

HISTORY OF CONSTRUCTION CULTURES



VOLUME 1



edited by
João Mascarenhas-Mateus
and **Ana Paula Pires**

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HISTORY OF CONSTRUCTION CULTURES



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History of Construction Cultures

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Introduction: *History of Construction Cultures*

We are what we build and how we build; thus, the study of Construction History is now more than ever at the centre of current debates as to the shape of a sustainable future for humankind. Embracing that statement, the present work takes the title *History of Construction Cultures* and aims to celebrate and expand our understanding of the ways in which everyday building activities have been perceived and experienced in different cultures, times and places.

This two-volume publication brings together the communications that were presented at the 7ICCH – Seventh International Congress on Construction History, broadcast live from Lisbon, Portugal on 12–16 July 2021. The 7ICCH was organized by the Sociedade Portuguesa de Estudos de História da Construção (Portuguese Society for Construction History Studies – SPEHC); the Lisbon School of Architecture, University of Lisbon; its Research Centre (CIAUD); and the College of Social and Human Sciences of the NOVA University of Lisbon (NOVA FCSH).

This is the first time the International Congresses on Construction History (ICCH) Proceedings will be available in open access format in addition to the traditional printed and digital formats, embracing open science principles and increasing the societal impact of research. The work embodies and reflects the research done in different contexts worldwide in the sphere of Construction History with a view to advancing on the path opened by earlier ICCH editions. The first edition of ICCH took place in Madrid in 2003. Since then, it has been a regular event organized at three-year intervals: Cambridge (2006), Cottbus (2009), Paris (2012), Chicago (2015) and Brussels (2018).

7ICCH focused on the many problems involved in the millennia-old human activity of building practiced in the most diverse cultures of the world, stimulating the cross-over with other disciplines. The response to this broad invitation materialized in 357 paper proposals. A thorough evaluation and selection process involving the International Scientific Committee resulted in the 206 papers of this work, authored by researchers from 37 countries: Australia, Austria, Belgium, Brazil, Bulgaria, Canada, China, Dominican Republic, Ecuador, Egypt, Estonia, France, Germany, India, Iran, Ireland, Italy, Japan, Mexico, Netherlands, New Zealand, Norway, Peru, Poland, Portugal, Puerto Rico, Russia, Serbia, Spain, South Africa, Sweden, Switzerland, Thailand, United Arab Emirates, United Kingdom, United States of America, and Venezuela.

The study of construction cultures entails the analysis of the transformation of a community's knowledge capital expressed in the activity of construction. As such, Construction History is a broad field of knowledge that encompasses all of the actors involved in that activity, whether collective (contractors, materials producers and suppliers, schools, associations, and institutions) or individual (engineers, architects, entrepreneurs, craftsmen). In each given location and historical period, these actors have engaged in building using particular technologies, tools, machines and materials. They have followed specific rules and laws, and transferred knowledge on construction in specific ways. Their activity has had an economic value and belonged to a particular political context, and it has been organized following a set of social and cultural models.

This broad range of issues was debated during the Congress in general open sessions, as well as in special thematic sessions. Open sessions covered a wide variety of aspects related to Construction History. Thematic sessions were selected by the Scientific Committee after a call for proposals: they highlight themes of recent debate, approaches and directions, fostering transnational and interdisciplinary collaboration on promising and propitious subjects. The open sessions topics were:

- Cultural translation of construction cultures: Colonial building processes and autochthonous cultures; hybridization of construction cultures, local interpretation of imported cultures of building; adaptation of building processes to different material conditions;
- The discipline of Construction History: Epistemological issues, methodology; teaching; historiography; sources on Construction History;
- Building actors: Contractors, architects, engineers; master builders, craftspeople, trade unions and guilds; institutions and organizations;
- Building materials: Their history, extraction, transformation and manipulation (timber; earth, brick and tiles; iron and steel; binders; concrete and reinforced concrete; plaster and mortar; glass and glazing; composite materials);

- Building machines, tools and equipment: Simple machines, steam operated-machines, hand tools, pneumatic tools, scaffolding;
- Construction processes: Design, execution and protective operations related to durability and maintenance; organization of the construction site; prefabrication and industrialization; craftsmanship and workshops; foundations, superstructures, roofs, coatings, paint;
- Building services and techniques: Lighting; heating; ventilation; health and comfort;
- Structural theory and analysis: Stereotomy; modelling and simulation; structural theory and structural forms; applied sciences; relation between theory and practice;
- Political, social and economic aspects: Economics of construction; law and juridical aspects; politics and policies; hierarchy of actors; public works and territory management, marketing and propaganda;
- Knowledge transfer: Technical literature, rules and standards; building regulations; training and education; drawings; patents; scientific dissemination, innovations, experiments and events.

The thematic sessions selected were:

- Form with no formwork (vault construction with reduced formwork);
- Understanding the culture of building expertise in situations of uncertainty (Middle Ages-Modern times);
- Historical timber constructions between regional tradition and supra-regional influences;
- Historicizing material properties: Between technological and cultural history;
- South-South cooperation and non-alignment in the construction world 1950s–1980s;
- Construction cultures of the recent past: Building materials and building techniques 1950–2000;
- Hypar concrete shells: A structural, geometric and constructive revolution in the mid-20th century;
- Can engineering culture be improved by construction history?

Volume 1 begins with the open session “Cultural translation of construction cultures” and continues with all of the thematic sessions, each one preceded by an introductory text by the session chairs. The volume ends with the first part of the papers presented at the open sessions, organized chronologically. Volume 2 is dedicated to the remaining topics within the general themes, also in chronological order.

Four keynote speakers were chosen to present their most recent research results on different historical periods: Marco Fabbri on “Building in Ancient Rome: The fortifications of Pompeii”; Stefan Holzer “The role of temporary works on the medieval and early modern construction site”; Vitale Zanchettin “Raphael’s architecture: Buildings and materials” and Beatriz Mugayar Kühl “Railways in São Paulo (Brazil): Impacts on the construction culture and on the transformation of the territory”.

The editors and the organizers wish to express their immense gratitude to all members of the International Scientific Committee, who, despite the difficult context of the pandemic, worked intensively every time they were called on to give their rigorous evaluation of the different papers.

The 7ICCH was the first congress convened under the aegis of the International Federation of Construction History, founded in July 2018 in Brussels. Therefore, we are also very grateful to all the members of the Federation, composed of the presidents of the British, Spanish, Francophone, German, U.S. and Portuguese Societies and its Belgian co-opted member. A special thanks is due for all the expertise and experience that was passed on by our colleagues who have been organizing this unique and world significant event since 2003, and in particular to our predecessors from all the Belgian universities who organized 6ICCH.

The editors wish to extend their sincerest thanks to authors and co-authors for their support, patience, and efforts. This two-volume work would not exist but for the time, knowledge, and generosity they invested in the initiative.

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João Mascarenhas-Mateus and Ana Paula Pires

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Luigi Santarella: Reinforced concrete design culture through the technical literature

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ABSTRACT: Luigi Santarella is considered to have been one of the most important Italian theorists in the field of reinforced concrete yet his professional activity is still completely ignored by the critical literature. The structures designed by Santarella – concrete frames, bridges, canopies for stadiums and roofing systems with innovative trusses – and built by contractors specializing in reinforced concrete construction represent the pragmatic experimental field of application of the building principles set out in his widespread theoretical books. The relationship between the building principles and the structural solutions analysed in his texts with his designed and realized structures, in the wider context of the design and construction culture of the time, will shed light on the interaction between the design process and construction instances as well as on the mechanics related to their dissemination through the technical literature.

1 INTRODUCTION

The Italian engineer, theorist and structural designer Luigi Santarella (Corato, June, 12 1886 – Milan, September 7, 1935) is considered one of the pioneers of the experimentation and application of reinforced concrete in Italy: yet although not completely ignored, his career and professional activities are still unexplored by the academic literature (Bologna 2015). And there has been little investigation into his life and accomplishments over the years compared to those of other Italian structural designers of his time, such as Attilio Muggia, Gustavo Colonnetti or Pier Luigi Nervi.

Having graduated from the Politecnico di Milano in 1910 with a degree in civil engineering, Santarella continued to be linked with the Milanese university until 1935, the year of his premature death. He was both a lecturer and director of the *School of Specialization for Reinforced Concrete Construction* promoted by the Fratelli Pesenti Foundation, one of the six Schools of Advanced Studies in the various branches of engineering, added to the five-year study course of the Regio Politecnico di Milano in 1926. In addition to teaching, he had also developed intense professional activities in the early 1920s, along with the dissemination of technical and scientific knowledge: both theory and practice represented two significant parallel and closely interrelated paths for the engineer.

Thanks to the widespread distribution of his books by the Milanese publishing house Ulrico Hoepli, Santarella established his reputation from

1923 onwards for his translation into Italian of volumes such as *Theory and Practice of Reinforced Concrete* [*Teoria e pratica del cemento armato*] by Emil Mörsch (Mörsch 1923) and *The Science of Construction* [*La scienza delle costruzioni*] by Heinrich Müller-Breslau (Müller-Breslau 1927). Santarella gradually developed his own personal and distinctive method of spreading technical knowledge through the publication of numerous articles, books and manuals on the theory and experiments carried out on reinforced concrete structures at the time. His *Handbook of Reinforced Concrete* [*Prontuario del cemento armato*], published by Hoepli, became a real best seller over the years and is still in print today. Having been progressively updated, it is now in its thirty-eighth edition and continues to contribute to the training of entire generations of architects and engineers.

The reason for the success of his books lies in the author's acknowledged ability to present and explain the results of research and experiments carried out on reinforced concrete, clearly and concisely, using drawings and construction diagrams but also numerous photographs of building sites and the respective works. The many reviews published from 1924 onwards in the most popular trade journals of the time, both in Italy and abroad – such as *Il Monitore Tecnico*, *L'industria italiana del cemento*, *Engineering* and *La Technique des Travaux* – bear valuable witness to this success. Santarella knew how to make complex principles of calculus and implementation of material accessible to architects and other operators in the construction

industry of the time who lacked the scientific preparation of engineers, publishing real theoretical-practical treatises on the subject. His books are richly illustrated: they contain numerous written recommendations, as well as design suggestions and theoretical explanations but, above all, explore matters of a constructive nature, providing examples of structural dimensioning calculations developed and commented on.

For example, in the first edition of *Italian Bridges in reinforced concrete* [*Ponti italiani in cemento armato*], published in 1924 with Eugenio Miozzi, another great Italian engineer of the time, Santarella's intention was to compile and circulate the most important projects for the reconstruction of the "glorious bridges sacrificed to war" (Santarella & Miozzi, letter to Mussolini, April 27, 1924a) built in Italy in recent years: with 350 pictures appearing in the text and 90 design boards published in the Atlas, design experts and site technicians alike were able to make use of numerous examples, described and illustrated by detailed executive drawings, without resorting to the complex calculus formulas that characterised most of the technical literature in the sector (Miozzi, letter to Hoepli, June 23, 1922).

According to Santarella, design and building site practice and the theory defined by the emerging discipline of building technology represented an indivisible whole. This approach allowed him to pursue a veritable action of scientific propaganda at the national level, disseminating through his publication's pictures of projects – many of which he had developed himself – and the most significant and daring (for the time) reinforced concrete constructions designed by engineers and implemented by Italian construction companies all over Italy.

2 BOOKS AS OPERATIVE TOOLS: A NEW RELATIONSHIP BETWEEN TECHNICAL TEXT AND IMAGE

Santarella and his books became part of a publishing current that had already been clearly defined by Hoepli, the so-called "Technical Library". Examples of this type of publication include the very popular *Manual for the Civil and Industrial Engineer* [*Manuale dell'ingegnere civile e industriale*] by Giuseppe Colombo (Colombo 1877) and *Concrete and Reinforced Concrete Constructions* [*Le costruzioni in calcestruzzo ed in cemento armato*] by Giuseppe Vacchelli (Vacchelli 1899), both of which were also used to support the teaching programmes of technical schools and aimed particularly at so-called "practical engineers" (Decleva 2001), whose activities mainly focused on building site practice. Unlike these books dedicated to structural dimensioning, Santarella's works establish a very different relationship between texts and pictures, producing real illustrated atlases.

Technical manuals represented one of Hoepli's main commercial lines of business. Santarella fitted into

it perfectly, innovating the communication system used to deal with complex issues, such as structural dimensioning and its implementation in cementitious structures, accompanying the formulas with descriptive texts as well as drawings of construction details, photographs of building site machinery and the analyzed structures (Santarella 1932). In 1926, Santarella published the first edition of *Reinforced Concrete in Civil and Industrial Construction* [*Il cemento armato nelle costruzioni civili ed industriali*], in two volumes (Santarella 1926). Divided into three parts, with 640 illustrated boards in the text and an atlas with 64 construction drawings, this book also aimed at highlighting the progress in reinforced concrete usage in Italy as well as providing builders and designers with a wealth of illustrative materials on significant examples. The innovation of Santarella's book lies precisely in the part dedicated to the so-called Monographs, illustrated technical data sheets of 39 works that he selected, accompanied by numerous construction details. Among the over 600 images contained, Santarella also included some pictures of his projects, such as the 1920 long span roof of the Fossati garage in Biella, in the work. The same photographs of his structures were simultaneously published in the pages of the most popular technical journals of the time along with projects by other engineers who were destined for greater critical success, such as the airship hangars built in Parma in 1918 and the Fiat Lingotto factory in Turin in 1922: structures built by the Ditta Giovanni Porcheddu, the North Italian licensee of the Hennebique patent (San Nicolò 1925).

The distribution of Santarella's book in Italy is indicative of the success of a communicative language that was unheard of at the time, extremely effective and destined to have far-reaching repercussions on professional practice. By 1927, the book was already in its second edition, completely renewed and expanded, described as the most complete and reliable volume on the subject on the Italian book market (*Atti del sindacato provinciale fascista ingegneri di Milano*, June 1927, 47). In the second edition Monographs, Santarella describes and publishes some pictures of other saw-tooth roofing which he had designed for the wool mill Trabaldo in Piaceri – near Biella –, the cotton mill Val Seriana in Gazzaniga – near Bergamo – and for the silk factory Seterie Stampate Tondani plant in Portichetto – near Como (Santarella 1927).

Two years later, and once again with Hoepli, Santarella published the first edition of the *Handbook of Reinforced Concrete* [*Prontuario del cemento armato*] (Santarella 1929d). The book's long subtitle – *Data and formulas to speed up the study and control of schematic design in the most common structures* – clearly defines its aims: to serve as a valuable educational tool for architects and engineers but also a pragmatic operational tool for professional practice. Santarella showed, once again, his constant interest both in providing the reader with theoretical contributions and in illustrating the main results of their

application. This reflected a process of transferral of scientific and technical knowledge capable of considering both theoretical aspects and professional and building site practice. Again, the diagrams and graphic elaborations – drawn by Santarella and re-elaborated by the publisher – aimed to highlight the technical progress made in the use of reinforced concrete in Italy, presenting solutions and design suggestions that were as bold as they were economically and constructively appreciable. “Optimization” was the key word often used by Santarella, with reference to both the construction materials used and the time dedicated to the design and construction of the building.

Santarella proved his design and educational skills to the academic and professional community at the time with these publications, enabling designer-readers to increase their creative capacity and stimulating their constructive intuition with a vast repertoire of dimensioned, calculated and built examples from which to draw inspiration. This publishing strategy turned out equally successful for both Santarella and Hoepli, the latter using it to expand its catalogue with editorial products of a purely technical nature comparable to those published outside of Italy by more famous American publishers (Hool 1918; Warren 1906). Critics of the time recognised this success as demonstrated by the numerous positive reviews that appeared in the architectural and engineering journals of the day.

3 BOOKS AS CATALOGUES OF GOOD PRACTICES

In the early 1920s, Santarella began collaborating with authoritative Italian engineering journals such as *Il Monitore Tecnico*, *L'Industria* and *Il Cemento Armato*, both with his articles and in his capacity as member of scientific and editorial committees. Using a narrative structure in which science and experience offered a balanced picture of the discipline, in both his books and articles, Santarella highlighted that much-discussed combination of theory and practice. The same formula, already widely tested for his books, was used for his numerous essays and articles, which appeared in the technical journals of the time: sketches, construction details and pictures accompanied calculus formulas, tables and diagrams. While teaching, Santarella was also able to conduct intense professional activities as consultant to construction companies specialising in the execution of reinforced concrete structures: the projects by Santarella – bridges, grandstands, stadium canopies and various roofing systems with innovative prefabricated trusses – represent that pragmatic experimental field of application of the principles of structural dimensioning as well as the technical and construction techniques displayed in his books. Santarella demonstrates his constant ability to deal with professional and building site practices, revealing an approach to



Figure 1. On-site prefabrication of the reinforced concrete truss girders within reusable wooden formwork (Santarella 1931: 346).

the theorisation of structural design still permeated by a purely nineteenth-century empiricism: “As has always been the case with technique, particularly in this field, in which experimental theoretical study is highly complex and indeterminate, the implementation of building practice precedes theory; but the development of the latter will definitely allow progress in applications, minimising the problem of empiricism as far as possible” (Santarella 1930a, IV).

However, it is this degree of empiricism derived from building site practice that led to the introduction in Italy of construction techniques that were decidedly innovative at the time. One such case was the design of long span roofs made of prefabricated reinforced concrete trusses: from 1918, Santarella claimed that he had designed and built triple saw-tooth prefabricated trusses made of reinforced concrete, with 20 metre spans, as the supporting structure for the roofing of huge industrial buildings. This means he was ahead of both the design of the large airship hangar roofs made of prefabricated reinforced concrete components promoted by the French engineer Henri Lossier from 1921 onwards on the pages of *Le génie civil* (Dantin 1921), and Nervi’s experiments, which were not patented until 1939 – after Santarella’s death – which led to the construction of his famous hangars for the Italian airforce (Gargiani & Bologna 2016).

Consequently, the roof of the Fossati garage in Biella in 1920 can be considered as one Santarella’s most innovative projects characterised by the highest degree of technical experimentalism (Figures 1–2).

As a result, its designer presented it in several publications of the time. Santarella described the roof as an “efficient, strong, light and, above all, economical construction” (Santarella 1922): the need to make the most of the space available, reducing the number and thickness of the supporting columns to the minimum, was met by using a triple saw-tooth truss system, thanks to which it was possible to create a large space of 20 × 40 metres, without any intermediate columns, measuring a total of 800 square metres (Figure 3). Each roof truss girder was prefabricated on the ground within the building site area, with a series of quick

operations, and then lifted and assembled (Santarella 1930c). This prefabricated system and building site organisation were never patented by Santarella but were taken up again later by architects, engineers and



Figure 2. Assembly operation of the reinforced concrete truss girders, previously prefabricated on the ground (Santarella 1931: 346).

companies for the design and construction of long span roofs in post-war Italy and indeed led to the construction of much more celebrated buildings and infrastructures (Iori 2001, 150).

The same lightness of structure and speed of execution can also be found in the design and construction of cast-in-place reinforced concrete railway bridges and viaducts, built using innovative and complex formwork systems. For example, analysis of the designs for the bridge over the River Erno, between Solco and Lesa – near Novara – built by the Attilio Sommaruga company in 1926 (Figure 4), and the bridge over the River Brembo – near Brembate – for the Milan-Bergamo motorway, built by the Bianchi-Steiner company in 1927 (Figures 5–6), both with a single span, highlights the result of a construction process that aimed to adopt solutions that were “as bold as they were economically viable” (Santarella 1930c): a balance between structural form and the physical and chemical properties of the concrete used. Santarella himself claimed that the study of these bridges could “enlighten the builder and strengthen the creative intuition of new forms, making them increasingly responsive to the needs of technology” (Santarella 1930c). It is no coincidence that what little literature exists on the subject has already defined them as “two remarkably bold works that honour the Italian technique” (De Ceglia 2007).

A striking example of his design approach with the use of cast-in-place reinforced concrete, which can still



Figure 3. 1920, L. Santarella, Garage Fossati, Biella. Interior view of the roofing system (A. Bologna, private archive).

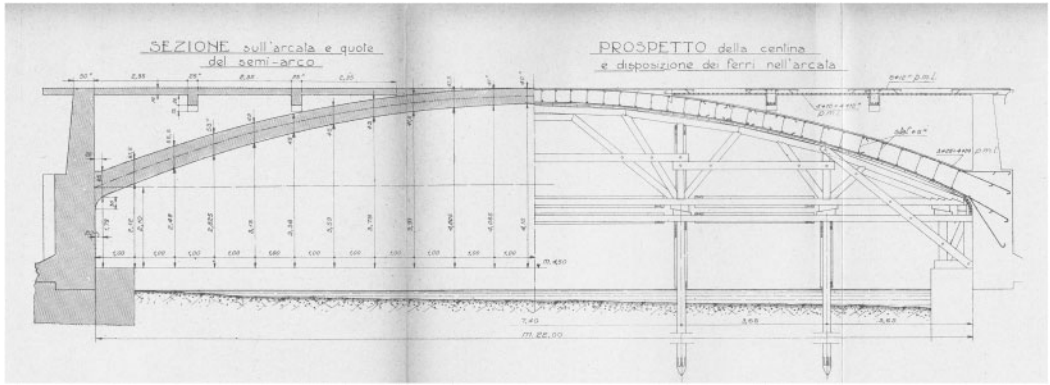


Figure 4. 1926, L. Santarella, bridge over the River Erno. "Section on the arcade" and "view of the rib" (Santarella 1932: tav. 51).

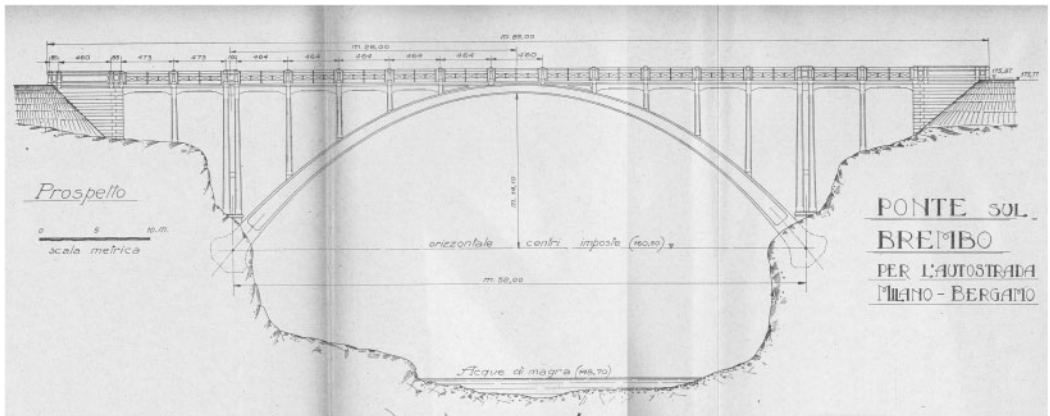


Figure 5. 1927, L. Santarella, bridge over the River Brembo (Santarella 1932: tav. 35).

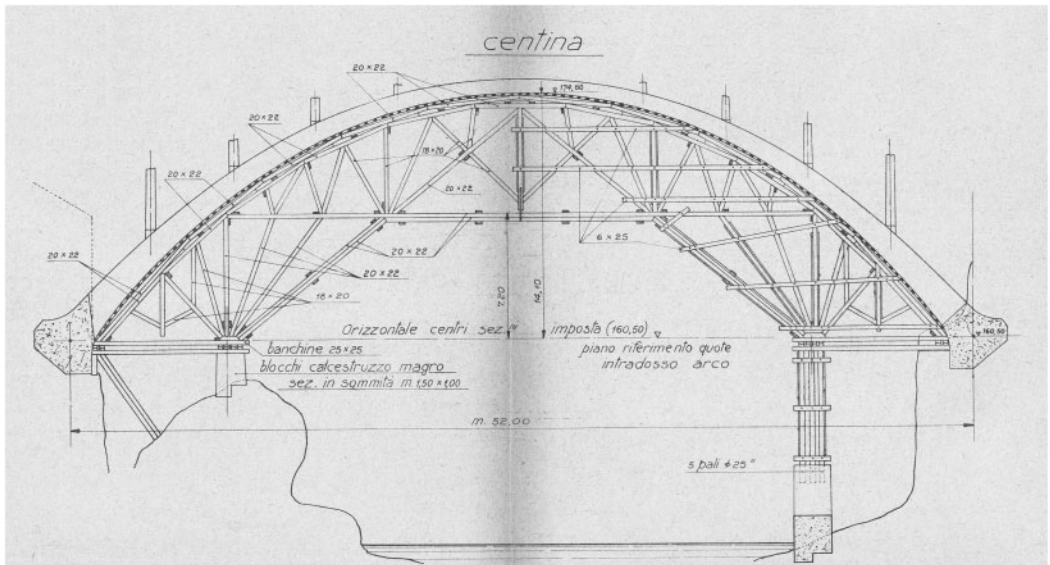


Figure 6. 1927, L. Santarella, bridge over the River Brembo. "Rib" (Santarella 1932: tav. 36).



Figure 7. 1928, L. Santarella, grandstand of the Bergamo Stadium (Santarella 1931: 231).

be seen today, is the canopy of the grandstand of Bergamo Stadium (Figure 7), completed in 1928 by the Oscar Gmür company: a structure that can be rightfully considered as the forerunner of the more famous canopy of the covered grandstand of the Berta Stadium in Florence, designed and built by Nervi in 1930. The roof designed by Santarella is made up of a series of cantilevered beams, spaced 4 metres apart, with an overhang of almost 13 metres, joined together by a brick flooring system. This project was also widely referenced by Santarella both in his books and journals articles, presented as good practice in the construction of cantilevered canopies. Nevertheless, the purely technical character of its descriptions, combined with a formal language derived from constructive rationality and mere calculation requirements, were unable to arouse the interest of the architectural literature prevailing as was the case with the more elegant and slender canopy of the Berta Stadium or, later, that of the Zarzuela racecourse in Madrid. The structure designed by Santarella lacks the design intention of being a sculptural object, regardless of its structural or construction efficiency. Santarella still saw structures as mere tools to provide a technical response to a static need and not as an expressive factor with the capacity to transform a structure into a work of architecture capable of generating spatial quality. His writings offer a striking example of this limit, which the Italian polytechnic culture of the time – in which he found himself completely immersed – had not yet overcome. His relationships, which we are able to reconstruct today, indicated his close collaboration with the world of the Italian cement-making industry – which was booming at the time – in the exploration of increasingly high-performance concretes, with the world of building

components, such as state-of-the-art formworks, or for the use of machinery such as mixers or mechanical vibrators capable of simplifying the casting of concrete mixtures (Santarella 1931, 1932).

These are the specialities that made Santarella one of the most competent and capable professionals in collaborations, as a consultant, with construction companies specialising in the construction of reinforced concrete structures, which were indeed quite bold for the time. Throughout his professional career, he seems to have lacked the relationship with architects that would have been essential to his progressive maturation of that aesthetic and spatial sensitivity in the usage of the structure which, combined with his undeniable ability and technical knowledge, could have led him to conceive works capable of tracing a true poetic in the use of reinforced concrete. Clearly, his premature death prevented this change from happening.

4 CONCLUSIONS

The fifth edition of *Reinforced Concrete* [*Il Cemento Armato*], the last updated by Santarella, was published in September 1935, shortly before his death. From 1953 to 1997, Franco Mattiazzo, an engineer from Milan and Santarella's son-in-law, was commissioned by Hoepli to carry out a progressive and careful review of the texts, drawings and calculation formulas, updating his father-in-law's volumes from time to time and also taking into consideration the evolution in Italian regulations and building technology. Over the decades, the Hoepli manuals published under the name of Santarella – despite the fact that their contents are updated in line with scientific developments in

construction technology and the design of reinforced concrete structures – have been commonly used in Italy as textbooks or in support of professional practice.

His early death prevented the path traced by his built structures from generating further and future prolific professional collaborations capable of evolving his compositional and expressive vocabulary from an architectural point of view. The same cannot be said for example for Nervi, who was just five years younger than Santarella and whose youthful production is entirely comparable to that of his colleague.

Several periodicals of the time reported the news of Santarella's death, summarising the unquestionable professionalism of the forty-nine-year-old Italian engineer. The various obituaries highlighted not only the multiplicity of works published but also the figure of a “dynamic and proactive” (*L'industria italiana del cemento* 1935) man, who contributed determinedly to the renewal of the dissemination of the engineering culture of the twentieth century. A few months after his death, in December 1935, the “National Fascist Federation of Cement, Lime, Gypsum and Cement Manufacturers” went to far as to launch a competition to honour the memory of the Italian engineer, with the aim of promoting the development of innovative projects and studies that had a direct impact on the practical and operational field in response to the autarkic requirements of the time (*L'industria italiana del cemento* 1935).

Santarella can, therefore, rightly be considered one of the main forerunners of twentieth century Italian structural engineering (Iori 2007) characterised both by progressive scientific advancement in the theoretical sphere which analyses and regulates the static behaviour of structures and by a still sometimes purely empirical experimentalism derived from building site practice. In this context, Santarella's name is linked exclusively to the evolution of techniques relating to the use of reinforced concrete, and his personal system of dissemination can be rightfully considered his most significant legacy: the pedagogical approaches pursued, for example, in Mario Salvadori's texts (Salvadori 1980) or, more recently, in those of Aurelio Muttoni (Muttoni 2011), can undoubtedly be considered a logical evolution of Santarella's analytical and publicist criteria.

In conclusion, we can say that, in just twenty-five years of activity, Santarella succeeded, thanks to its publications, in becoming the undisputed authority of his time on the theorising, designing and building of reinforced concrete structures and also a mentor for successive generations of scholars and designers.

The authors consider their individual contributions to the writing of this paper as 50%, resulting from constant debate and joint effort. All the archive research was conducted by Cinzia Gavello. For the sole purpose of academic evaluations, it should be noted that Sections 1 and 2 were written by Cinzia Gavello and reviewed by Alberto Bologna; Sections 3 and 4 were written by Alberto Bologna and reviewed by Cinzia Gavello.

REFERENCES

- Bologna, A. 2015. *Il progetto del calcestruzzo armato in Italia tra empirismo e calcolo*. In E. Dellapiana & G. Montanari, *Una storia dell'architettura contemporanea*: 276–277. Novara: Utet Università.
- Colombo, G. 1877. *Manuale dell'ingegnere civile e industriale*. Milan: Ulrico Hoepli.
- Dantin, C. 1921. Hangar en béton armé pour deux dirigeables à Luçon (Vendée). *Le génie civil. Revue générale hebdomadaire des industries françaises at étrangères*, Tome LXXVIII, 7-2009:145–148.
- De Ceglia, F.P. 2007. *Scienziati di Puglia*. Bari: Mario Adda Editore.
- Declava, E. (ed) 2001. *Ulrico Hoepli, 1847–1935. Editore e librario*. Milan: Ulrico Hoepli.
- Gargiani, R. & Bologna, A. 2016. *The rhetoric of Pier Luigi Nervi. Concrete and ferrocement forms*. Lausanne-Oxford-New York: EPFL Press-Routledge: 111–137.
- Hoepli, U. 1922. *Mezzo secolo di vita editoriale, 1872–1922*. Milan: Ulrico Hoepli.
- Hool, G. A. 1918. *Concrete engineers' handbook*. London-New York: McGraw-Hill Book Company Inc.
- Iori, T. 2001. *Il cemento armato in Italia dalle origini alla seconda guerra mondiale*. Rome: Edilstampa: 150.
- Iori, T. 2007. L'ingegneria del “miracolo italiano”. In T. Iori & S. Poretti (eds.), *Ingegneria italiana*, monographic number of *Rassegna di architettura e urbanistica* 121–122: 33–59.
- Miozzi, E. 1922. *Letter to U. Hoepli*. Santarella Folder, Ulrico Hoepli Historical Archive, Milan.
- Mörsch, E. 1923. *Teoria e pratica del cemento armato*. Milan: Ulrico Hoepli.
- Müller-Breslau, E. 1927. *La scienza delle costruzioni*. Milan: Ulrico Hoepli.
- Muttoni, A. 2011. *The art of structures. Introduction to the functioning of structures in architecture*. Lausanne: EPFL Press.
- Salvadori, M. 1980. *Why buildings stand up. The Strength of Architecture*. New York-London: W.W. Norton & Company.
- San Nicolò, R. 1925. Il cemento armato nelle costruzioni industriali. *Ingegneria* 11(IV): 401–403.
- Santarella, L. 1922a. Il rigurgito nelle acque nel sottosuolo di Corato. *Ingegneria* 2: 3–15.
- Santarella, L. 1922b. Moderne strutture industriali in cemento armato. *L'Industria* 8: 142–144.
- Santarella, L. 1923. La percentuale d'acqua negli impasti per cementi armati. *Le industrie costruttive* 2: 9–12.
- Santarella, L. 1926. *Il cemento armato nelle costruzioni civili ed industriali*. Milano: Ulrico Hoepli.
- Santarella, L. 1927. Il ponte di Lesa sul torrente Erno per la strada nazionale del Sempione. *L'industria: rivista tecnica ed economica illustrata* 7: 179–184.
- Santarella, L. 1928a. La scuola di specializzazione per le costruzioni in cemento armato per ingegneri ed architetti. *Il Monitore Tecnico. Giornale d'ingegneria, architettura, meccanica elettrotecnica, ferrovie, agronomia, catasto ed arti industriali* 5: 77–78.
- Santarella, L. 1928b. La scuola delle costruzioni in cemento armato al Politecnico di Milano. *L'industria: rivista tecnica ed economica illustrata* 7: 190.
- Santarella, L. 1928c. Il II congresso internazionale per la costruzione dei ponti. *L'industria: rivista tecnica ed economica illustrata* 20: 575–577.
- Santarella, L. 1929a. *Il cemento armato*. Milano: Ulrico Hoepli.

- Santarella, L. 1929b. Il ponte “Cobianchi” a Intra. *L'industria: rivista tecnico-scientifica ed economica* 3–4: 38–40.
- Santarella, L. 1929c. *Ponti in muratura ed in cemento armato. Fondazioni, opere marittime*. Milan: Gruppo Universitario Fascista Milanese.
- Santarella, L. 1929d. *Prontuario del cemento armato*. Milan: Ulrico Hoepli.
- Santarella, L. 1930a. *La tecnica delle fondazioni con particolare riguardo alla costruzione dei ponti e delle grandi strutture*. Milan: Ulrico Hoepli.
- Santarella, L. 1930b. Il V Congresso Internazionale della stampa tecnica a Barcellona, *L'industria: rivista tecnica ed economica illustrata* 2: 27–29.
- Santarella, L. 1930c. Il cemento armato in Italia. *L'industria italiana del cemento* 8–9: 45–55.
- Santarella, L. 1931. *Il cemento armato. Volume II. Le applicazioni nelle costruzioni civili ed industriali*. Milan: Ulrico Hoepli.
- Santarella, L. 1932. *La vibrazione del calcestruzzo di cemento*. Milan: Ulrico Hoepli.
- Santarella, L. 1933. *Arte e tecnica nella evoluzione dei ponti*. Milan: Ulrico Hoepli.
- Santarella, L. & Miozzi, E. 1924a. *Letter to B. Mussolini*. Santarella Folder, Ulrico Hoepli Historical Archive, Milan, Italy.
- Santarella, L. & Miozzi, E. 1924b. *Ponti italiani in cemento armato*. Milano: Ulrico Hoepli.
- Un concorso in memoria di Luigi Santarella 1935. *L'industria italiana del cemento* 12: 384.
- Vacchelli, G. 1899. *Le costruzioni in calcestruzzo ed in cemento armato*. Milan: Ulrico Hoepli.
- Warren, F. D. 1906. *A handbook on reinforced concrete for architects, engineers and contractors*. New York: Van Nostrand.

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