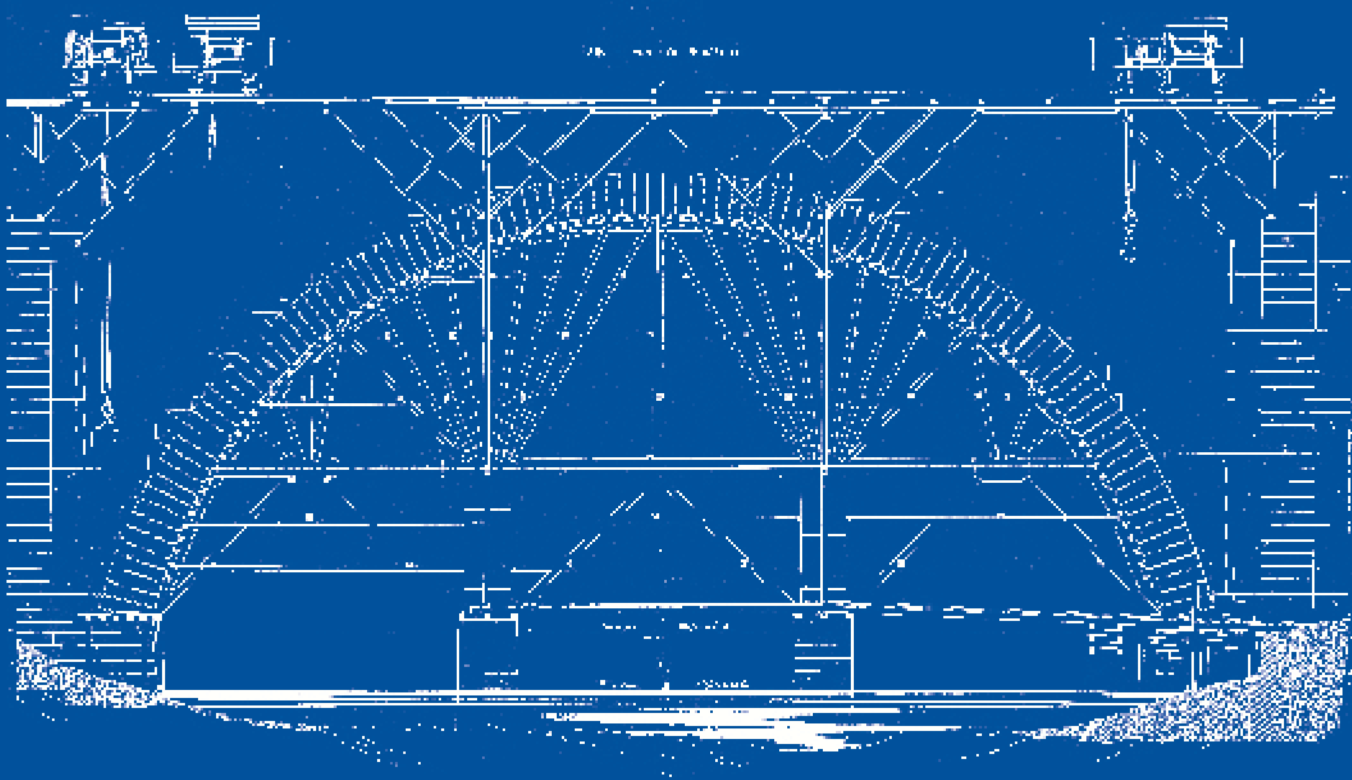
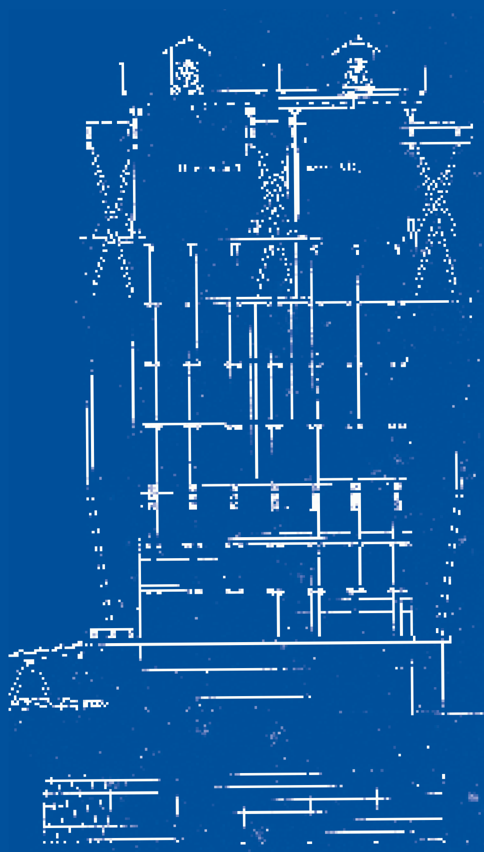
Proceedings of the 8th International Congress on Construction History
Stefan Holzer, Silke Langenberg, Clemens Knobling, Orkun Kasap (Eds.)



Construction Matters



Construction History is still a fairly new and small but quickly evolving field. The current trends in Construction History are well reflected in the papers of the present conference. Construction History has strong roots in the historiography of the 19th century and the evolution of industrialization, but the focus of our research field has meanwhile shifted notably to include more recent and also more distant histories as well. This is reflected in these conference proceedings, where 65 out of 148 contributed papers deal with the built heritage or building actors of the 20th or 21st century. The conference also mirrors the wide spectrum of documentary and analytical approaches comprised within the discipline of Construction History. Papers dealing with the technical and functional analysis of specific buildings or building types are complemented by other studies focusing on the lives and formation of building actors, from laborers to architects and engineers, from economical aspects to social and political implications, on legal aspects and the strong ties between the history of construction and the history of engineering sciences.

The conference integrates perfectly into the daily work at the Institute for Preservation and Construction History at ETH Zurich. Its two chairs – the Chair for Building Archaeology and Construction History and the Chair for Construction Heritage and Preservation – endeavor to cover the entire field and to bridge the gaps between the different approaches, methodologies and disciplines, between various centuries as well as technologies – learning together and from each other. The proceedings of 8ICCH give a representative picture of the state of the art in the field, and will serve as a reference point for future studies.

Prof. Dr. Ing. Stefan M. Holzer, Chair of Building Archaeology and Construction History, holzer.arch.ethz.ch
Prof. Dr. Ing. Silke Langenberg, Chair of Construction Heritage and Preservation, langenberg.arch.ethz.ch
Dr. Clemens Knobling, Chair of Building Archaeology and Construction History, IDB, ETH Zurich
Orkun Kasap, Chair of Construction Heritage and Preservation, IDB, ETH Zurich

ETH zürich

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
 ISBN 978-3-7281-4166-8

Contents

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

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

Construction innovation for factory roofs in the second half of the 20th century. Two Italian cases of thin shed vaults

Francesco Spada[1], Laura Greco[2]

[1]Department of Civil Engineering, University of Calabria, Rende, Cosenza, Italy; [2]Department of Civil Engineering, University of Calabria, Rende, Cosenza, Italy

Abstract: This paper refers to studies on 20th century construction techniques oriented towards the role of designers and construction companies in the evolution of construction processes and techniques in Italy. From the mid-1950s, the expansion of industrial production encouraged the construction of numerous factories, mainly in central-northern Italy. Important clients entrusted well-known professionals and large construction companies who worked together on useful solutions to combine building architectural features with modern production needs. In this paper, the Siemens factory in via Monte Rosa in Milan (1955–57), designed by Carlo Rusconi-Clerici, and the Perugina factory in Perugia (1961–62), designed by Aldo Favini and Carlo Rusconi-Clerici, are studied for their particular roofs, characterized by thin shed vaults in reinforced concrete, useful for covering large spans without intermediate pillars and which allow wide natural lighting of the factories. Both factories were built by Sogene construction company. The paper focuses on the construction process of the vaults; indeed, special wooden ribs are used to speed up the casting of the roofing elements. The analysis of the two buildings is framed in the Italian construction history context to evaluate the specificity of that construction in relation to the national context. The two case studies refer to a first phase of construction site mechanization introduced in Italian construction history starting in the 1950s, so techniques used for construction of the Siemens and Perugina factories refer to on-site structural elements prefabrication.

Introduction

In Italy between the 1930s and 1950s, a period during which many factories were built, thin vaults in reinforced concrete developed. Due to construction characteristics and functional needs, factory design was an opportunity to suggest thin vaults in reinforced concrete for shed roofs. In the 1950s, the reconstruction of buildings destroyed by the war also involved factories. New industrial buildings were built with a regular planimetric layout, characterized by medium-span frames of 15–30 metres and roofs with zenithal light. In Italy in the 1950s, processes for standardization and on-site prefabrication of singular structural elements or parts of complex structures to be connected by casting on site, were developed. At the same time, studies on prestressed reinforced concrete advanced; they also influenced the design and construction of factory roofs. In this context, the use of thin vaults became one of the themes of the evolution of the Italian construction history preceding the advent of foreign industrialised prefabrication systems in the early 1960s. Starting from the precursors of the 1930s, also thanks to the influence of foreign construction systems, it took advantage of the work of designers such as Aldo Favini (1916–2013) and construction companies such as Sogene. Among the studies conducted so far in Italy, it is useful to consider those that have investigated the influences of the Zeiss-Dywidag system (Russo and Currà 2018, 207–213), the solutions of Italian designers such as Giorgio Baroni (Currà and Russo 2018, 509–517), the role of some industrial buildings in the developments of national structural engineering in the years of transition from traditional to industrialized construction (Giannetti 2017, 80–97), and the original interpretation given by Pier Luigi Nervi (1891–1979) to the theme of thin vaults with structural prefabrication and ferrocement (Poretti 2017, 54–65).

Starting from these studies, this paper deepens the cases of the Siemens factory in Milan (1956–57) and the Perugina factory in Perugia (1961–63), designed by the Milanese architectural and engineering office Rusconi-Clerici and built by Sogene. The two factories are characterized by thin shed vaults in reinforced concrete, both cast on site. The German firm Dyckerhoff & Widmann designed the roof structure of the Milan factory, while Aldo Favini developed that of the Perugina complex. The analysis and comparison of the two factories offer a possibility to identify a case of application of foreign systems in the Milanese factory in Italy, of highlighting similarities and differences between the solutions used in Milan and Perugia. It also offers the opportunity to underline Sogene's attitude towards this type of structure, whose onerous execution required specific procedures.

1. Developments of thin reinforced concrete vaults in Italy in 1950s

In Italy, the developments of thin reinforced concrete vaults received a particular impulse from the spread of medium span roofs for industrial spaces in the 1950s (Currà, Giannetti, and Russo 2023, 193–207). Following experiments in the interwar years, this innovation moved by European studies was favoured by autarchic policies of the fascist regime oriented to the saving of building materials in the 1930s. The thin vaults were a solution used in bold buildings for the industrial sector and related to other lines of Italian construction development of those years, such as prestressed reinforced concrete. Already from the 1930s, their development moved between influence of the well-known Zeiss-Dywidag system and Italian proposals.

The realization of public buildings that needed advanced construction solutions favoured structural experimentation in the 1930s. The large span roofs in reinforced concrete, to which thin vaults belong, were part of a construction research of which it is worth remembering the most relevant experiences. Pier Luigi Nervi developed a first line of research, with the projects for hangars (1935–1941), based on on-site prefabricated elements, connected to each other by concrete cast on-site. These projects launched research on structural prefabrication on which Nervi worked at length (Nervi 1965, 34). However, this solution was an exclusive of the Italian engineer, while several designers and companies referred to thin reinforced concrete vaults to solve the roofs of medium and large spans. This type of structure advanced in Europe in the early 1920s, thanks to the work of the German contractor Dyckerhoff & Widmann AG, as evidenced by the first application for the planetarium of Jena (1922–23), realized in collaboration with the Carl Zeiss Company. The German success was due to the design skills of Franz Dischinger and Ulrich Finsterwalder, to progress the theoretical development of Walter Bauersfeld, due to the impact in the media guaranteed by the Zeiss planetariums series (Roland 2012, 133–141). The Zeiss-Dywidag system, used for cylindrical thin shell roofs and protected by patents held in Germany, spread in Italy thanks to the Roman construction company of Engineer Rodolfo Stoelcker, specialized in reinforced concrete structures. Stoelcker obtained the license to use the German system and created two buildings in Rome: the garage of the Società Trasporti Automobilistici (STA) in Via Tuscolana (1928–1938) and the garage of the public transport company ATAG in Trastevere (1931–32). In the first case, the roof of the garage was based on eight vaults in succession (8 cm thickness) which covered a span of 15 meters, completed by longitudinal beams and diaphragms, according to the Zeiss-Dywidag system. In the ATAG garage in Trastevere, the roof was based on four vaults (thickness of 8 cm), placed on a span of 14 meters. Also in this case, there were longitudinal beams and diaphragms that completed the structure of the Zeiss-Dywidag system (Russo and Currà 2018, 207–213). Autarchic laws promoted Italian experiments with thin vaults, among which the case of the engineer Giorgio Baroni stood out. Baroni became known for a 3 cm thick hyperbolic paraboloid reinforced concrete roof (Baroni 1936). Limited use of material was the result of resistance by form of the structure, coinciding with a double-curved ruled surface, which rationalized formworks construction, despite complex roof geometry. After the interruption caused by the war, the reconstruction of many factories destroyed by bombing and construction of new complexes offered opportunities for the implementation of techniques for medium span roofs. Construction manuals on factories were published: a fundamental reference was Armando Melis' manual *Gli edifici per l'industria* (Melis 1953) and, later, Pasquale Carbonara's guide *Architettura Pratica* (Carbonara n.d.), and Giampiero Aloi's repertoire *Architetture industriali contemporanee* (Aloi 1966). Melis' book first included thin reinforced concrete vaults among the available construction options, indicating them as a suitable solution to improve ventilation and lighting of shed and skylight roofs (Melis 1953, 73–87). The author, recognizing progress made in the calculation of thin vaults, described essential components of the scheme, and indicated recommendations for the realization of wooden formworks, that were particularly expensive. The use of thin vaults was a solution, amongst other cheaper and faster ones, considering that they were limited to experiments conducted by well-known designers or wealthy clients.

The 1950s were a decisive decade for the diffusion and evolution of experiments of the 1930s, which continued around two themes, to which the developments of thin vaults also referred. On the one hand, evolution of on-site prefabrication of structural parts to be connected with cast on-site and, on the other hand, development of prestressed reinforced concrete technique. Nervi's structural prefabrication, based on ferrocement prefabricated elements to be connected on-site, was the source of ingenious corrugated or pleated profile roofs to enhance the effect of resistance by form, in which the use of the original engineer's procedure exceeded one of the limits of the development of thin vaults, namely the costs of formworks (Nervi 1965, 31). It is an original interpretation of thin vaults, linked to Nervi's research and favoured by the presence, alongside the designer, of Nervi and Bartoli, of the construction company founded by the Italian engineer in 1932. The large, vaulted thin roofs such as that of the *Palazzo delle Esposizioni* in Turin (1948), and the domed roofs of the *Salone delle Feste delle Terme* in Chianciano (1952–53), and of the *Palazzo dello Sport* in Rome (1956–57) proposed competitive solutions to reduce costs thanks to workers' skills, to specially designed formworks and machines for handling prefabricated elements. On the other hand, studies on prestressing technique continued; important progress was due to patents secured by engineers, such as Riccardo Morandi (1902–1989) and Aldo Favini, with evidence of competitive solutions even on structural spans of 20–30 meters. In the 1950s, Morandi, an expert designer of large structures for bridges and viaducts, also directed the design of some factories, including the B.P.D. Study Center in Colleferro (Rutelli 1955, 512–514) and the complex in Castellaccio (1954), the Fiat factory in Naples (1956), and the A.B.C.D. factory in Ragusa (1958). In these cases, the Italian engineer applied his design and execution procedures, already assessed in other works, and consisting, among other things, of on-site prefabricated slabs placed on prestressed reinforced concrete frames for large spans (Morandi 1955, 217–220; 241–244).

In those years, the engineer Aldo Favini stood out in the history of thin vaults. Favini, a refugee in Switzerland during the war, studied and worked at the Polytechnic University of Lausanne and at the Polytechnic University of Zurich, where he collaborated with Gustavo Colonnetti (1886–1968), the Italian expert of reinforced concrete construction and of prestressed structures. In Zurich, he concentrated on thin vaults studies. In 1945 he published a book entitled *Volte sottili in cemento armato* (Favini 1945). It was a prelude to his projects of the 1950s, with thin reinforced concrete vaults, cast on wooden centerings and arranged on structural

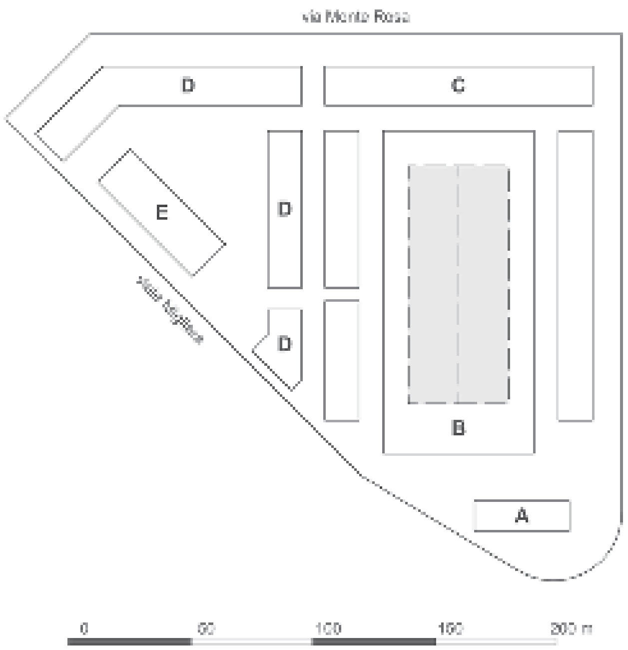


Figure 1. Layout of the Siemens complex in via Monte Rosa in Milano (drawing by the authors): offices (A), workshops (B-C), laboratories and services (D), canteen (E).

spans between 15 and 30 meters. The contribution that Favini offered to development of thin vaults also concerned the use of prestressing systems, a result of his 1951 and 1954 patents, which he used for thin vaults (Favini 1951; 1954).

The case of Nervi and Bartoli is distinctive among Italian building companies because it is linked to the figure of professor Nervi. However, other company were also interested in the rationalization of static schemes and construction phases. An example was the construction company Sogene, engaged in the 1950s to organize a design-construction process and a system of equipment suitable for taking advantage of construction site rationalization, according to a proto-industrialized approach. The successful experience of the Sogene company—particularly appreciable in the period 1950–1970—was the result of a successful business plan strictly defined by the new management in the post-war period (Spada 2023). Sogene aimed to implement a complete production cycle, to guarantee a company organization able to follow the entire building process, from concept to construction. This approach, which referred to American experiences, guaranteed application of global design criteria already in the early 1950s (Cuccia 2003, 46–50; US-SGI 1952, 16–25). Sogene built many factories with reinforced concrete structures, some with thin shed roofs: the FIAT warehouse in via Giordano Bruno (1951) and the Nuova Fonderia Grandi Motori Fiat (1951–52) in Turin; the Fiat branch in Palermo (1956–57); the Palmolive complex in Anzio (1956–57), where much of the roof is characterized by "half-moon" shaped reinforced concrete domes cast on site which form a series of cross vaults; the Ceramiche Pozzi factory in Sparanise (1961–62), designed by Luigi Figini and Gino Pollini, whose roof is built by prefabricated elements with V-section; the Perugina complex in Perugia, designed by Carlo Rusconi-Clerici and Aldo Favini, whose roof is built by thin shed vaults in prestressed reinforced concrete on a 20–meter span; the Siemens complexes in Milan (1955–57), where the German Dyckerhoff & Widmann system was used

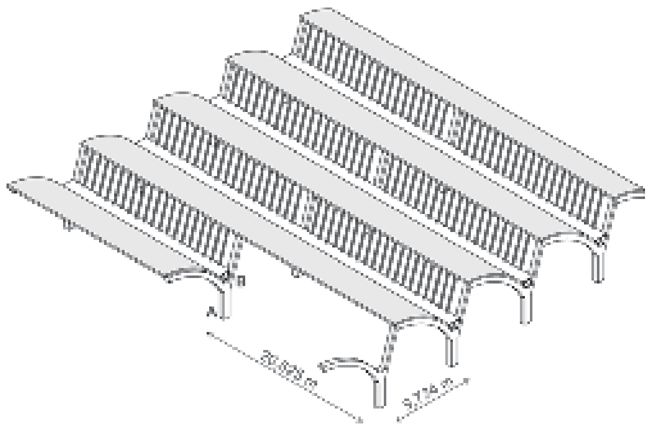


Figure 2. Siemens complex in via Monte Rosa in Milan, structure of the workshop building (drawing by the authors): thin vaults are supported by parabolic beams on the pillars (A) and connected by prefabricated window shed struts (B).

for the thin shed vaults, and in Santa Maria Capua Vetere (1962), whose roof is built by prefabricated "Z" components. The Perugina and Milanese Siemens factories involved Sogene in thin shed vault construction: the roofs are similar but designed by different professionals. The analysis of the two cases can help to clarify some aspects that have been highlighted in the context outlined so far: the use of the Zeiss-Dywidag system in the Milan factory; the involvement of Italian structural designers such as Aldo Favini in the field of thin vaults, testified in the Perugia complex; and Sogene's approach in construction of this type of structures.

2. The Siemens complex in via Monte Rosa in Milan (1955–1957)

The story of the Siemens complex in Milan is linked to a wider reconversion action of the area previously occupied by the Isotta Fraschini factory, acquired by Siemens in 1949 for the purpose of building a new and modern complex by demolishing much of the existing buildings, damaged by bombing during the war.

The factory was built between 1955 and 1957 (ACS-SGI 1955–57, 4091-117) and consisted of several buildings (Fig. 1): the offices (volume A) facing Piazzale Zavattari, the workshops (volume B and C), and the buildings for laboratories and services (volumes D); between 1962 and 1963 was built the canteen (volume E).

All buildings were designed by the Rusconi-Clerici engineering office (within which Carlo Rusconi-Clerici was in charge of the project), except the workshop (volume B) with a shed roof, designed by the Sogene technical department.

This study focuses on building B, characterized by thin self-supporting reinforced concrete vaults, used for the sheds of the large central hall (Fig. 2), which stood out for attention to standardized solutions and proven economy. The reinforced concrete technique was used after discarding the metal structure due to high costs, similarly to what happened for the Velasca Tower built by Sogene in the same period (Pifferi 1959, 1–41). The choice was made by "determining, during the design phase, all those elements that could prelude a serial production", with a work plan based on "continuous contacts and close collaboration of designers and the construction manager with the technical office of the Company Client".

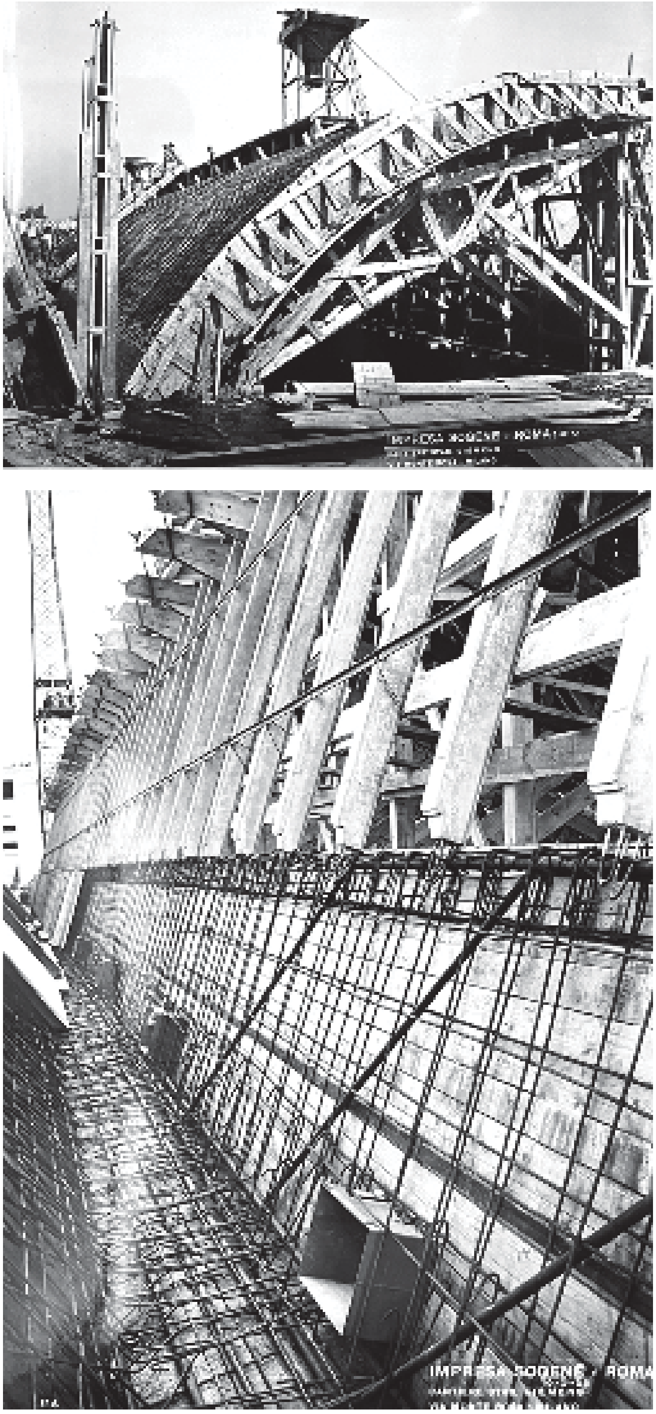


Figure 3. Siemens complex in via Monte Rosa in Milan. Upper: formworks of the roof consisting of reusable wooden centerings. Lower: formwork of the hollow beams at the vault springing line, connected to the vault upper line through prefabricated window shed struts. Courtesy of Ministero della Cultura-Archivio Centrale dello Stato, SGI-Sogene collection (subsequent citations ACS-SGI), folder 4091-117.

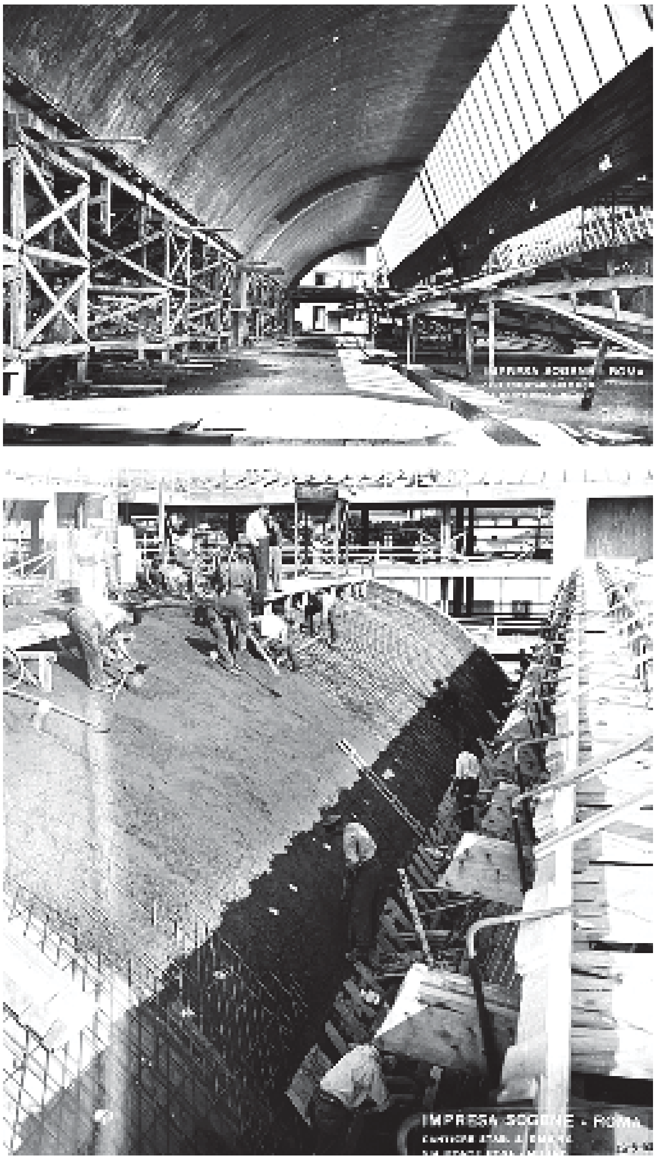


Figure 4. Siemens complex in via Monte Rosa in Milan. Upper: interior of the workshop building (B). Lower: vault concrete casting (ACS-SGI, folder 4091-117).

The serial production concept referred to on-site procedures supported by a careful study of module and modular design "that made it possible to simplify the formworks" of the roof (Rusconi-Clerici 1958, 71), consisting of reusable wooden centerings (Fig. 3) (ACS-SGI 1955–57, 4091-117). Again as with the Velasca tower, "experimental tests on full size model to determine perfection degree of concrete castings were made" (Rusconi-Clerici 1958, 12) and other experiments that "allowed to define the connections between concrete structure and facades, between windows and systems, realizing a very quick assembly and considerable economic savings" (Rusconi-Clerici 1958, 71). The Sogene technical office developed structural calculations of all the buildings designed by Rusconi-Clerici, except for building B, whose "special structures" had the contractor engage Dyckerhoff & Widmann. The German group designed the roof of the building, "made by thin self-supporting concrete vaults reinforced at the perimeter" from which "derives a parabolic shed entirely made of reinforced concrete without any transverse chain" (Rusconi-Clerici 1958, 87).

The roof of the production area (about 41x97 meters) was composed of 20 shed elements divided into two rows. The center distance of each thin vault was 9.734 m (repeated ten times in the longitudinal direction), and the span was 20.625 meters (repeated twice in the transverse direction) (Rusconi-Clerici 1958, 87). Pillars were shaped to support beams with a parabolic profile: following the curvature of the vaults, the beams constituted a transversal connection between pillars (Fig. 2; Fig. 4). Furthermore, curved beams supported vaults, while at the vault springing line there were hollow beams

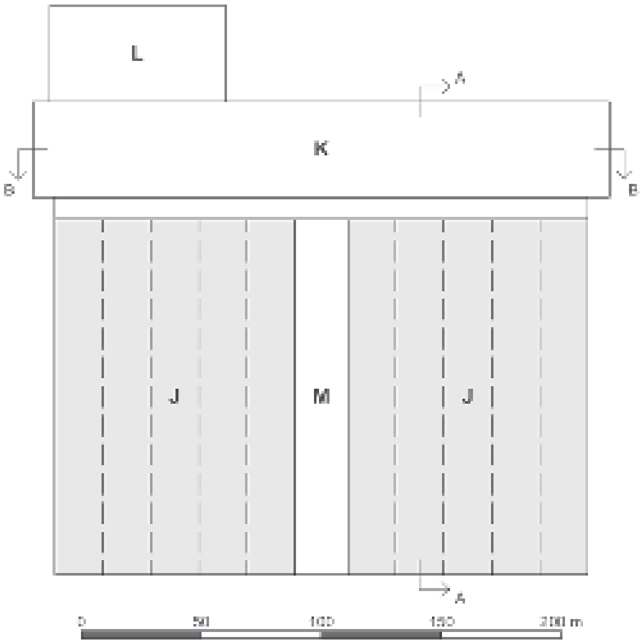


Figure 5. Layout of the Perugina factory in Perugia (drawing by the authors): manufacturing (J), logistics and packaging (K), shipping (L), services (M).

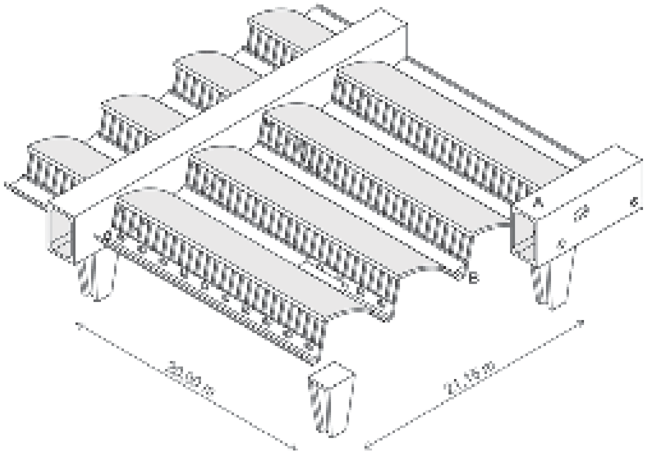


Figure 6. Perugina factory in Perugia, structure of the manufacturing building (drawing by the authors): thin vaults are supported by box beams (A), cross connected by hollow beams (B).

inside which air distribution ducts were arranged (Fig. 3). The window shed struts allowed connection between vaults. They were made by prefabricated concrete elements, connected to vaults (on the upper side) and to a hollow beam (on the lower one) (Fig. 3): binding of steel bars and subsequent concrete casting guaranteed connexion between vaults and hollow beams. So, when concrete casting was completed, the roof looked like a concrete megalith, without the use of a tie-beam (Fig. 4). Vaults were supported on the entire perimeter: two beams on the sides, hollow beams at springing line, prefabricated struts at the top.

Construction site photos highlight an accurate layout, which rationalized manufacturing within an artisanal construction site through, for example, the use of reusable wooden formworks to reduce assembly times of provisional works. However, concrete casting was founded on basic manual operations which allowed the employment of unskilled workers (Fig. 4). In addition, a global design approach involved the reduction of work phases: before concrete casting, "all elements interfering with structure were arranged, such as: chassis for air inlets, Bauer elements for electrical cables passages and for connection of lighting lamps, downpipes and pipes in general" (Rusconi-Clerici 1958, 87).

3. The Perugina factory in Perugia (1961–1963)

The story of the Perugina complex began in the early 1960s, when the well-known Italian confectionery company, led by the entrepreneur Giovanni Buitoni (1891–1979), entrusted the design of a new and large factory on an area of about 295,000 square meters to Rusconi-Clerici engineers.

The factory was built between 1961 and 1963. It consisted of a large one-storey building (220x150 meters), with thin shed vaults in prestressed reinforced concrete, connected to another three-storey building, characterized by a reinforced brick vault on the roof (Fig. 5).

Aldo Favini developed the structural design. The roof of the Perugina one-story building was an advanced application of the Italian engineer's experimentation on thin vaults. After a first realization in the Aquila service station in Sesto San Giovanni (1949), he applied his patent on the prestressing system to thin vaults (Barazzatta 2004, 20–23). The result was an improvement of the structural principle of resistance by form, evident in the roof of the Bocconi University refectory in Milan (1955), where prestressing cable anchorages were hidden in the 8 centimeter thickness of the concrete elements (Barazzatta 2004, 26–27). Favini's prestressing system applied to factory construction highlights buildings with roofs similar to the Siemens Milanese case, highlighting his interest in German school experiences and techniques. In 1956 the Italian engineer designed the roof of the Officine Elettromeccaniche Ernesto Silvestri in Dormelletto (Novara) with five thin shed vaults in prestressed reinforced concrete with a span of about 20 meters (Barazzatta 2004, 34–35). Later, a bolder solution was applied on a 31-meter span in the Fimi factory in Rescaldina (Milan) (Barazzatta 2004, 58–61), simultaneously with Perugina (1961). These buildings were the last before Favini's interest shifted from thin vaults—emblem of on-site techniques—to the use of industrial prefabricated elements, considered as pieces of structural design. His works in collaboration with Angelo Mangiarotti and Bruno Morassutti were the most evident sign of this (Giannetti 2017, 80–97).

For the Perugina factory, a double system of prestressed reinforced concrete parabolic sheds was used. The large manufacturing area (about 220x150 meters) was divided into two parts by the services (that occupied a zone of 20x150 meters). Each zone had a roof that covered an area of about 100x150 meters (Fig. 5). Each roof was made up by 105 shed elements divided into several rows: the center distance of each thin vault was 7.05 meters (repeated 21 times on the longitudinal direction), the span was equal to 20 meters (repeated 5 times on the transverse direction). Therefore, each roof was obtained with 21 rows of sheds, composed of five thin vaults each. Pillars followed a structural layout of 20x21.15 meters, with a column every three rows of the shed.

As in the Milanese case, each thin vault was based on a hollow beam inside which the air distribution ducts were arranged. Prefabricated concrete struts of the windows

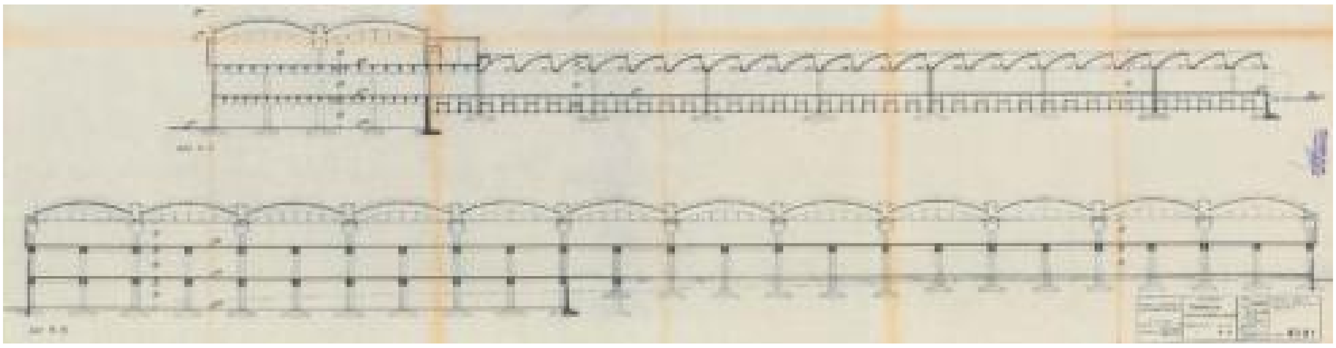


Figure 7. Perugina factory in Perugia: longitudinal section (A-A) and cross section (B-B) (ACS-SGI, folder 4096-72).

guaranteed continuity between vaults. Unlike the Siemens factory, in the Perugia building the thin vaults were laterally based on box beams (Fig. 6) that—together with tapered downward pillars—supported the roof (Aloi 1966, vol.2, 136–148). Inside the box beams (on the sides of the vaults), system control units were arranged; they distributed air through inlets placed along the hollow beams (on the vaults springing line). Therefore, the box beams were perpendicularly arranged to the hollow beams (Fig. 6). This solution highlighted Favini's interest in rationality and cost-effectiveness of construction, in this case focused on structural and system integration, first tested in the Fimi factory, then applied in Perugina in an improved version.

The thin prestressed reinforced concrete vaults were cast on-site using wooden centerings, already employed for the Officine Silvestri (Favini 1960, 161–171). They were similar to those of the Siemens factory. The formwork system was based on a standard reusable element of 75 cm, which transformed the on-site construction into on-site prefabrication, demonstrating the serial-construction approach pursued by Favini. A similar system—with reference to formworks used for construction—was used by Dyckerhoff & Widmann for the construction of the Siemens factory in Via Monte Rosa in Milan (1955–57).

The Perugina construction process was a large-scale test: there were 210 vaults, cast in groups of 30, built in five months (Giannetti 2017, 85), proving a possible integration of aesthetic, functional and system engineering requirements with the speed of construction.

Archival documents allow the study of the development phases of the vaults project. Tender specifications assigned structural design to the construction company, requiring the appointment of a structural designer approved by the client and the construction management (ACS-SGI n.d., 4096-72). Thus, Favini was not involved in the initial phase teamwork. It is possible that Rusconi-Clerici provided for thin concrete shed vaults in a preliminary draft already assuming to use the Favini system. To support this hypothesis, it is worth remembering that Rusconi-Clerici and Favini had already met in the Winthertur camp during the war; therefore, Rusconi-Clerici were familiar with Favini's studies on thin vaults and his subsequent achievements. Archival documents confirm Favini's involvement only in a second phase of the project. In fact, drawings attached to the tender were signed by the Client (Perugina) and by the Rusconi-Clerici engineering office, not by Favini (ACS-SGI 1961, 4096-72). In Rusconi-Clerici's drawings structural geometries are similar to the built version, but do not fully correspond (Fig. 7). Instead, the graphic documents of Favini's archive (relating to a more advanced design phase) show structural details corresponding to construction site photos held in Sogene's archive.

Furthermore, the company's archive attests construction phases (Fig. 8; Fig. 9). Construction time was limited to 14 months (ACS-SGI n.d., 4096-72). The building site photos show an intense activity between January and March 1962 in terms of the realization of structures: more than half of those of building "B" were completed in May, while those of the three-storey building committed for logistics had just started. All structures were almost completed in March 1963 (ACS-SGI 1962–63, 4091-158).

4. Conclusions

Case studies highlight similarities for design-construction process organization and the techniques used. In both cases, Carlo Rusconi-Clerici was the project manager and Sogene was the construction company. The two experiences highlight the key role of Rusconi-Clerici in architectural and systems design; however, the final design was conducted by Sogene, which engaged expert structural designers, to underline the experimental nature of thin vaults. For Siemens, Dyckerhoff & Widmann designed structures: in the early 1950s, an Italian know-how was not yet available which was able to satisfy rationalization and modernity required by the client. Furthermore, there was reticence towards steel technology: it was evaluated in preliminary design phase but rejected for economic reasons. The Italian cultural and entrepreneurial context was comforted by reinforced concrete technique, to such an extent that a foreign company was entrusted with developing structural design of the Siemens Milanese factory.

Dyckerhoff & Widmann's choice was also favoured by a German client, but at the same time was linked to the spread in Italy of the German system, whose use dated back to 1930s. On the other hand, in the 1950s the Italian school of structural engineering made invaluable progress on thin vaults—even beyond personal and well-known interpretation of the theme proposed by Nervi - thanks to Aldo Favini, who was entrusted with the design of the Perugina factory. Noticing the same architectural designer and the same contractor, Favini's involvement documents a step forward compared to the expertise available in the early 1950s, a period during which the Italian engineer was still studying Fressynet's experiences, before his patents on prestressing (Giannetti 2017, 82–83).

For its part, Sogene's work stands out for the rationalization of roof construction processes, becoming a reference in the

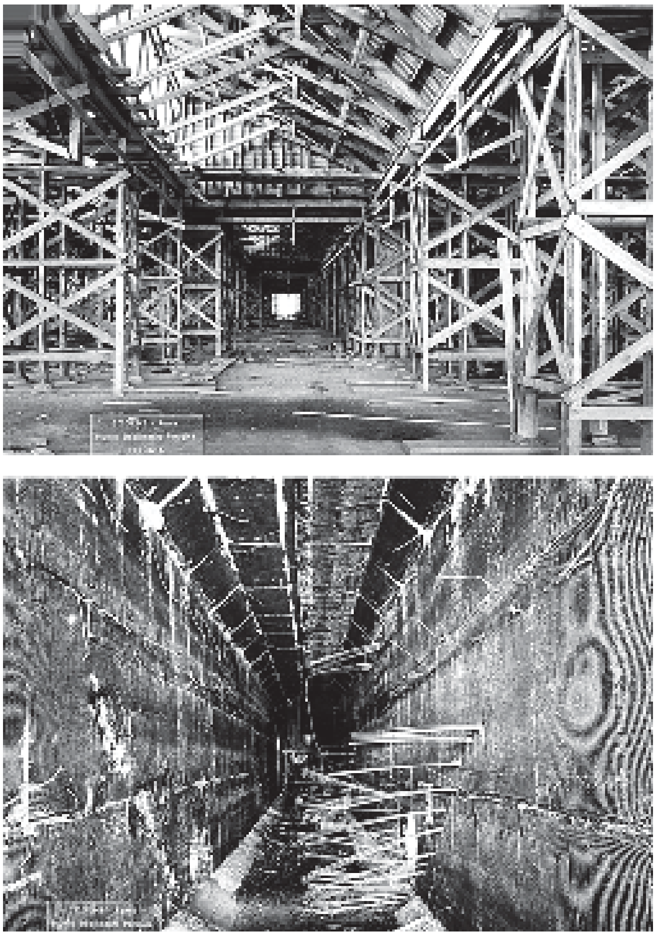


Figure 8. Perugina factory in Perugia. Upper: formworks of the roof consisting of reusable wooden centerings. Lower: interior of a box beam with steel cable before prestressing (on the right) (ACS-SGI, folder 4091-158).

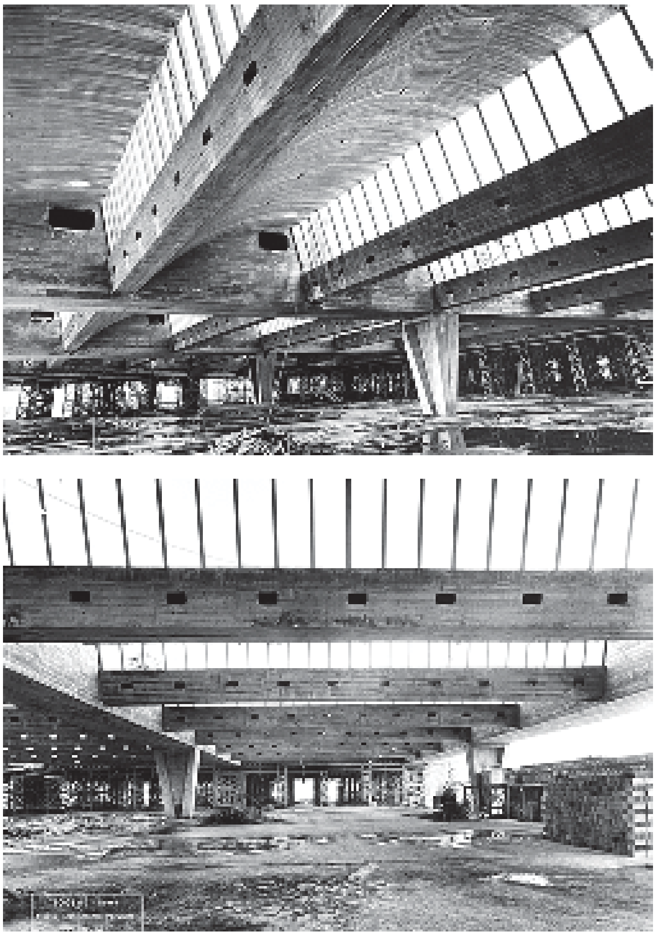


Figure 9. Perugina factory in Perugia, interiors of the manufacturing building (ACS-SGI, folder 4091-158).

national framework for the evolution of the theme, both in use of cast-on site roofs, and in prefabricated roofs. Therefore, Sogene's path in this typological field testifies different lines of experimentation on roofs for industrial buildings, starting from thin vaults cast on site, up to the advent of off-site prefabricated elements, also with use of prestressing procedures.

Roofs of the two factories investigated in this study are characterized by quite different proportions (4,000 square meters for the Siemens factory, 30,000 square meters for the Perugina factory). In both cases they were thin vaults fixed on four perimetral sides. However, in the Siemens case, curved beams following vault geometry were used, while in the Perugina complex, Favini introduced box beams able to combine structural and systems requirements. Box beams—in addition to prestressing technique—represented the main evolution compared to the German system: they allowed Favini to increase the thin vaults span up to 30 meters for the Fimi factory and, in the Perugina case, to repeat the same module, in series, to cover a very large area. Although Favini's system could be considered as an evolution of the German system, an important analogy linked to the construction process is evident: the use of specific reusable wooden formwork. These formworks allowed the Sogene company to complete the works in a brief time, despite the different proportions. The German system proved to be fast and efficient, compatible with the craftsmanship of the Italian construction site and appreciated by a construction context not yet ready to move towards prefabrication in the 1950s. For his part, Favini paid attention to costs and construction problems, therefore, it is not surprising that one of the masters of Italian structural engineering embraced the German system, confirming the 1950s national trend that preferred the on-site procedure.

Bibliography

Aloi, Giampiero. 1966. *Architetture industriali contemporanee*. Milan: Hoepli.

Barazzetta, Giulio. 2004. Aldo Favini. *Architettura e ingegneria in opera*. Polytechnic University of Milan: Libreria Clup.

Baroni, Giorgio. 1936. *Copertura in cemento armato e relativo procedimento di fabbricazione*. Patent n. 346696 (23/11/1936).

Carbonara, Pasquale. n.d. *Architettura pratica*. Turin: Utet.

Cuccia, Giuseppe. 2003. "Il ciclo produttivo". In *La Società Generale Immobiliare. Storia, archivio, testimonianze*, edited by Paola Puzzuoli, 46–50. Rome: Palombi Editori.

Currà, Edoardo and Martina Russo. 2018. "Reinforced concrete in Italy through the works of two generations of engineers: Mario and Giorgio Baroni". In *Building Knowledge, Constructing Histories*, edited by Ine Wouters, Stephanie Van de Voorde, Inge Bertels, vol. 1, 509–517. London: Taylor & Francis Group.

Currà, Edoardo, Ilaria Giannetti, and Martina Russo. 2023. "Spazi e strutture per l'industria: evoluzioni della volta sottile autoportante in Italia". In *In Transizione: sfide e opportunità per l'ambiente costruito*, edited by Fabio Fatiguso, Francesco Fiorito, Mariella De Fino, Elena Cantatore, 193–207. Monfalcone: EdicomEdizioni.

Favini, Aldo. 1945. *Volte sottili in cemento armato*. Wintherthur: Edizioni Centro Studi per l'Edilizia.

Favini, Aldo. 1951. *Dispositivo per ancorare una serie di 3 o più fili o tondini metallici, particolarmente per l'applicazione del sistema del cemento armato precompresso*. Patent n. 482296 (18/12/1951).

Favini, Aldo. 1954. *Dispositivo per tendere in modo uguale una serie di tre o più fili o tondini metallici, particolarmente per tendere fili o tondini costituenti armatura di strutture in cemento armato precompresso*. Patent n. 503538 (6/12/1954).

Favini, Aldo. 1960. "Volte sottili a shed in cemento armato precompresso". *Giornale del Genio Civile* 2–3: 161–171.

Giannetti, Ilaria. 2017. "Design strutturale a Milano (1960–1980). Una mutazione interna alla Scuola italiana di ingegneria". In *Storia dell'ingegneria strutturale in Italia*, edited by Tullia Iori and Sergio Poretti, vol. 4, 80–97. Rome: Gangemi.

May, Roland. 2012. "Shell Wars: Franz Dischinger and Ulrich Finsterwalder". In *Nuts and Bolts of Construction history. Culture, technology and society*, edited by Robert Carvais, André Guillerme, Valérie Nègre, Joël Sakarovitch, vol. 3, 133–141. Paris: Picard.

Melis, Armando. 1953. *Gli edifici per l'industria*. Turin: Lattes editori.

Morandi, Riccardo. 1955. "Un esempio di contemporanea adozione di ritrovati tecnici moderni per grandi edifici industriali". *L'Industria italiana del cemento* 9: 217–220; 10: 241–244.

Nervi, Pier Luigi. 1965. *Costruire correttamente*. Milan: Hoepli.

Pifferi, Emilio. 1959. "La Torre Velasca a Milano". *Quaderni della Società Generale Immobiliare* 11: 1–41.

Poretti, Sergio. 2017. "Nervi che visse tre volte". In *Storia dell'ingegneria strutturale in Italia*, edited by Tullia Iori and Sergio Poretti, vol. 4, 54–65. Rome: Gangemi.

Rusconi-Clerici, Carlo. 1958. *Nuovo complesso industriale San Siro per telecomunicazioni*. Milan: Siemens S.p.a.

Russo, Martina and Edoardo Currà. 2018. "The diffusion of the Zeiss-Dywidag system in Italy: two cases in Rome". In *Building Knowledge, Constructing Histories*, edited by Ine Wouters, Stephanie Van de Voorde, Inge Bertels, vol. 1, 207–213. London: Taylor & Francis Group.

Rutelli, M. 1955. "l centro studi della BPD di Colleferro". *Architettura Cronaca e Storia* n.d.: 512–514. https://cittamorandiana.it/centro-studi/

Spada, Francesco. 2023. "L'industrializzazione edilizia nell'attività della Società Generale Immobiliare (SGI)-Sogene in Italia. Strategie, tecniche e realizzazioni d'impresa (1955–75)", PhD Thesis, Department of Civil Engineering, University of Calabria. Tutor Prof. Laura Greco.

Ufficio Studi Società Generale Immobiliare (US-SGI). 1952. "Ordinamento della progettazione integrale". *Architettura cantiere* 1: 16–25.

Archival sources

Capitolato speciale di appalto delle opere murarie. Nuovo stabilimento Perugina in Perugia. Parte I, n.d., Ministero della Cultura-Archivio Centrale dello Stato, SGI-Sogene collection (subsequent citations ACS-SGI), folder 4096–72.

Construction site photographs of the Perugina factory in Perugia, 1962–63, ACS-SGI, folder 4091-158.

Construction site photographs of the Siemens factory in via Monte Rosa Milan, 1955–57, ACS-SGI, folder 4091-117.

Drawings attached to the contract for construction of the Perugina factory, 1961, ACS-SGI, folder 4096-72.

Technical report, n.d., folder CVII.1, Archivi storici Politecnico di Milano, Aldo Favini collection.