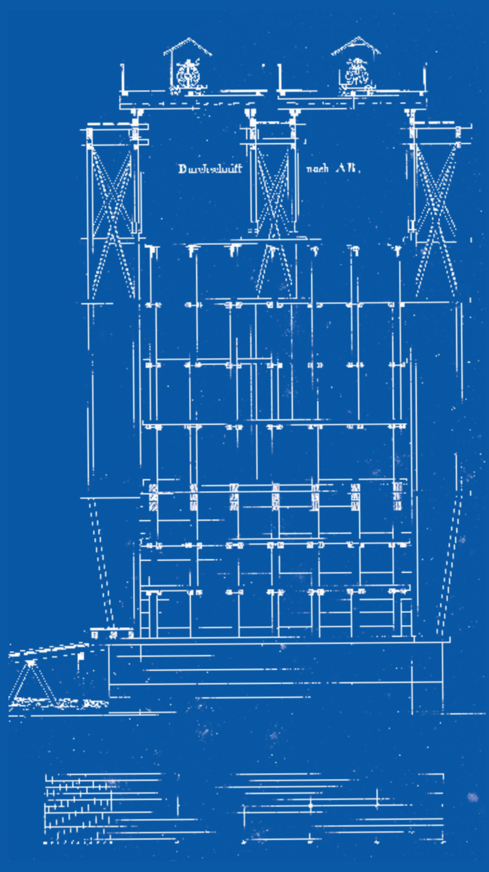
The innovation of reinforced concrete in the automotive factories in the early 1900s. Patents, technologies and constructive experimentation

Proceedings of the 8th International Congress on Construction History
Stefan Holzer, Silke Langenberg, Clemens Knobling, Orkun Kasap (Eds.)



Construction



Matters

Stefan Holzer, Silke Langenberg,
Clemens Knobling, Orkun Kasap (Eds.)

Construction Matters

Proceedings of the 8th International Congress on Construction History

vdf

Bibliographic information published by the Deutsche Nationalbibliothek
The Deutsche Nationalbibliothek lists this publication in the Deutsche Nationalbibliografie; detailed bibliographic data are available in the Internet athttp://dnb.dnb.de.

Download open access:

ISBN 978-3-7281-4166-8 / DOI 10.3218/4166-8

www.vdf.ch
verlag@vdf.ch

8th International Congress on Construction History – Zurich
© 2024 Copyright the Author(s), ISBN 978-3-7281-4166-8

Contents

Scientific Committee

The scientific committee of the 8ICCH consists of distinguished international experts in specific fields and topics within the discipline of construction history. It is responsible for the selection and review of submitted abstracts and papers.

Bill Addis (United Kingdom)
Wesam Al Asali (IE University, Spain)
Alejandra Albuerne (IE University, Spain)
Michela Barbot (Université Paris-Saclay, France)
Antonio Becchi (MPIWG, Germany)
Matthias Beckh (TUDresden, Germany)
Nick Beech (University of Westminster, United Kingdom)
Philippe Bernardi (UP I Panthéon-Sorbonne, France)
Inge Bertels (Universiteit Antwerpen, Belgium)
Eugen Brühwiler (EPF Lausanne, Switzerland)
Tobias Büchi (ETH Zürich, Switzerland)
Laurens Bulckaen (UL Bruxelles, Belgium)
Valentina Burgassi (Politecnico di Torino, Italy)
James W.P. Campbell (University of Cambridge, UK)
Robert Carvais (CNRS, France)
Emmanuel Château-Dutier (UdeM Montreal, Canada)
Yunlian Chen (Gunma University, Japan)
Mike Chrimes (United Kingdom)
Linda Clarke (University of Westminster, UK)
Thomas Coomans (KU Leuven, Belgium)
Krista De Jonge (KU Leuven, Belgium)
Rika Devos (Université Libre de Bruxelles, Belgium)
Francisco Domouso de Alba (UE de Madrid, Spain)
Alexandra Druzynski von Boetticher (BTUCottbus, Germany)
Bernard Espion (Université Libre de Bruxelles, Belgium)
Robert Flatt (ETH Zürich, Switzerland)
Donald Friedman (Old Structures Engineering, NY, USA)
Paula Fuentes González (Universidad de Alcalá, Spain)
Franz Graf (EPF Lausanne, Switzerland)
Benjamin Hays (UVA, Charlottesville, USA)
Regine Hess (ETH Zürich, Switzerland)
Stefan M. Holzer (ETH Zürich, Switzerland)
Santiago Huerta (UP Madrid, Spain)
Merlijn Hurx (Katholieke Universiteit Leuven, Belgium)
Tullia Iori (Università di Roma 2 Tor Vergata, Italy)
Andreas Kahlow (Fachhochschule Potsdam, Germany)
Kai Kappel (Humboldt-Universität zu Berlin, Germany)
Orkun Kasap (ETH Zürich, Switzerland)
Jana Keck (GHI, Washington, USA)
Alexander von Kienlin (TU München, Germany)
Clemens Knobling (ETH Zürich, Switzerland)
Karl-Eugen Kurrer (Hochschule Coburg, Germany)
Maxime L'Héritier (UP1 Panthéon-Sorbonne, France)
Massimo Laffranchi (GfI, Switzerland)
Guy Lambert (ENSA Paris-Belleville, France)
Silke Langenberg (ETH Zürich, Switzerland)
Thomas Leslie (Iowa State University, USA)
Werner Lorenz (BTU Cottbus, Germany)
Nicoletta Marconi (Università di Roma 2 Tor Vergata, Italy)
Rafael Marín-Sánchez (UP València, Spain)
João Mascarenhas-Mateus (ULisboa, Portugal)
Torsten Meyer (Deutsches Bergbau-Museum Bochum, Germany)
Nathalie Montel (École des Ponts ParisTech, France)
Beatriz Mugayar Kühl (Universidade de SãoPaul, Brazil)
Valérie Nègre (UP I Panthéon-Sorbonne, France)
John A. Ochsendorf (MIT, Cambridge, USA)
Yiting Pan (Soochow University, Suzhou, China)
Eberhard Pelke (Germany)
Uta Pottgiesser (TU Delft, Netherlands)
Wido Quist (Technische Universiteit Delft, Netherlands)
Enrique Rabasa Díaz (UP Madrid, Spain)
Christoph Rauhut (Landesdenkmalamt Berlin, Germany)
Mario Rinke (Universiteit Antwerpen, Belgium)
Jasmin Schäfer (ETH Zürich, Switzerland)
Sarah M. Schlachetzki (ETH Zürich, Switzerland)
Hermann Schlimme † (TU Berlin, Germany)
Rainer Schützeichel (FH Potsdam, Germany)
Chang-Xue Shu (KU Leuven, Belgium)
Philippe Sosnowska (Université de Liège, Belgium)
Amit Srivastava (University of Adelaide, Australia)
Laurent Stalder (ETH Zürich, Switzerland)
Iva Stoyanova (Bulgaria)
Klaus Tragbar (ZI für Kunstgeschichte, Germany)
Louis Vandenabeele (ETH Zürich, Switzerland)
Stephanie Vande Voorde (VU Brussel, Belgium)
Gabri van Tussenbroek (UvAmsterdam, Netherlands)
Clemens Voigts (ETH Zürich, Switzerland)
Christine Wall (University of Westminster, London, UK)
Christiane Weber (Universität Stuttgart, Germany)
David Wendland (BTU Cottbus, Germany)
Ine Wouters (Vrije Universiteit Brussel, Belgium)

8th International Congress on Construction History – Zurich

The importance of patents in the development of building structures in the 19th century

Francisco Domouso de Alba

School of Architecture, Engineering and Design. Universidad Europea de Madrid, Spain

Abstract: A patent is an exclusive right granted by a state to protect an invention. Patents played a key role in the development of new construction systems in the second half of the 19th century and the early decades of the 20th. A look at the historical origins of patents is necessary to understand how the foundations of the contemporary patent system were laid. In this regard, the early patents for reinforced concrete offer a good example of the technical, financial and even speculative nature behind the intellectual protection of the invention of a material that revolutionized construction in the 20th century.

Introduction

The aim of this thematic session is to highlight the importance of patents in the innovation and implementation of new materials, technologies, and structural systems in the 19th century. The contribution of these patents was hugely important for construction in Europe and the United States in the early decades of the 20th century, although the importance of patents remained strong throughout the 20th century and continues today.

The development of the second Industrial Revolution consolidated the legal and economic foundations of intellectual protection. Patents served to finance the theoretical, technical, and constructive development of new materials and structural systems, which initially had little or no theoretical support.

Patents played a fundamental role in this transition from product to technology. For this reason, it is important to study their contribution to the building process.

1. A look at the historical origins of patents

1.1. The origin of patents

The concept of monopolistic recognition as a knowledge protection system date back to the 6th century BC. In the Greek colony of Sybaris, in the Calabria region of present-day Italy, chefs had the right to temporarily "protect" the dishes of food they invented (Athenaeus, Deipnosophists, 349). As with patents, this protection also applied to the technique of preparing the dish and the text of the specific recipe (Tobón; Varela, 2011, 149).

Patents, as we know them today, originally arose in the Middle Ages with the Litterae Patentes, open letters used by rulers to announce their granting of a privilege of some kind. Over time, these privileges came to be granted above all to inventions applicable to industry. The forebears of patents are invention privileges.

Invention privileges developed in their full complexity in 15th-century Venice. In 1470, the Republic of Venice (holding full governmental autonomy and the powers of a state for all intents and purposes) resolved to grant privileges (privatae leges), which consisted in legal favours.[1]

The first law regulating the emerging industrial privileges granted to inventors to reward their contributions to intellectual progress was published in the Republic of Venice[2] in 1474. This law is the first piece of legislation containing all the basic legal principles to be considered a patent in conditions similar to those of today: exclusivity, territoriality and compensation for the transfer to society of the knowledge of the invention.

These are first known privileges, which define this legal tool as an entitlement to produce, trade and store a product under a monopolistic scheme in exchange for the inventor's disclosure of the knowledge to society[3].

1.2. The modern patent system

The origins of the modern patent system can be traced to Great Britain in the 17th century, although the first patent law per se would not be enacted until 1852.

1 Invention privileges are temporary monopolies that grant the holder, more than a right of ownership, exclusive manufacturing rights.

2 One of the most famous inventors of the time is Galileo Galilei, beneficiary of a 20-year monopoly granted by the Republic of Venice in 1594 for the manufacturing and operation of irrigation machines.

3 It is believed that the first privilege in the world was granted to the architect Brunelleschi in 1421 in the Republic of Florence for the development of his "barge with hoisting gear to transport marble". In this regard, the Council of Venice had already granted an exclusive monopoly right for a term of 50 years to Franciscus Petri of Rhodes in 1416 entitling him and his heirs to construct machines of their own invention to produce cloth. However, it is unclear whether this monopoly was compensation for his invention and contribution to knowledge about the state of the art of these machines in that era or a mere payment or reward for other services rendered.

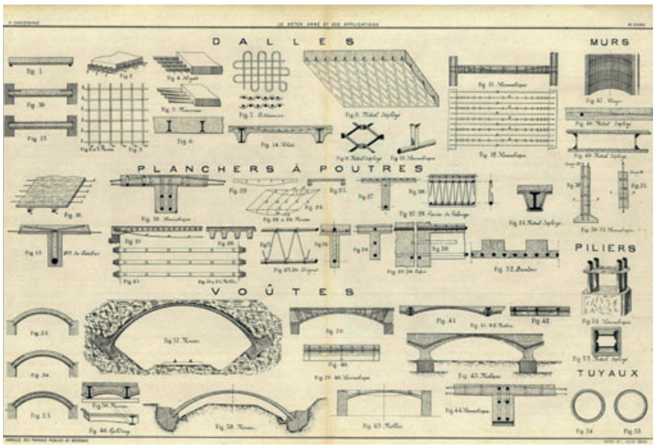


Figure 1. Le béton armé et ses applications (Christophe. July 1899. Magazine: Le Béton Armé).

The Statute of Monopolies of 1623 contained the seeds of what can be considered modern patent law. This statute declared that it was illegal to grant monopolies in England, except for new inventions, which could be granted temporary exploitation monopolies (Ortiz-Villajos, 1999. 56).

The United States and France were the first two countries to enact patent laws, in 1790 and 1791, respectively. In the United States, the origins of this law can be found in Section 8 of the US Constitution, which recognises the capacity to create knowledge as one of the fundamental rights of humans.

At that time, such laws were ushered in by the development of the first Industrial Revolution already gaining momentum in the late 18th century. In a very short span of time, other countries began enacting new laws for the protection of industrial property. For the first time in history, inventors were granted intellectual and industrial property rights over their inventions for a specific period of time.

By the 19th century, the modern system of industrial property protection had expanded across the Western world: the patent and trademark system. Rather than privileges being granted by monarchs, they became private property rights.

In Europe, the industrial and economic development nature of patents was emphasised in a French law from 1844 (which amended the act of 1791), requiring inventions to have a clearly industrial nature. This law develops the concept of claims to an invention or authorship by the inventor, making it possible to specify the scope of the invention and to defend it in the event of litigation or conflict of interest (Simonnet, 2005. 47).

In 1878, the first international conference on intellectual property was held in Paris, aimed at harmonising existing European patent laws.

The first international patent convention was the Paris Convention, signed on 20 March 1883. Later, the Berne Convention, ratified on 9 September 1886, was a decisive step in Europe's efforts to unify industrial protection legislation[4], laying the groundwork for the contemporary patent system.

2. Patents in relation to the origins of reinforced concrete

2.1. The first reinforced concrete patents

Patents were essential and necessary in the early development of reinforced concrete for two reasons: the product and the business.

Patents provided a product that generally worked well. For example, early reinforced concrete structures were not calculated and built according to a standard but were actually purchased. The result was, in most cases, satisfactory for the intended use. The best patents offered innovative structures and materials that were backed by the experience and knowledge of their inventors but were opaque in terms of calculations and technical assumptions[5].

Business is the main reason behind the existence of the first patents for reinforced concrete. For the first time in construction history, an invention and its countless, diverging patents were profitable on a large scale for those exploiting them, and there were many. Entrepreneurs, inventors, builders, architects and engineers saw an opportunity to profit greatly by selling patents for reinforced concrete products or complete or partial structural systems whose internal functioning only they knew or sensed.

And that was possible because the development of the second Industrial Revolution had strengthened the legal basis of intellectual property, and because reinforced concrete had to be invented to construct the infrastructures, constructions and buildings of the cities of the 20th century. The market open to reinforced concrete was virtually infinite.

Patents often served to finance the trial-and-error processes of reinforced concrete construction systems with limited theoretical and technical support[6]. But they also helped finance an advertising model based on showing the virtues of the material by means of testing of all kinds, such as load testing, fire resistance, etc. These tests, documented in a wide range of graphic information (photographs and diagrams) and certified by highly reputable scientists and experts of that era (both linked and unrelated to the patent), were the best calling card for gaining customers.

Furthermore, patents were important in the late 19th century because they offered a rapid transfer of technology from more advanced countries in terms of construction development to less developed ones. The main European patents for reinforced concrete systems were simultaneously patented in numerous countries. The reason for this was the strong expectations for profit sparked by the new material for use in construction.

4 Following the conference in 1878, another conference was held in Paris in 1880 attended by 19 countries, for the purpose of establishing an international office. In March 1883, the international Paris Convention for the Protection of Industrial Property was signed, giving rise to the International Union for the Protection of Industrial Property, composed of 10 countries, in 1884. General rules were established, and conferences were held regularly to discuss any issues that arose.

5 Early patents did not indicate the calculation methods used. This prompted the belief that patented systems were based on empirical calculations. That was true in many cases, but not in others, such as the Hennebique patents, for example, where the calculations were not shown in the patents, but they did exist and were in keeping with the best knowledge of the time.

6 Patent exploitation rights ranged from 15% to 20% of the total cost of the structure.

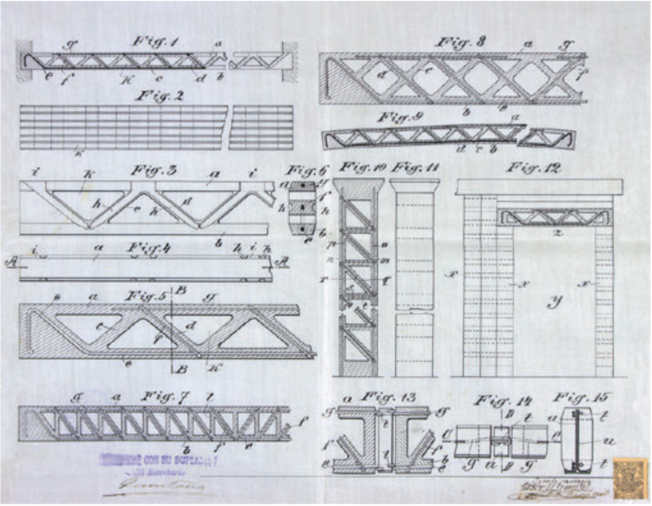


Figure 2. Patent: Trussed beam (author: Visintini (Zurich, Switzerland). 1903. Patent filed in Spain No. 31097).

2.2. The importance of reinforced concrete patents in Spain

Through patents, the best technology and knowledge about reinforced concrete in that era reached Spain very early on, in the late 19th century, even though examples of concrete in construction were anecdotal at best. The main foreign patents for reinforced concrete were filed in Spain between 1884 and 1902, just a short time after they were originally filed in their countries of origin[7]. 84% of these patents were put into practice, thus enabling a real transfer of techniques and technology to the construction sector.

This transfer of the best construction technology of the time fostered the swift development of reinforced concrete in Spain between 1901 and 1906. Patents afforded experience already proven in other countries, which notably reduced the tedious process of trial and error involved in implementing new construction techniques and technologies.

Conclusion

Patents were important in the late 19th century and the early decades of the 20th century for the development and implementation of new structural systems like reinforced concrete, but also in other fields related to construction. Their economic relevance in the construction sector was significant, enabling a rapid transfer of knowledge and technology for use in construction.

Examples of the importance of patents in diverse construction systems can be found in the excellent papers in this Thematic session: The importance of patents in the development of building structures in the 19th century.

- Building Paper 1869 to 1919—a hidden material revealed by patents. Author: Isaacs
- New techniques, ancient forms. Deneux's patents for reinforced concrete frameworks. Author: Vitale.
- The innovation of reinforced concrete in the automotive factories in the early 1900s. Patents, technologies, and constructive experimentation. Author: Maspoli, Saponaro.
- Between Rationalism and "Engenhosidade", and why not a little Empiricism: the introduction of Portland cement and reinforced concrete in Brazil. Author: Macedo Xavier De Freitas.

Bibliography

Christophe, P. 1902. Le béton armé et ses applications. Ed. Librairie Polytechnique Ch. Béranger. Paris.

Ortiz-Martín, J. M. 1999. Tecnología y desarrollo económico en la historia contemporánea. Estudio de las patentes registradas en España entre 1882 y 1935. Ed. OEPM. Madrid.

Saiz González, J. P. 1995. Propiedad Industrial y Revolución Liberal. Historia del sistema español de patentes (1759–1929). Ed. OEPM. Madrid.

Simonnet, C. 2005. Le béton, histoire d'un matériau. Ed. Éditions Parenthèses. Paris.

Tobón, N. ; Varela, E. 2011. "Patentes y Privilegios: El origen de la protección de obras literarias y artísticas". Magazine: Revista de Análisis Especializados de Jurisprudencia, no. 42.

7 This was the case of the patents by Considere, Cottancin, Golding (métal déployé), Visintini, Habrich, Hennebique, Koenen and Wayss, Mátrai, Monier, Siegwart, Visintini and Wilson.

8th International Congress on Construction History – Zurich

The innovation of reinforced concrete in the automotive factories in the early 1900s: Patents, technologies and constructive experimentation

Rossella Maspoli[1], Giulio Saponaro[2]

[1]Department of Architecture and Design, Politecnico di Torino, Torino, Italy; [2]Department of Architecture and Design, Politecnico di Torino, Torino, Italy

Abstract: This paper investigates the initial applications of reinforced concrete in both industrial and architectural field during the first two decades of the twentieth-century in Turin, with a focus on its connection to the inception of the automotive sector. The introduction of the main foreign patents into the city, such as the Hennebique System, was facilitated by the activities of Giovanni Porcheddu's construction company. In Italy the diffusion of reinforced concrete was rapidly directed towards the foundation of the new pre-Fordist production sites related to French and American construction models, such as Coignet (Symmonet 1992) and Kahn and Ransome Systems (Mikesell 2019).
This paper stems from an ongoing cataloguing activity, conducted under the TAHN (Turin Automotive Heritage Network) Protocol within the Department of Architecture and Design at Politecnico di Torino, that meticulously identified numerous case studies from the automotive sector in the city of Turin, many of which were previously undocumented. The study delves into the analysis of structural and typological solutions in reinforced concrete, correlating them with the evolution of the industrial system. It draws connections to prior research conducted at both local and sectoral levels. This paper explores exemplary cases, categorized by urban and functional type, technological and structural innovations. An emblematic case is Lingotto (constructed from 1916 onwards), where the remarkable serial nature of the building stands as a noteworthy outcome of the shift from horizontal to vertical factory design.

Introduction

During the nineteenth-century, Europe opened up to perfect and implement existing studies in the motoring sector. A radical turning point came with the advent of the internal combustion engine, which implied the emersion of the car industry, particularly in Germany and France, and the gradual transition from artisanal experimentation to the actual automotive industry. The advent of the new sector took place in Italy, as in other countries, about five years later, in particular in the areas of Turin and Milan. Approximately 287 automotive companies have been officially registered until the 1920s (MAUTO 2002).

The affirmation of Turin as the "Italian capital city of the automobile" is rapid, like other already established motor towns such as Paris and Detroit, thanks to the provision of favorable territorial and cultural conditions: the existence of a seventeenth-century construction tradition of mechanics and coachbuilders; the availability of multiple water sources; the large presence of artisan labor and technical-scientific expertise; a technical-managerial class trained at the renowned School of Engineering; the provision of new areas available for the industry; support for industry by the municipal administration with tax breaks for industrialists; the propensity to invest and take entrepreneurial risk; openness to internationalization, both in terms of patent acquisition and market; the connections with developed European countries such as France (Biffignandi 2013).

In the automotive sector, innovation unfolded through continuous technical advancements. This evolution commenced with the development of foreign patents for engines and mechanical components, exemplified by pioneers such as Clément Bayard, De Dion-Buton, and Peugeot. Concurrently, there was a parallel transition in production towards horseless carriages, with notable contributors including Locati & Torretta, Alessio, and Ciocca. Additionally, complementary sectors, like the tire industry, played a pivotal role in the expansion of the first Michelin factory from France in the northern region of Turin. This expansion also catalyzed the development of Società Tedeschi, later evolving into INCET (1888), and eventually CEAT (1925). This technical-industrial process, in turn, spurred the evolution of the typological-constructive system for the new reinforced concrete production structures (Maspoli 2020).

Reinforced concrete spread in parallel with the development of the automotive sector. The new material was initially tested for the construction of the first automotive factories because it could meet specific needs arising from the production sector. In the automotive sector, the use of reinforced concrete signified the transition from artisanal to industrial production sites, the implementation of mass production systems for developing production line machinery, the versatility of roofing systems for ventilation and shielded lighting, the enhancement of the daylight factor through regular and modular openings, and the incorporation of excellent hydraulic and fire resistance characteristics.

1. Diffusion of reinforced concrete patents in Italy and first uses

Italy didn’t directly participate in the pioneering phase of reinforced concrete experimentation. The first patents filed in Italy were by Coignet (1856), for an economic conglomerate composed of sand and gravel, Monier (1883), Bordenave (1887), and Cottancin (1889). Subsequently, there were improved Italian patents for prefabricated beams and lightened floors with brick components. In 1878, American Thaddeus Hyatt experimented the use of Portland cement combined with iron to make floors and roofs for civilian houses (Iori 2001). In 1884 Ernest L. Ransome, received a first patent for a twisted square metal reinforcing bar. The development of reinforced concrete in America was slightly earlier than that of Europe (Mikesell 2019).

The disclosure of reinforced concrete in specialized journals remained limited until the early 1900s (Iori 2001). The first Italian article dedicated to the new material surfaced in 1885 in the journal «L’ingegneria civile e le arti industriali». It stated that “the combined use of iron and cement is expected to prove very useful in both large-scale industrial applications and the manufacturing of intricate decorative elements, assuming greater significance in architectural constructions” (Dameri 2012, 209; Iori 2001). A decisive turning point in the construction field occurred with the introduction of the Hennebique patents (1892) in Europe. The system proposed exceptionally light, resistant, and economical floor beams compared to traditional materials, and later, rigid frames (Iori 2001). Hennebique embarked on a highly effective and groundbreaking campaign to promote his patent. This involved organizing the inaugural congress on reinforced concrete in 1897 and introducing the magazine «Le Béton Armé» in 1898. Furthermore, he strategically established a network of contractors across Europe for the widespread dissemination of his innovative technology.

The Hennebique patents were introduced in Italy in 1894 by Giovanni Porcheddu, the owner of the Technical Office of Engineers Ferrero and Porcheddu in Turin. In 1898, the studio gained autonomy for the design and calculation processes and made some improvements to the original system. Porcheddu initiated an almost monopolistic expansion starting in 1895. He used lightened slab blocks inside the floors, bringing them to the level of the overhang of the beams, and perfected the application of metal stirrups in pillars and beams for shear stresses. In the initial years, concrete floors and flat roofs were built, leaning on load-bearing masonry structures (Nelva and Signorelli 1990).

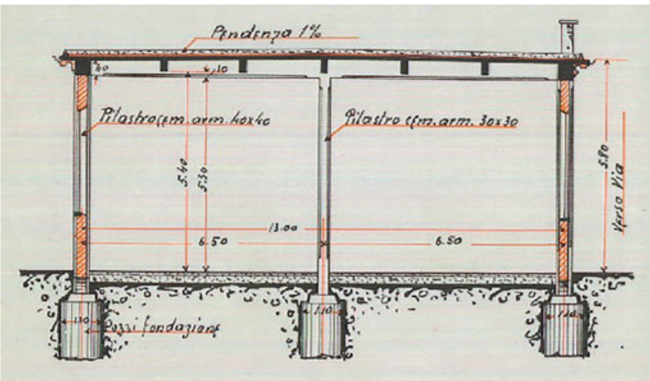


Figure 1. Garage Carrozzeria Alessio. Section drawing, 1906 (Historical Archive of the City of Turin, PE1906_0470_TAV_02).

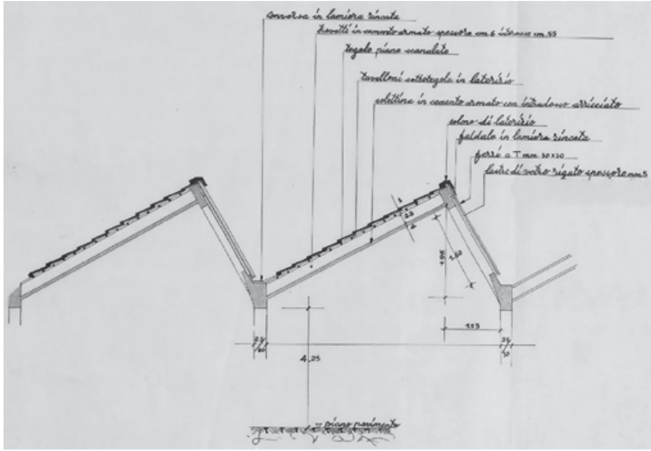


Figure 2. Piacenza-FIAT-Mardichi. Detail section drawing of the roof system, 1940s (Military Property Archive, Turin).

One typology is characterized by two cement slabs with an air gap in between. One serves as the intrados, defined as a reinforced ceiling, and the other as the extrados, supporting the floor or the roof, with a slight inclination to ensure the flow of rainwater.

Another typology involves the rigid frame system with a thin reinforced concrete slab, ranging from 6 to 14 cm in thickness depending on the loads. It features a 6 x 6 m modular mesh of two main and four secondary perpendicular beams per module. These beams connect to the slabs, forming resistant structures with a “T” section. Concerning the roofs, the reinforced slab aligns with the upper end of the beams. In some cases, the slab aligns with the lower end of the beams, with brick blocks supporting the roofing tiles, forming an air gap. (Fig. 1–2) At the beginning of the twentieth century, reinforced concrete emerged as the primary material in the construction field. The theories on structural calculations were still empirical, and they began to be studied in Italian universities by Camillo Guidi in Turin and Silvio Canevazzi in Bologna, leading to an approximate yet sufficiently accurate calculation method (Panetti 1942). Reinforced concrete proved to be capable of addressing various needs within the productive plant. Its use was associated with:

- the excellent fireproof properties of the material, thanks to the presence of metal bars connected in the lower and upper parts of the beam;
- the improved resistance to aggressive chemical agents;
- the flexibility in relation to the structure and the internal spatiality, also dictated by the presence of machinery;
- the ability to create, through the structural module, a system of openings, both on the façade and on the roof, to improve the internal lighting and ventilation.

2. Advent of the automotive industry

2.1. History context. The informal factory

The first car with a four-wheel combustion engine, designed by Michele Lanza, was built in Turin in 1895. Lanza presented his wagonette drawings at the Officine Martina mechanical

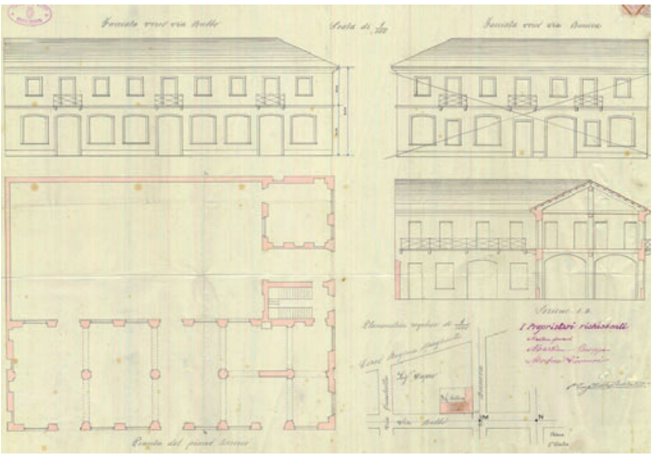


Figure 3. Martina factory. Plan, section, elevation drawings, 1880 (Historical Archive of the City of Turin, PE1880_0135_TAV_02).

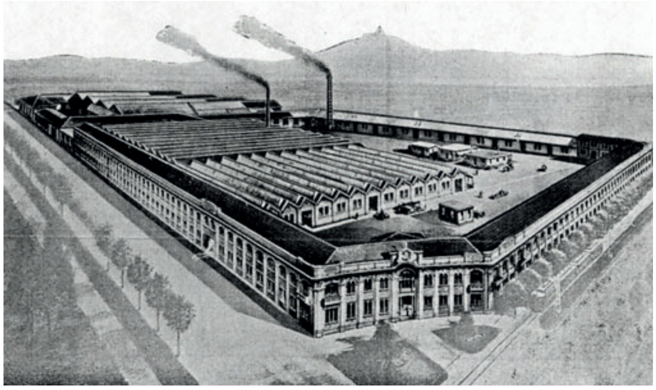


Figure 4. Former SCAT factory. General view, 1910s (Gastaldi, Gino, Società Ceirano Automobili, in «Torino. Rivista mensile municipale», A. VIII, n. 3, marzo, 1928, pp. 151-153, reported in Museo Torino.

factory in Borgo Vanchiglia, where the prototype was manufactured. In the last decade of the nineteenth century, the first commercial automobiles were created in the small workshop of the Ceirano brothers, located in the courtyard of a residential building. The production was purely artisanal, requiring only a few specialized workers.

The initial production sites were not spatially and typologically adequate for standardized mass production. The first cars were manufactured in existing spaces, such as the ground floors of residential or commercial buildings, or in independent structures within urban blocks. These spaces were readapted for production, expanded with load-bearing masonry structures, traditional roofing systems, and closing technologies in iron or wood. Exemplary cases include the Martina factory (1880), the Locati body shop (1886), the first headquarters of STAR in Barriera di Nizza, and the Beccaria factory (1910).

Initially, production focused on chassis construction, with other car components supplied by external body shops and carpenters. The production was, therefore, specialized and not yet integrated.

The progressive development of the automotive sector, transitioning from artisanal to serial production, prompted companies to give an industrial footprint to factories by increasing spatial dimensions. The goal was to consolidate different phases of the production cycle within a single site.

2.2. The typologies of the first automotive factory

Three main and recurring types of automotive production and industrial sites can be identified referring to the period between the end of the nineteenth-century and the beginning of the twentieth-century:

- Traditional load-bearing masonry structures—on the ground floor of residential buildings or in internal courtyards with wooden or metal trussed roofs—relating to the first reuse structures, in which the automobile was born (informal factory-existing building); (Fig. 3)
- Factories with modular spans, predominantly in reinforced concrete, which responded to the adaptability for the different processes of the production (formal factory-urban block);
- Large structures for the steel industry, with the evolution of warehouses and trussed roofing with "shed" and "M" type lighting-ventilation systems.

The second typology became widespread in Turin since the early 1900s with the adoption of patents of the Hennebique System by Porcheddu (Delhumeau 1999).

The frame system, featuring modular mesh in reinforced concrete, marked a crucial phase in transitioning from informal factories, scattered throughout pre-existing building fabrics, to formal factories, organized in a pre-Fordist layout. The new factory was built into a delimited part of an urban block, enclosed within production boundaries, and evolved into a complex system of pavilions during the initial stages of urban expansion.

2.3. The urban factory. From informal to formal

The gradual expansion in both size and spatial demands of industrial and automotive plants significantly influenced the urban development of twentieth-century cities, consequently reshaping the overall territory. Factories strategically settled in new suburbs, such as San Salvario and Borgo San Paolo, within urban blocks. As a result, the Urban Master Plan of the City of Turin from 1906 established building regulations aimed at promoting health and urban aesthetics on the streets, including the standardization of gutter lines, alignments, and molding frames. The contemporary image of the industrial sector was connoted by the emergence of textile-automotive factories (Berta 2008).

At the beginning of the twentieth-century, factories were generally characterized by a representative building overlooking the street. This building served to advertise and to manage functions. Additionally, there was a production facility located within the site, accompanied by smaller service buildings. All the production cycles were consolidated within a single area, forming the urban block. The production buildings on the site were single-story with a repetitive modular structure. Typically, these buildings were enclosed by a shed roof with northern exposure, facilitating indirect illumination of the large internal spaces. (Fig. 4) Traditional construction techniques were alternated with reinforced concrete, employing the technology for pillars, beams, floors and roof structures, as well as foundations. However, the facades retained their traditional masonry. Furthermore, it is possible to note the persistence of neo-Romanesque and, in some cases, neo-Gothic taste is noticeable in the majority of industrial construction projects (Nelva, and Signorelli 1979). (Fig. 5)

The facades of the production departments held a balance between maintaining traditional elements and embracing modern aesthetics, drawing from stylistic repertoires while also incorporating elements of proto-rationalism. A new repertoire of industrial architecture facades spreads, becoming an iterated type from the beginning of the twentieth-century to the 1920s, consistently with the application of reinforced concrete and initially with structures still hidden in the external facade. The stylistic and construction themes are predominantly present in the works of key architects and engineers, including Pietro Fenoglio, Michele Frapolli, and Enrico Bonelli. Representative buildings and garages still follow a traditional construction system and show decorative elements, in transition between eclecticism and adherence to Art Nouveau (Nelva and Signorelli 1979).

2.4. The factory as an urban block

In the first and second decades of the twentieth-century, notable industrial complexes emerged, including FIAT Dante (1900), Itala (1906), Diatto (1905), SPA (1906), Lancia (1911–1919), and FIAT Lingotto (1916). These establishments were regarded not just as symbols of the burgeoning industrial society but also as “cathedrals of work” (Taroni and Zanda 1998).

Within the Turin study context, the transitional phase preceding the Fordist era witnessed the widespread adoption of reinforced concrete, aligning with the dimensional expansion of factories.

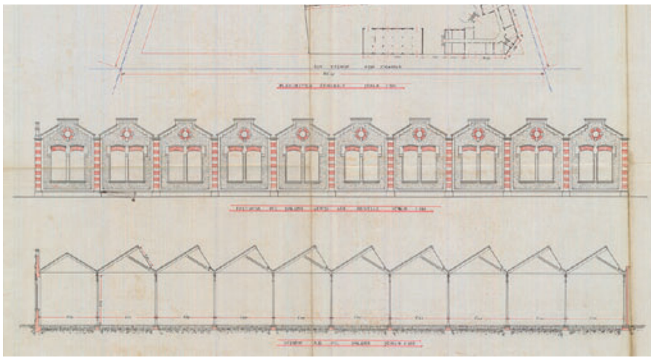


Figure 5. Former Diatto-Clement factory. General planimetry, section and elevation drawings, 1905 (Historical Archive of the City of Turin, PE1905_0291).

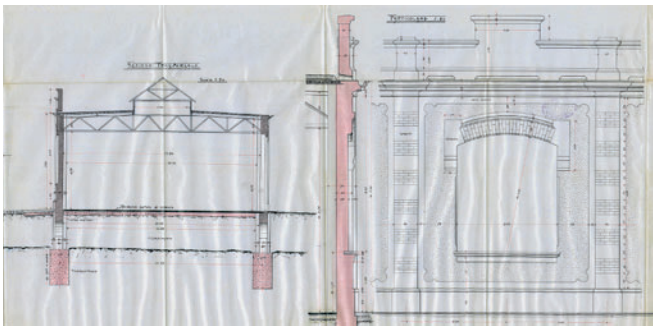


Figure 6. Krieger Factory. Section and detail of the facade drawings made by Pietro Fenoglio, 1905 (Historical Archive of the City of Turin, PE1905_0382_TAV_02)

The Krieger factory, designed and constructed by Pietro Fenoglio in 1905 in Borgo Vanchiglia, Turin, stands out as an early example where the use of reinforced concrete was alternated with traditional techniques and materials. Although the factory is no longer in existence, it comprised three distinct structures: two production departments and a central administrative building, interconnected by two covered passages, within a spacious site. The buildings featured a load-bearing brick masonry structure, incorporating reinforced concrete for foundations, floors, and external finishes, alternating with brick. Iron roofs closed the production departments, while the representative building embraced the Art Nouveau style. (Fig. 6) In 1915, the expansions and renovations were designed by engineers Pagliani and Bongioannini and characterized by the use of single-story reinforced concrete structures, with metal shed roofs, which iterated and adapted the theme of the facade. Another noteworthy example is Itala (1905), designed by Fenoglio. The factory no longer exists and it was situated on a vast site in the Borgo San Paolo expansion area.

The internal space of the production department was characterized by a series of regular bays, supported by slender cast iron pillars that upheld a double-pitched wooden shed roof. Skylights were strategically inserted for each nave to ensure the entry of natural light and internal ventilation. The external walls were constructed with masonry. The representative building, fashioned in the Art Nouveau style, maintained its load-bearing masonry structure. The construction of mechanical workshops within the site utilized reinforced concrete, following the principles of Hennebique patents. This involved a network of pillars supporting a flat roof, interrupted by regular skylights. (Fig. 7–8)

In the existing SCAT factory on Francia Road (1913–17), some sections of the production site still feature cast iron pillars and wooden shed beams. Others have a steel truss

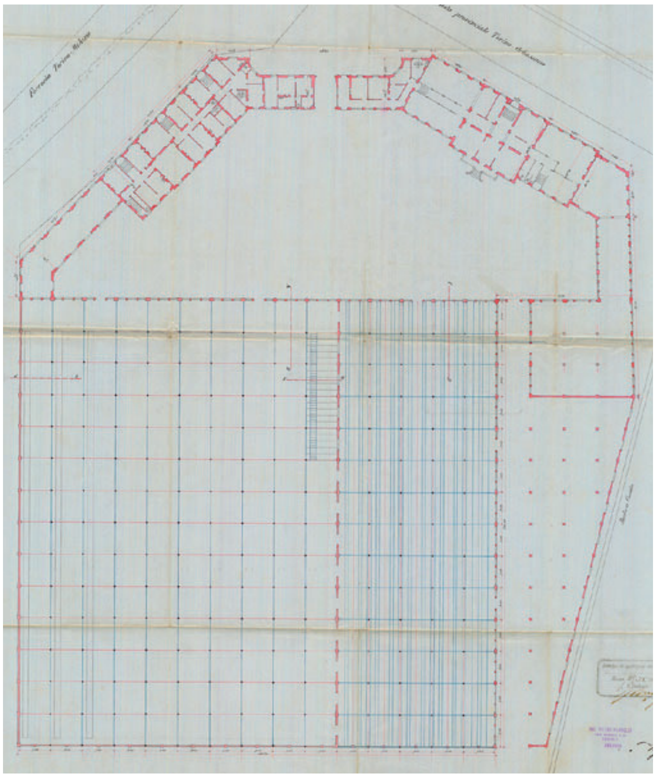


Figure 7. Former Itala factory. General planimetry drawing, 1905 (Historical Archive of the City of Turin, PE1905_0291).

structure with a shed roof and concrete pillars, while the workshops are predominantly constructed with shed roofs employing various meshes of reinforced concrete.

Another significant example is the former SPA factory, designed and built in 1906 by engineer Lodovico Lavagnino within a large site, a result of several expansions in Borgo San Paolo.

On the industrial site, there were diverse buildings, primarily constructed with reinforced concrete and characterized by different construction typologies. The prevailing typology was based on the coupling of modular mesh with varying heights. The taller sections facilitated mechanical processing with overhead cranes and winches, and internal lighting through the incorporation of bands of upper side windows. (Fig. 9)

This construction typology represented an innovation compared to the traditional shed roof system and played a crucial role in determining the external facade design, concealing the structure. Along the perimeter, various buildings intended for administrative and service use were arranged, highlighted by their two-floor structure, accentuating the factory enclosure.

2.5. The construction typologies of the reinforced concrete automotive factory

In the development of Turin during the first decade of the twentieth century, four recurring and innovative construction typologies in reinforced concrete can be identified:

- Modular structures with a single-story frame and crossed beams, featuring geometries tailored to the lot and sections congruent with loads (up to 500–700 kg/m2);

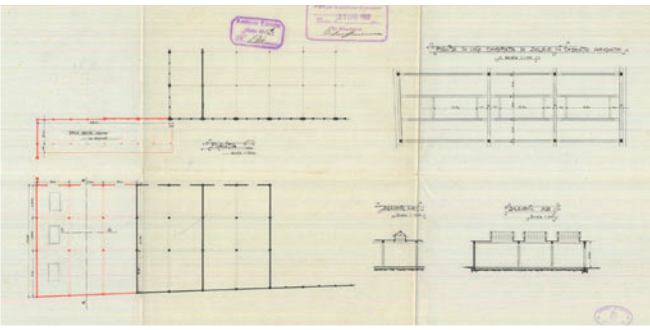


Figure 8. Former Itala factory. Plans and sections drawings, 1912 (Historical Archive of the City of Turin, PE1912_0608_TAV_01).

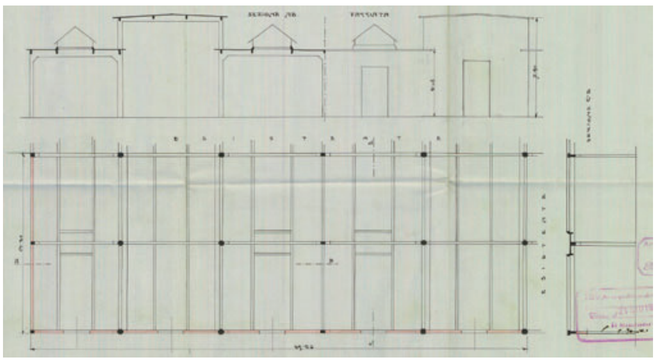


Figure 9. Former SPA factory. Section details drawings, 1911 (Historical Archive of the City of Turin, PE1911_0511_TAV_01).

- Modular mesh with beams supporting a shed roofing system oriented towards the north to minimize sun exposure, as seen in the Alessio body shop (1907) designed by Fenoglio;
- Frame system with varying heights, reaching up to 15 m, incorporating intermediate stiffening beams and flat roofs with skylights, designed for both production and services. An example of this is the FIAT facility on Cigna Road (1915), designed by Giacomo Mattè Trucco;
- Composite truss beam systems, commonly employed to enclose large mechanical openings, featuring continuous lighting and ventilation towers on the roof. Examples include the FIAT Foundry Workshops at the Barriera di Nizza (1916) and the FIAT steelworks on Cigna Road (1922).
- A table is shown featuring some of the most significant case studies of automotive factories, categorized by urban typology and the utilization of reinforced concrete, following Hennebique patents, in various contexts. (Fig. 10)

Sites	Urban tipology	Functional and construction tipology
S.T.A.R (1904-16)	Part of urban block	Frame system; modular mesh
Diatto (1905)	Urban block	Frame system (flat roof); modular mesh; external finishes and decorations
Krieger (1905)	Urban block	Foundations, floors, external finishes and decorations with traditional materials
Carrozzeria Locati e Torretta (1905)	Urban block	Frame system (flat roof with skylights); modular mesh
Fiat Grandi Motori (1906)	Urban block / multi-storey building	Frame system (flat roof)
Farina (1906)	Urban block	Regular complex with concrete spans and shed roof system
Itala (1906)	Urban block	Frame system (flat roof with skylights); modular mesh
SPA (1906)	Urban block	Frame system at different heiths (flat roof with skylights); modular mesh
Carrozzeria Alessio (1907)	Urban block	Frame system (shed roof); modular mesh
Lancia via Monginevro (1911-34)	Urban block / multi-storey building / vertical factory	Frame system (flat and shed roofs)
SCAT corso Francia (1914)	Urban block	Modular mesh (pillars) with traditional materials
Chiribiri (1915)	Urban block	Frame system supporting shed roof system; administration building and external finishes-decorations
Lingotto (1916-22)	Vertical factory	Frame system
Lancia c.so Racconigi (1919-22)	Urban block / multi-storey building	Frame system (flat roof); modular mesh
RIV (1926)	Vertical factory	Frame system

Figure 10. Table showing some significant case studies of automotive factories.

3. The vertical factory

Despite substantial progress in the industrial sector during the first two decades of the twentieth century, the production cycle still grappled with external diseconomies, leading to long and discontinuous lead times.

The rationalization of Italian factories sought inspiration from industrial and construction models directly imported from the U.S.A. (Bigazzi 2020). Taylorism ushered in radical changes in industrial organization by seamlessly integrating the work of experts and engineers with that of accountants.

This integration was crucial because the challenges of company management involved both technical and administrative aspects. In this transformative era, the worker and the machine became the objects, rather than the subjects, of the new production model (Gabetti 1955).

Henry Ford managed to surpass Taylor's experimentation in the automotive sector by perfecting his method. In Europe, Fordism spread more slowly than in the United States, particularly between the two wars. However, in European workshops, the gradual prevalence of mechanical overhead conveyors corresponded, in certain sectors, to the persistence of highly specialized workers, as seen in the mechanical sector. The typology that best represented this industrial model was the vertical factory. In Italy, one of the earliest examples is represented by FIAT's Lingotto factory.

At the beginning of the twentieth century, FIAT had its own factory district on Dante Road. The construction of the Lingotto vertical factory aimed to consolidate the entire production cycle within a single building. Designed and built by Giacomo Mattè Trucco, with the initial management of the construction site overseen by Giovanni Porcheddu, the Lingotto, still standing today, presents itself as a monolithic structure with 5 floors above ground. It is based on a 6 x 6 m modular mesh in reinforced concrete. The repetitive composition of the frame, comprising beams and pillars, allows for limitless vertical expansion (Zorgno, 1994). It is considered that the Porcheddu company requested patents in 1909 and 1911, aimed at also experimenting in Lingotto, with the first types of steel reinforcing bars or deformed steel bars have ribs, to good bonding is achieved between concrete and to improve the tensile strength of concrete (Schlimme 2012). The building features two parallel longitudinal bodies joined by five transversal elements, each housing two staircases and delimiting four internal courtyards. A unique architectural element is the car track on the roof, extending for more than 1 km. Lingotto, therefore, became a model for subsequent vertical constructions in Turin, such as the Lancia case in Issiglio Road (1934), preceding the new industrial plant ideology in Mirafiori (1939)

In 1926, near Lingotto, the RIV factory was constructed, replacing the Locati and Torretta body shop complex built by Fenoglio at the beginning of the century. The initial building had a length of 150 m and 5 floors above ground, with a total height of approximately 27 m. The project was based on a modular mesh with three naves, where the central one was larger than the two lateral ones. The reinforced concrete frame repeated in height. In 1938, a twin building was added, mirroring the first (Fig. 11–12).

The exposed reinforced concrete structure defined the facades and openings, a design feature also observed in Mattè Trucco's works from the mid-1910s, such as FIAT Acciaierie in via Cigna and OGM (Pozzetto 1970).

3.1. The international typological evolution and the vertical factory

The Lingotto is inspired by American models, the Packard Motor Plant 10 of Detroit (1905), the Ford of Highland Park (1909) and the River Rouge Complex (1917), in which a standardized and partially prefabricated structural system was adopted. The frame is characterized by flanges bent at 45° and fixed in the steel carpentry to distribute tensile stresses and increase the resistance of the reinforced concrete. The system allows high operating loads beyond the improvement of the daylight factory (Maspoli 2022).

The combination of "program, structure and economy" is based on the American automotive model, constructively represented by Albert and Julius Kahn. It addressed the new challenges of industrial buildings, in relation to new integrated engineering systems (Hildebrand 1974).

In 1905, Albert Kahn designed Packard Building 10, the first reinforced concrete building in Greater Detroit. Traditional brick or stone masonry in the U.S.A. was replaced by reinforced concrete in large factories in the same decade. Kahn's Trussed Bar System became the dominant system in the automotive sector, competing with the Coignet patents, and with those perfected by Ernest Ransome, in relation to Hennebique patents. The reinforced concrete construction therefore opened up a broad, cultural and symbolic vision of the modernization of the early 1900s, as underlined by Amy Slaton for the American case (Slaton 2001, 12): "The shifting social relations of concrete construction resonated with a broader vision of a modernized industrial nation: the stark, functionalist aesthetic of the factories emerged from the hands of builders willing and ready to create a fully modern milieu".

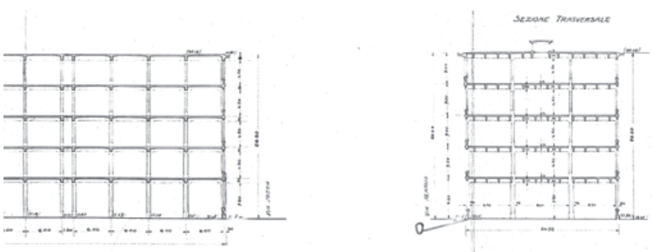


Figure 11. Former RIV factory. Section details drawings, 1926 (Historical Archive of the City of Turin, PE1926_1_00038).

Figure 12. Former RIV factory. Nizza road, 1972 (Historical Archive of the City of Turin, FT 13A07_017).

Conclusion

The rapid pace of technological innovation influenced the construction of automobiles and the development of automotive factories. Technological choices and settlement conditions shaped the appearance of these buildings, prompting the exploration of a new industrial architectural language. This evolution ranged from eclecticism to Art Nouveau, eventually leading to the rationalist approach of exposing structures in reinforced concrete. Production buildings became more prominent in the urban structure, overlooking roads.

The reinforced concrete frame system, complete with thin slabs, beams, and pillars, paved the way for creating multi-story buildings, defining the integrated and pre-Fordist industrial model. Notable examples include the Fiat Grandi Motori (1906), the Rothschild workshops (1906) by Enrico Bonelli, the Lancia factories in Borgo San Paolo (from 1911), and the FIAT complex in Dante and Cigna roads (1913–15). These structures, with their stylistic and formal transition from late Art Nouveau to the adoption of modernism in reinforced concrete, foreshadowed subsequent creations like the Lingotto factory (1916–21). The study of this industrial and construction transition opens up a reflection that can be fruitful in international terms, as an incitement to recognition, heritage, cultural tourism and compatible reuse. Moreover, the evolution of technological advancements runs in parallel with the establishment of the foundational modern framework for engineering and construction companies. This framework is a prototype for local design firms, as well as for the technical design and construction structure within corporate entities.

Bibliography

Berta, Giuseppe. 2009. L'Italia delle fabbriche. La parabola dell'industrialismo nel Novecento. Bologna: Il Mulino.

Berta, Giuseppe. 2008. *Torino Industria. Persone, lavoro, imprese.* Torino: Archivio Storico della Città di Torino.

Biffignandi, Donatella. 2013. "Nascita e sviluppo dell'industria automobilistica." In *Enciclopedia Italiana di scienze, lettere ed arti*. EDITORS? PAGE RANGE? Roma: Istituto della Enciclopedia Italiana.

Bigazzi, Duccio. 2008. *Torino Industria. Person, lavoro, imprese.* Torino: Archivio Storico della Città di Torino.

Dameri, Annalisa. 2012. "Il cemento armato e lo 'stile nuovo': Ecco lo stile nuovo come." In *Architettura dell'eclettismo. Studi storici, rilievo e restauro, teoria e prassi dell'architettura*, ed. Loretta Mozzoni e Santini Stefano PAGE RANGE? LOCATION? PUBLISHER?.

Delhumeau, Gwenael. 1999. *L'invention du béton armé, Hennebique 1890–1914.* Paris: Norma Editions.

Gabetti, Roberto. 1955. Origini del calcestruzzo armato. Torino: Edizioni Ruata.

Gabetti, Roberto. 1977. Architettura industria Piemonte negli ultimi cinquant'anni. Torino: Cassa di risparmio.

Gabetti, Roberto. 1979. Fordismo e territorio in Italia durante il fascismo. In *Storia Urbana*.

Girocchi, Giacomo, Rossella Maspoli. 2022. "La fabbrica formale e la fabbrica informale:Prospettive di patrimonializzazione e turismo industriale / The formal factory and the informal factory: Prospects for capitalization and industrial tourism." In *2° Stati Generali del Patrimonio Industriale*, ED.??? 7289–7319. Roma-Tivoli.

Hildebrand, Grant. 1974. Designing for Industry: Architecture of Albert Kahn. Boston: MIT Press.

Iori, Tullia. 2001. Il cemento armato in Italia dalle origini alla seconda guerra mondiale. Roma: Edilstampa.

Maspoli, Rossella. 2020. "The innovation of reinforced concrete in the textile and mechanical factories of the early 1900s in the North-West: Buisness models, patents and critical issues of recovery." *Patrimonio Industriale*. VOL.? PAGE RANGE?

Maspoli, Rossella. 2022. "L'evoluzione della distribuzione verticale e il cemento armato nella fabbrica industriale del primo Novecento, in Scale e risalite nella Storia della Costruzione in età Moderna e Contemporanea." In Scale e risalite nella Storia della Costruzione in età Moderna e Contemporanea, ed. Construction History Group, 417–438. Torino: Politecnico di Torino.

MAUTO, Centro di Documentazione. 2002. Elenco delle aziende italiane dedicatasi alle costruzioni automobilistiche. Disegno di legge, n. 1628. Senato della Repubblica. Atto parlamentare, Roma-Torino.

Mikesell, Stephen. 2019. Ernest Leslie Ransome: A Vital California Engineer and Builder. California Historical Society. (pp. 77–96)

Miletto, Enrico, Donatella Sasso. 2017. *Torino città dell'automobile. Un secolo di industria dalle origini a oggi.* Torino: Edizioni del Capricorno.

Nelva, Riccardo, Bruno Signorelli. 1979. Le opere di Pietro Fenoglio nel clima dell'Art Nouveau Internazionale. Bari: Dedalo Libri.

Nelva, Riccardo, Bruno Signorelli. 1990. Avvento ed evoluzione del calcestruzzo armato in Italia: il sistema Hennebique. Milano: Edizioni di scienza e tecnica.

Panetti, Modesto. 1942. Camillo Guidi Commemorazione della vita e dell'opera scientifica (1853–1941). *Atti R. Accademia delle Scienze di Torino*. (pp. 302–307)

Pozzetto, Marco. 1970. *La Fiat-Lingotto, un'architettura.* Torino: Centro Studi Piemontese.

Schlimme, Hermann. 2012. "Das internationale Hennebique-Patent zur Herstellung von Stahlbetonbauten und seine Anwendung in Italien." *Romisches Jahrbuch der Bibliotheca Hertziana* (pp. 39–426).

Slaton, Amy E. 2003. Reinforced Concrete and the Modernization of American Building, 1900–1930. Johns Hopkins University Press.

Symmonet, Cyrille. 1992. "Le Béton Coignet. Stratégie commerciale et déconvenue architecturale." *Le cahiers de la richerche architecturale* (n. 29, pp. 15–32).

Taroni, Stefania, Antonio Zanda. 1998. *Cattedrali del lavoro.* Torino: Allemandi.

Zorgno, Anna Maria. 1994. "Un grande cantiere." In *Il Lingotto 1915–1939. L'architettura, l'immagine e il lavoro*, ed. Carlo Olmo. PAGE RANGE? Torino: Allemandi (pp. 57–122).

Archival sources

Progetti edilizi, I Cat., 1770–1915, Historical Archive of the City of Turin.