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THE INDUSTRIALIZATION OF CONSTRUCTION IN THE SECOND HALF OF THE XX CENTURY

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EDITORIAL

THE GREAT ILLUSION. ORIGINS, PROSPECTS, AND DECLINE OF RESEARCH ON BUILDING INDUSTRIALIZATION IN ITALY

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I recall construction sites in Rome during the early 1950s: the post-war reconstruction era and the expansive building efforts that would transform the city. My father often took me along during his inspections as the site director for the *Istituto Autonomo Case Popolari* (former IACP and now ATER - *Azienda Territoriale per l'Edilizia Residenziale*). I was struck by the sight of a forest of timber scaffolding where countless workers diligently labored, performing all tasks manually.

Indeed, in Italy, during the post-war period and well into the early 1950s, mechanization in construction was either absent or extremely limited. These limitations were partly due to the fact that only a few construction sites were connected to the electrical grid. Most workers were unskilled laborers recruited from the massive migration waves from southern Italy and rural areas, often awaiting further relocation to industrial cities in the north. To better understand those times for those who did not live through them, I recommend watching (or revisiting) Luchino Visconti's movie masterpiece, *Rocco e i suoi fratelli*.

Master builders were generally highly skilled masons who typically worked alongside a laborer. The latter assisted with utmost respect and obedience in all tasks, from transporting materials to handing them over at the right moment and helping with their installation. With the emerging diffusion of reinforced concrete, specialized roles such as cement workers, rebar installers, and formwork carpenters began to form. Scaffolding, however, was still entirely wooden, usually handhewn.

In the Architectural and Building Design (*Architettura Tecnica*) courses within the engineering faculties, these "traditional" construction techniques were presented and taught even at high-level education. In this regard, it is valuable to consult Carlo Roccatelli's two-volume work *Elementi delle Costruzioni Civili* (1950), which followed Giovanbattista Milani's seminal manuals (1930-40).

However, studies on applying the principles and techniques of the Industrial Revolution – focusing on mechanized serial production – to construction had already begun outside Italy.

The research started much earlier in Weimar, during the post-World War I period in France and Germany. It was under the direction of prominent architects of the Modern Movement that the key conceptual lines of European construction industrialization were defined (the United States represents a separate historical narrative).

Le Corbusier's *Maison Citrohan*, designed in 1922 and realized in 1927 for the *Stuttgart Werkbund*, represents the archetype of a serial model conceived for industrial production. A few years later, in 1932, Beaudoin and Lods realized an extraordinary social housing project in Drancy, near Paris. This project was entirely executed using a serial prefabrication process involving reinforced concrete panels on a steel structure – a prototype of subsequent industrialized systems based on large panels. France was thus both conceptually and technically prepared for the extensive post-war reconstruction and subsequent intense development of large-scale housing projects, known as *Grands Ensembles*. These developments were based on specific building typologies that could be replicated with components industrially produced in factories and assembled onsite. This approach was defined as "*closed-cycle industrialization*" and was often referred to as "*heavy pre-*

fabrication" due to the use of large reinforced concrete panels.

Simultaneously, in Weimar, the Bauhaus was advancing the design of building components, often in steel or wood, focusing on developing the "universal joint". Notable here is the work of Wachsman, who later furthered these concepts in the United States. The rise of Nazism disrupted this research network, dispersing many scholars, several of whom ran away to Great Britain. It was there, in the post-war period, that systems based on the industrial prefabrication of "*lightweight components*" emerged. These systems were used in reconstruction efforts and the development of New Towns. Initially tied to the assembly of specific building types, they soon evolved to include components designed to be bought by catalog. In 1955, the CLASP (*Consortium of Local Authorities Special Programme*) was established in the UK to develop a system for school construction. This initiative was quickly followed by several similar consortia, each proposing unique systems. Generally, these systems relied on steel structural frames combined with reinforced concrete slabs and lightweight envelopes produced by various industrial factories. This laid the groundwork for what would later be known as "*open industrialization*".

By the late 1950s, Italian construction sites had begun adopting more rationalized production processes. Forward-thinking builders sought more efficient and economical alternatives to traditional techniques. Typically skeptical of research (as they remain today), especially academic research, Italian builders closely observed developments abroad, selectively importing innovations they deemed valuable. I recall many Italian entrepreneurs traveling to France, returning in awe of the newly acquired construction technologies. This was the era of on-site industrialization, marked by the widespread adoption of tunnel formworks and systems such as "*banches et tables*", which allowed for rapid construction at the expense of typological and performance limitations. Some builders pursued independent research into automated formwork systems, such as those developed by Grandi Lavori S.p.A. in Bologna under the guidance of Chief Executive Officer (CEO) Mario Tamburini. By the early 1960s, Italian industrialists began importing French patents for closed-cycle industrial prefabrication and established significant manufacturing facilities, particularly in Northern Italy – among the first being the Marcegaglia MBM factory.

Within this technical and cultural context, and with these necessary forewords, the 1960s witnessed the birth of Italian research on building industrialization in some universities. The aspiration was to profoundly renew construction practices, blending designers' compositional freedom with the industry's productive capacity.

Numerous critiques emerged regarding the approach of industrialization through predefined building models. The primary criticism was conceptual, focusing on the impact these models – albeit of high design quality – would have on the architecture of cities, which risked being reduced to monotonous repetitions of a few identical types. Another significant criticism concerned the industrial production process, which required large prefabrication plants concentrated in a few strategic locations and operating under oligopolistic conditions. This approach contrasted sharply with the vision of a distributed network of small and medium-sized mutually complementary industries, which appeared to be the natural evolution of the construction sector.

Other scholars firmly believed that the sector's development should rely on a widespread industrialization process based on the serial production of "open-cycle" components – an approach also referred to as "*component-based industrialization*". This principle involved producing building components independently of the design of the architectural organism in which they would be integrated. Consequently, the process was envisioned to occur on two distinct but closely integrated levels: the design of components and the architectural design of the whole building. Essential features linking these two levels were modular dimensional coordination, joint coordination, and the components' catalog.

The two founding principles of this approach were: firstly, the diffusion of many small to medium-sized industries across the territory capable of innovating and improving through dynamic competition; secondly, the absolute freedom for designers to create architectural organisms supported by the ability to select industrialized components freely. Due to their "small" dimensions, these components would play a compositional role in the project akin to bricks in architectural history. Therefore, the production of components could begin industrially, selected by designers, offered on the open market as construction products, and purchased through the catalog.

Criticism of this approach was not absent. For example, Pierluigi Spadolini, despite recognizing the intellectual merit of this process, expressed deep doubts about the actual "openness" of the architectural outcomes. He argued that these components, as defined, were far more complex than traditional bricks and thus carried substantial semantic implications that could undermine the "compositional freedom" of architectural design. In response to such critiques, research focused on two primary areas: the deepening of techniques related to modular dimensional coordination and joint design – an area primarily rooted in theoretical elaboration – and experimentation with the design of open-cycle components.

The leading proponents and initiators of these research approaches in Italy included the following professors: Giuseppe Ciribini (1913-1990) at the *Politecnico di Milano* (from 1968 in Torino), Pierluigi Spadolini (1922-2000) at the *Facoltà di Architettura* in Florence, Enrico Mandolesi (1924-2014) at the *Facoltà di Ingegnaria* in Cagliari (from 1971 in Rome), and Marcello Grisotti (1919-2012) at the *Facoltà di Ingegneria* in Bari (later in Milan). These figures became essential references for research in this field.

Giuseppe Ciribini was the philosopher of this movement. In addition to his studies on the relationship between human sciences and architecture, he was the leading theorist of building standardization and modular coordination as foundational elements of industrialization. At the *Politecnico di Milano*, and later during the 1970s and 1980s, his work was complemented by Pietro Natale Maggi, a distinguished scholar of the construction process, design methodology, and work ergonomics – essential prerequisites for defining the building industrialization process.

Pierluigi Spadolini, an architect who also practiced as a well-known yacht interior designer, was interested in industrialized production, focusing mainly on component design. He was also a top-level consultant for state-owned Italstat (*Società Italiana per le Infrastrutture e l'Assetto del Territorio S.p.A.*) and a close friend of its president, Ettore Bernabei. In this role, he was pivotal in implementing the nationwide program for post offices (at least one in every Italian municipality), designing the external shell components, and giving the plan of these buildings their characteristic stamp-like shape.

Grisotti and, even more so, Mandolesi were holistic architectural designers. This feature was evident in how they approached research on building industrialization through components. Mandolesi, in particular, stood out for his pragmatism and exceptional dynamism. Alongside Grisotti, he revolutionized the historical teaching of Architectural and Building Design, a fundamental discipline in building engineering faculties. Professionally, in collaboration with Marcello Grisotti, Federico Gorio, and Achille Petrignani, Mandolesi designed the experimental CECA (*Comunità Europea del Carbone e dell'Acciaio*) neighborhood in Piombino for Italedil (*Italiana di Edilizia Industrializzata S.p.A.*), a controlled branch of Italstat. This project served as the basis for his highly rationalized approach to construction sites, which he later carried into research on building components.

I first met Mandolesi in 1970 when he was appointed full professor of Architectural and Building Design at the *Facoltà di Ingegneria* in Rome. At that time, he was again researching for Italedil. This time, he was involved in designing open-cycle steel components for residential buildings and invited me to assist him. He transformed his studio and the entire villa where he lived into a laboratory for experimental models, both at scale and full size (Fig. 1).

The applied research unfolded in several phases: conceptual development of components, detailed morphological and dimensional development, and modeling with wooden prototypes. The geometric design focused on structural elements, cross-braced floor slabs to be assembled on-site, vertical partition elements (walls and doors), vertical closures, and external frames. All components were to be made of steel, dimensionally

Fig. 1. *Italedil research project. Study for including of steel structures and construction elements in the open-cycle building industrialization process.*

coordinated, and pending technological and performance verification in workshops and laboratories using real materials. I vividly recall the complexity of certain elements, such as the beam-column joint, which was also prototyped in steel for various structural profiles (Fig. 2).

Mandolesi devised a full-scale model he dubbed "*visual netting*" to better experiment with grid systems in modular building design. It consisted of a set of 3-meter-long interlaced metal tubes spaced 10 cm apart, half of which were painted longitudinally. By rotating them, the modular reference lines highlighted in red could be used to verify the position of components on a full scale accurately.

The Italedil research project concluded in the early mid-1970s. Its studies were acquired by IpiSystem firm, a company owned by Italedil, with a prefabrication facility for "closed-cycle" steel systems for residential buildings and schools in Pennabilli; in the Marche region. Unfortunately, from then on, the experimentation with prototypes never advanced. Was the system too complex? Did its "open-cycle" component nature cause concern? Or was it deemed too costly to implement? Apparently, the times were not yet ready (and perhaps never would be) (Fig. 3).

By the mid-1970s, Tecnocasa S.p.A. was established in L'Aquila. The company, with shareholders including IMI (*Istituto Mobiliare Italiano*), Montedison, Italstat,

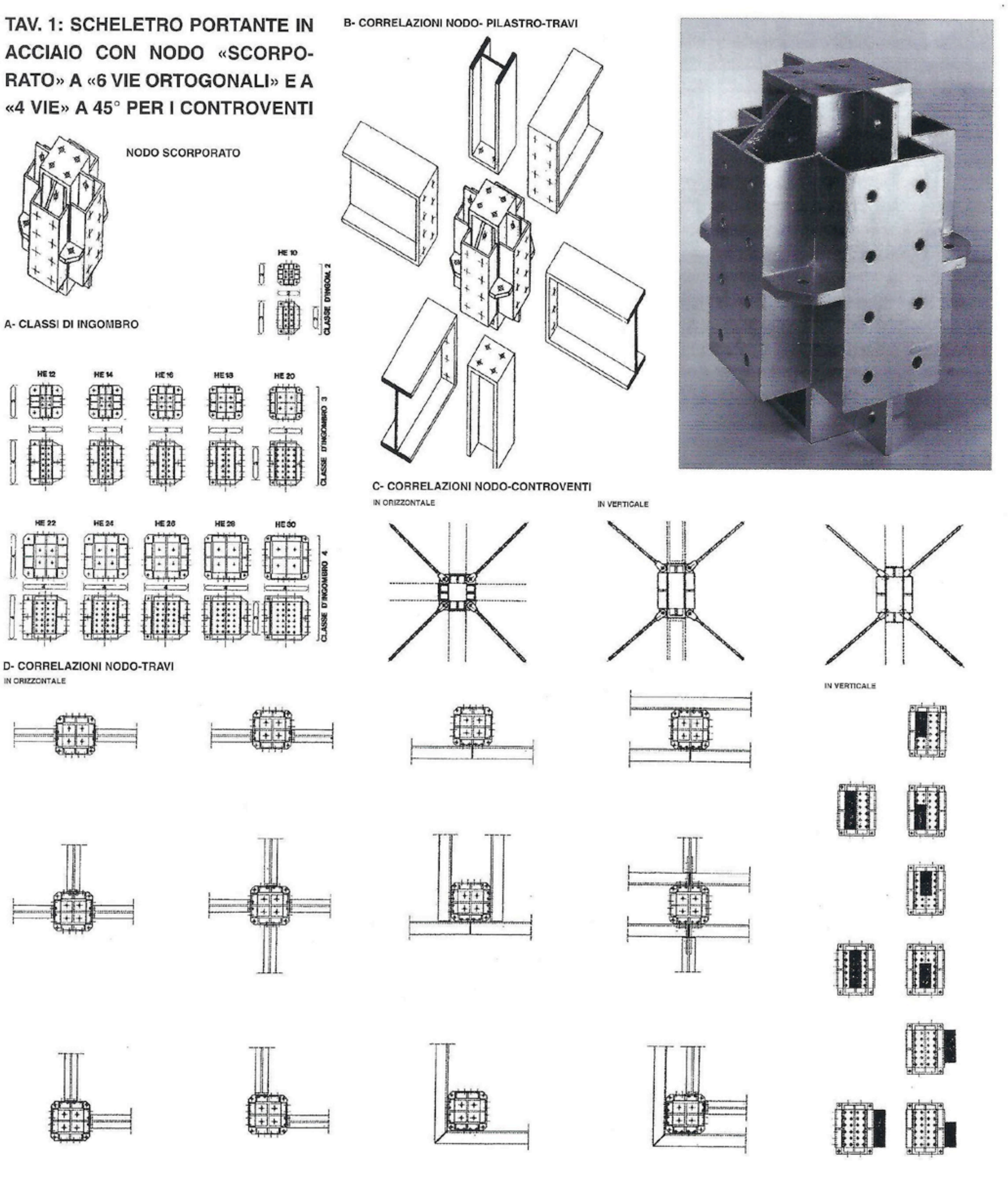

Fig. 2. *Italedil research project. Modular joints for steel load-bearing frame structures.*

and SIR (*Società Italiana Resine*), was a research entity dedicated to promoting and experimenting with new methods and models for industrialized construction. A generational shift saw the coordination of research activities handed over to a group of (then) young researchers active in the field, who had been mentored by the aforementioned "Great Masters", particularly Ciribini and Spadolini. This group included Nicola Sinopoli, Beppe Turchini, Ettore Zambelli, Aldo Norsa, and Marco Simonazzi, who, in various ways, became essential

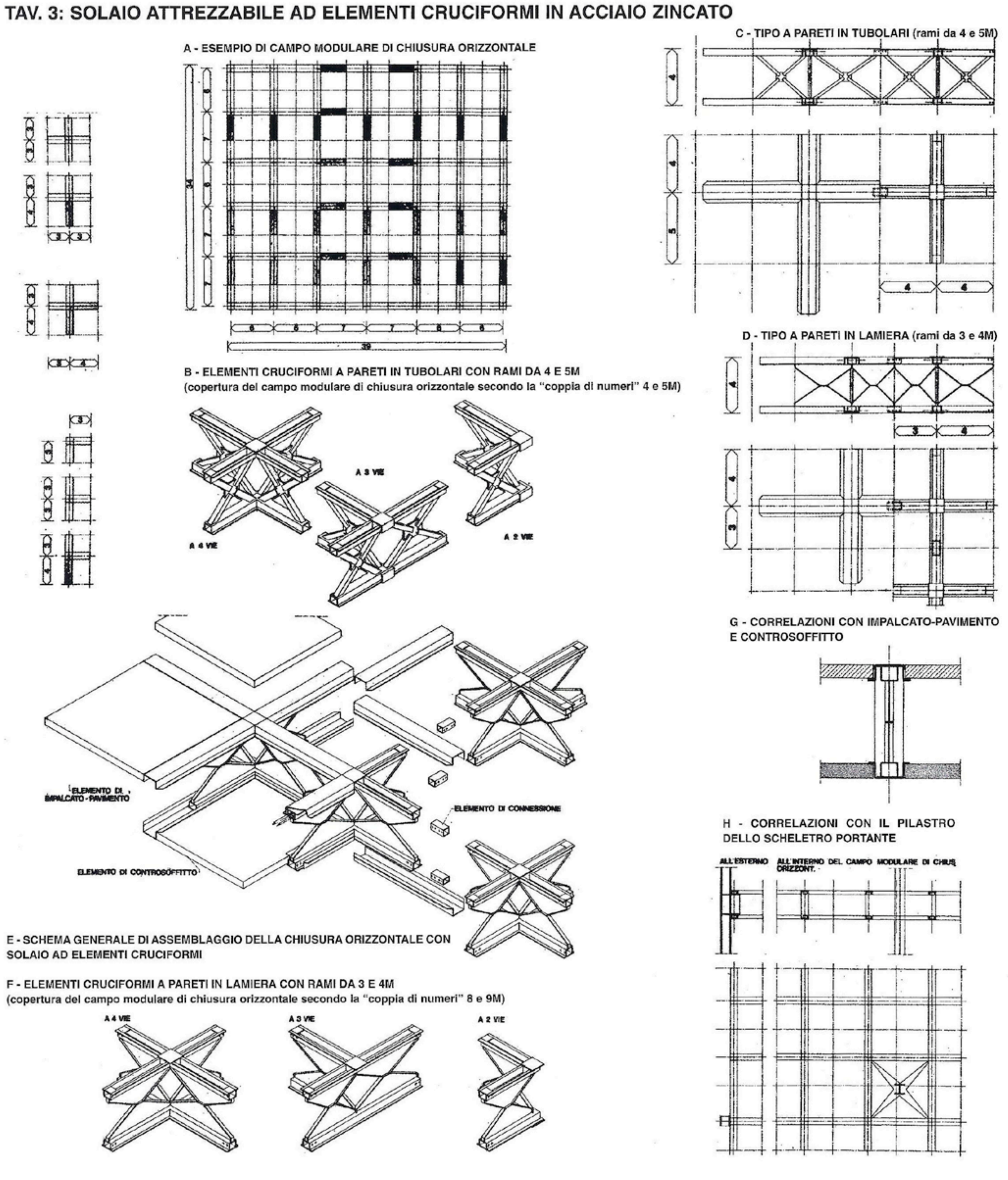

Fig. 3. *Italedil research project. Steel open cycle components for technical installation equipped floors.*

in developing and implementing the teachings of their mentors.

At Tecnocasa, fundamental studies were conducted on several topics, including the construction process – an innovative topic at the time –, the modularization of industrialized "open-cycle" components and technical performance standards. I participated with Mandolesi in a Tecnocasa research project to develop an open system for residential construction. Mandolesi's undeniable creativity in typology and architectural composition was ev-

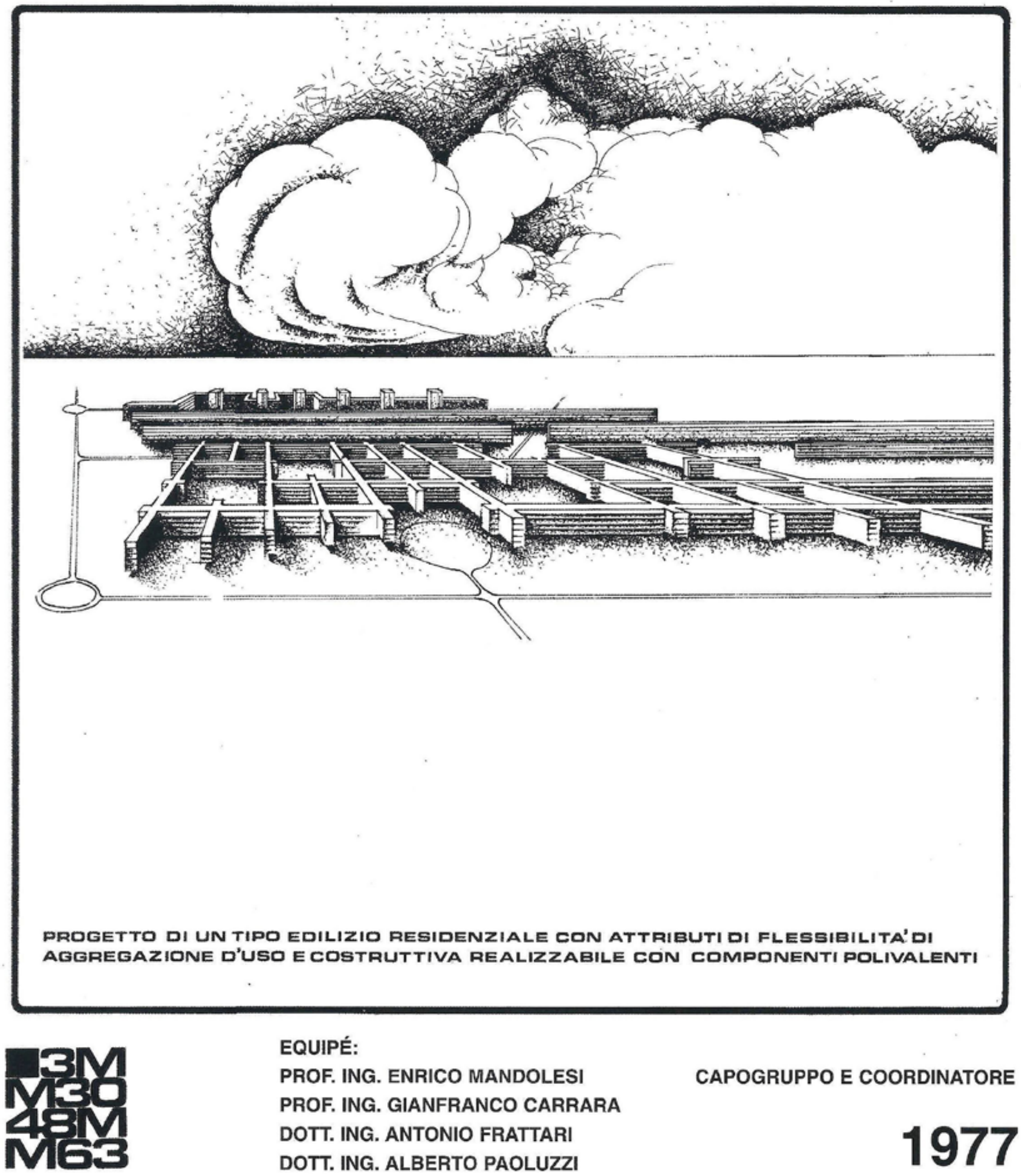

Fig. 4. *Tecnocasa research project. Design of a residential building typology with features of flexibility of use and construction aggregation realizable with multifunctional components.*

ident in the variety of housing schemes that could be assembled into numerous building types. These types were constructed using a reduced set of cataloged components intended for industrial production (Fig. 4).

However, some aspects of the project left me uneasy. The combinatory repetition in assembling components across various housing solutions seemed at odds with the design methods we used then. These methods relied solely on manual drafting on tracing paper, using pencils, and then redrawing with ink. I felt there had to be a more effective way to explore the compositional potential of combinability, and I saw the solution in computers – though, in the mid-1970s, the idea of computers as tools for architecture was still quite futuristic. Thus, I began experimenting with computational graphics at the *Facoltà di Ingegneria* at the *Sapienza Università di Roma*, working with Alberto Paoluzzi, a young graduate in Civil Engineering (later a full professor of Computer Graphics at *Università degli Studi Roma Tre*). Together and with a small group of enthusiastic Italian and international researchers, we entered the international world of research for the first time.

Another unresolved issue concerned the systemic relationship between the static and energy performance of

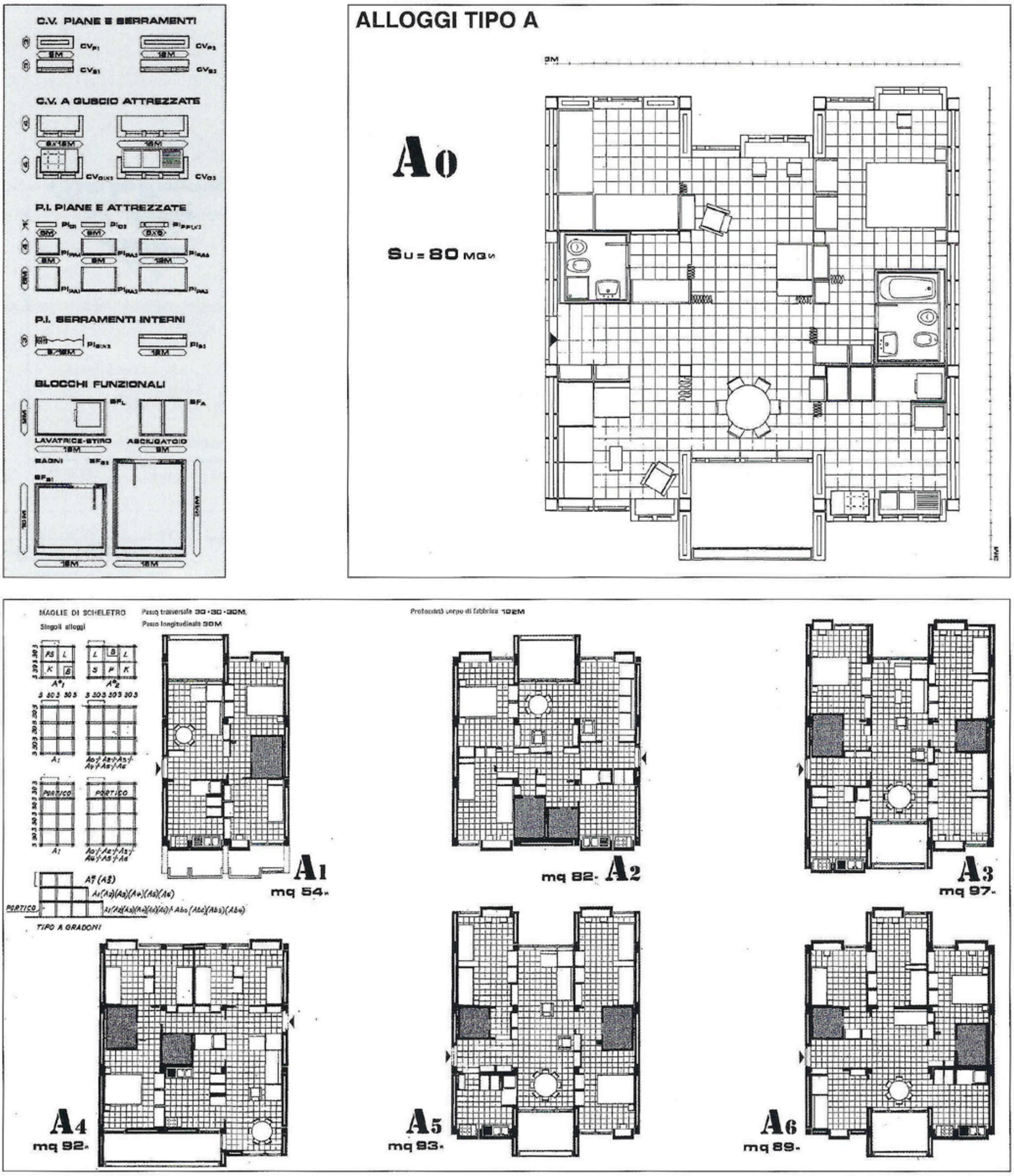

Fig. 5. *Tecnocasa research project. One of the several layout diagrams analyzing different aggregation possibilities of housing units with various sizes based on a dimensional coordination modular grid.*

individual components and the overall performance of the building assembled from these components. Paoluzzi and I initiated research on this topic – a journey that would take me far, encompassing numerous re-evaluations, changes in direction, and dead ends, but also significant successes and recognition (mainly on the international stage, validating the adage, *nemo propheta in patria*) (Figs. 5-6).

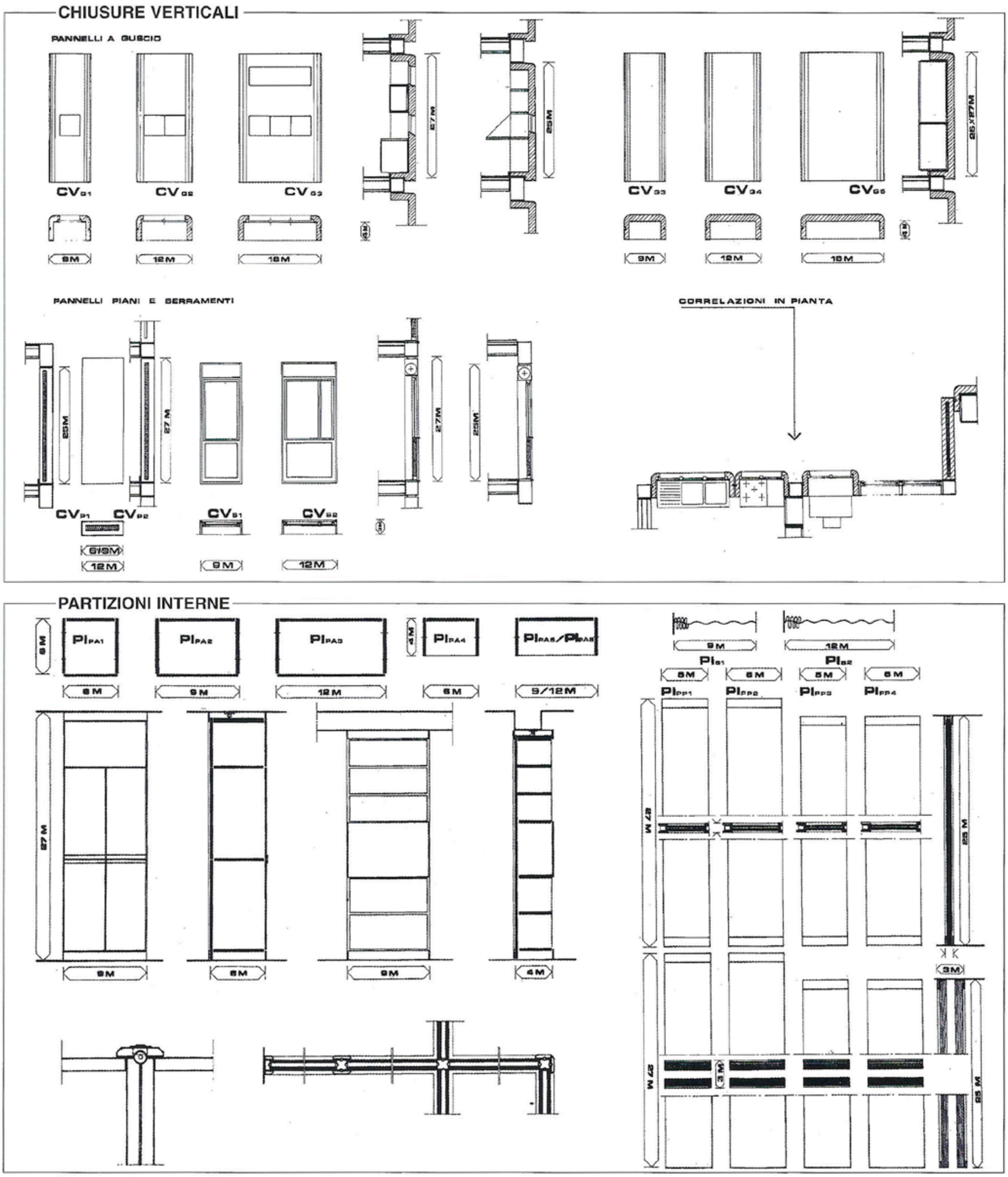

Fig. 6. *Tecnocasa research project. Prefabricated components for vertical closures and internal partitions.*

The outcomes of the Tecnocasa studies were documented in a series of publications. However, no experimental implementation or realization occurred, and the company eventually ceased its activities. Nonetheless, with the relocation of the Tecnocasa researchers to Bologna, the group became the foundation for the Emilia-Romagna Regional Technical Standards Research Group, directed by Nicola Sinopoli with contributions from the

ANIACAP Group (*Associazione Nazionale Istituti Autonomi per le Case Popolari*), led by Elio Piroddi. These studies soon became the benchmark for Italian building regulations.

In the early 1980s, many of us joined the CER (*Comitato per l'Edilizia Residenziale*) under the Ministry of Public Works. We worked on an experimental program for residential construction, coordinated with remarkable intelligence and competence by Massimo Bilò. This program was developed in response to Italian Law No. 94/82, which aimed to foster experimental residential projects in various parts of Italy, emphasizing advanced technological innovation.

The program became a platform for exchanging and applying theories and technological innovations developed through industrial research. However, only a small number of the projects conceived within the program's broad conceptual framework were realized – and even those were delayed for long periods.

Rather than housing, the program primarily produced valuable applied research studies, many of which remain relevant today. Unfortunately, most of these studies were never applied in practice. A wealth of technical and scientific proposals and documents emerged from the program, significantly contributing to an updated building design and production culture. These contributions were incredibly influential in addressing emerging energy conservation and sustainability themes.

Among the experimental projects presented, I recall the SERA (*Sistema Edilizio Residenziale Aperto*) Project, developed by the Production Cooperatives of Emilia-Romagna. The project aimed to prepare a catalog of "open-cycle" components designed through dimensional coordination and joint systems. These components were based on existing industrially manufactured elements adapted for the project by participating industries. This catalog marked the first (and only) attempt in Italy of which I am aware to experiment with an effective production system for "open-cycle" components. Even internationally, similar attempts were limited and largely unsuccessful. Unfortunately, the SERA Project did not progress beyond the production of an interesting catalog (a rare copy of which I still jealously preserve).

About a decade later, in 1994, I worked as a consultant on industrial research funding. I was called to assess a funding request of approximately 3 billion *lire* (approximately 1.5 million euros) from the same Cooperative Associations to implement the SERA Project industrially. Although I reviewed the project and visited the companies' facilities, I sensed that the enthusiasm and confidence once present in applied research had waned. It seemed as though the funding request was motivated more by financial concerns than by a genuine intent to pursue innovation in the sector. Around the same time, I was called to evaluate a funding request for 13 billion *lire* (approximately 6.5 million euros) submitted by Permasteelisa firm. The request was for applied research into advanced façade systems for office buildings, focusing on "double-skin" façades with high energy performance and systems for fully recovering energy produced by lighting and office equipment. The project involved renowned designers and consultants, including Renzo Piano and Thomas Herzog of the Munich Polytechnic.

It was clear that research on building innovation had already taken a different path!

In 1985, the National Council of Research CNR (*Consiglio Nazionale delle Ricerche*) established a commission to conduct a feasibility study for the Finalized Building Project (*Progetto Finalizzato Edilizia*) to advance the sector's scientific and technological development. Together with other notable figures such as professors Benedetto Colajanni, Giuseppe Ciribini, Marcello Grisotti, Pierluigi Spadolini, and Corrado Beguinot, I was invited to join the preparatory commission and later the executive committee of this five-year project, directed by Professor Paolo Bisogno (1989-1995).

The project included three thematic sections open to competitive proposals (*appel d'offres*) from researchers and industry players across Italy: technological innovation, typological innovation, processes and procedures. Many of the submitted and approved research projects were of considerable conceptual interest. Contrary to expectations, the most significant contributions to innovation did not come from advancements in construction technology or studies of production and implementation processes but rather from developments connected to ICT (Information and Communication Technology). Nowadays, it is evident that this outcome was inevitable.

One example is the research conducted by the CARTESIANA consortium (*Computer Aided Research Team for Expert System Implementation and Network Applications*). This consortium collaborated with the research group I led at the Department of Architecture and Urban Planning at the *Sapienza Università di Roma*. Together, we developed a knowledge-based model for representing building systems, known as KAAD (Knowledge Assistant for Architectural Design). This model later became a foundation and reference for subsequent and more recent studies on knowledge representation and collaborative design using techniques that would today be classified as Artificial Intelligence.

As we can see, the research trajectory inevitably diverged from the classical studies on building industrialization.

Despite the high expectations held by the scientific community and, to some extent, by industry stakeholders, the *Progetto Finalizzato Edilizia* had a limited impact on the actual construction world – if not an entirely negligible one. Numerous missteps contributed to this outcome. Chief among them was the insufficient involvement of the most innovative players in the industry and, concurrently, the failure to consider the digital revolution's effects on the sector adequately.

Construction was transforming through entirely different causes and pathways. Above all, the real innovation came from applying the digital revolution to construction materials and products, eliminating the need to mass-produce identical elements. This transformation was driven by the advent of computer-controlled machines, which allowed for parametric manufacturing and enabled the production of homologous components that were similar but not identical.

A paradigmatic example of this era was Frank Gehry's Guggenheim Museum in Bilbao, designed between 1992 and 1993 and inaugurated in 1997. The building's twisted, curvilinear forms, clad in limestone, glass, and titanium, were composed of unique and exclusive elements, each specifically designed for its precise location. As a matter of fact, in the early 1980s, pushed by the high-tech architecture movement, the construction industry began to customize building systems tailored to the innovative designs of new "starchitects", such as Norman Foster, Richard Rogers, Renzo Piano, Jean Nouvel, and Frank Gehry. Industries that embraced this architecture underwent a profound transformation, necessitating new construction technologies that shifted labor from traditional masons to precision-focused technicians akin to automotive workers. These industries developed innovative solutions, particularly in façade technologies, manufactured parametrically with computer-controlled processes.

Among the most prominent companies in this arena was the Italian firm Permasteelisa, founded by Massimo Colomban in San Vendemiano near Conegliano. Permasteelisa pioneered developing and producing cutting-edge components, becoming a key collaborator for leading architects worldwide.

At this juncture, Italy experienced an unforeseen phenomenon by academics and researchers: the industry began to translate the *haute couture* of architectural design, conceived by starchitects, into *prêt-à-porter* products for the construction market. However, this simplification process often banalized the quality of architectural expression, influencing contemporary architectural standards – frequently in a non-positive manner.

Today's typical construction site has become a complex mix of production activities where the industry provides highly diversified products that significantly diverge from the traditional notion of industrially prefabricated serial components. Instead, they generally combine on-site specialized artisanal craftsmanship for specific tasks, such as drywall partition systems and sophisticated industrial components customized to the specific project. The result is not the comprehensive industrialization of construction long pursued with firm belief by the great masters of the past – starting in the 1920s with Walter Gropius and Le Corbusier and continuing through Ciribini, Mandolesi, Spadolini, and others. Instead, what has emerged is a patchwork of solutions assembled on a case-by-case basis for each project and site. This hybrid approach blends artisanal and industrial methods, relying partly on standardized components and advanced but project-specific industrial solutions.

Thus concludes *The Great Illusion* – the illusion of a radical, all-encompassing industrialization of the construction sector. This illusion shaped the theories and aspirations of more than one generation of distinguished researchers. It now ends, alongside the prospects of closed-cycle building-model industrialization and open-cycle component industrialization. These approaches had been studied and heralded extensively but were deeply rooted in a dated cultural framework. This framework originated before the First World War, developed between the two world wars, and was based on the concept of mass-producing identical objects.

This outcome was inevitable. As our culture transitioned from industrial to post-industrial, how could we still expect construction to be a sector to fully industrialize – given the fact that it had never truly been industrialized in the first place? Today, construction is better characterized as a relatively underdeveloped sector with a growing tendency toward post-industrial forms of service-oriented production.

What remains relevant today from the half-century of research and experimentation? First and foremost, the history of those events and the enthusiasm of their protagonists. Second, and perhaps more fundamentally for Italian construction, the introduction of research itself into a world (even the academic one) that previously had no concept of what research meant. Finally, the sector incorporated essential principles of construction that are now indispensable: sustainability, energy efficiency, and performance-based standards. From the past studies, what endures is a rigorous methodological approach and techniques that may seem outdated but await rediscovery and application as reliable tools for project control – particularly when integrated with the latest computational simulation technologies.

Technology has always changed the world, from the invention of the wheel onward (perhaps even earlier). However, how these changes unfold depends on the cultural, social, and ethical attitudes of the society in which they occur.

The construction sector has been profoundly influenced by new technologies, primarily through the application of computers (with their countless uses) in design and production. This development has not only transformed the tools used but has also fundamentally altered how we think and perceive, becoming a vehicle for a new culture still in progress – a culture moving toward an uncertain future.

The power of computers has brought not only technical advancements to design but also the ability to construct and visualize unconventional geometric forms almost effortlessly. It has introduced a new way of conceiving architectural shapes, with both positive and negative consequences. The changing cultural context and pervasive globalization have done the rest.

Today, we face a crisis of values, a pervasive fear of the future, and a dominant sense of uncertainty. These are reflected in a design philosophy that breaks with the past, where increasingly complex technologies are called upon to address formal problems that cannot be understood or evaluated using the parameters of the recent past.

The unwavering faith of the "Great Masters" in specific ideological and cultural reference points has given way to relativism, where everything is virtually possible and justifiable.

In this relativist framework, there is no longer any place for *The Great Illusion*!

All figures are extracted from Pugnaletto M (ed) (2007) Operosità di Enrico Mandolesi. Centro Studi Consiglio Nazionale Ingegneri, Roma. See also Mandolesi's papers: https.//archivio.enricomandolesi.it

THE BUREAUCRATIC MECHANISMS OF THE TEMPORARY HOME. EXAMINING THE DEVELOPMENT OF PREFABRICATED HOUSE-TYPES THROUGH TRADE CONTRACTS BETWEEN FINLAND AND ISRAEL, 1948-1958

Tzafrir Fainholtz, Mia Åkerfelt

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Abstract

In the 1940s and 1950s, Finland became a major exporter of wooden prefabricated detached houses. The growth of this industry coincided with a great global demand for housing which followed the Second World War. Different companies and sawmills were active on the Finnish market, among them, the sales organizations *Puutalo Oy* and *Puurakenteiden myyntiyhdistys*. One of the biggest importers of the Finnish houses in the early post-war years was Israel. Gaining independence in 1948, the country had to resettle thousands of displaced refugees, arriving from Europe and the Mediterranean in need of a home. Israel's trade agreements with Finland laid the foundation for a long-distance planning process when the state and other agents negotiated the designs of the houses with the Finnish manufacturers. The aim was to develop types suited especially for the Israeli needs. Based on ongoing research, this paper presents the complex diplomatic, economic, and political story of the import of the houses and the development of the models. The case is a challenging opportunity to learn from this period in mass housing history, building a methodology based on the paper trail left in official documents, correspondences, and architectural drawings, as well as in contemporary media, to discover the bureaucratic, political and economic mechanisms that shaped it.

Keywords

Prefabrication, Housing, Crisis architecture, Wooden architecture, Finland.

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1. INTRODUCTION

After the Second World War the Finnish industry for prefabricated wooden houses gained momentum and quickly surpassed the production rates from the pre-war decades. Fueled by the rapid payment of war reparations to the Soviet Union in goods – as prefabricated wooden housing – the industry also became an important part of Finland's international diplomacy.

The export on a global scale demanded that prefabricated types were developed for different climates and different users. However, due to the scarce archival sources, the details of the planning process can only be obtained in a few cases from the main archives in Finland. One of the main customers around 1950 was Israel. Here, thousands of houses and several prefabricated hospitals were sent between 1948 and 1952. Archival material on the specific development of shelters and building types to Israel is limited. However, valuable data on the planning process and type development can be obtained by close reading of sales contracts and correspondence between the Finnish and Israeli counterparts. The case of the planning of types for Israel provides an opportunity to try out methodologies for dealing with disappeared architecture and the planning of buildings, puzzling together a multitude of data from various archival sources to gain understanding of the planning process and its results. Therefore, the aim of the article is to examine how bureaucratic documents, as well as letters, architectural drawings, and photographs can contribute to piecing together the story of how prefabricated shelters were developed in collaboration between Finland and Israel. The central questions the article seeks to answer are: What was the political background and scope of the import of Finnish houses to Israel and how can the available data be assessed to gain information on the planning process? The material consists of a wide array of archival documents. The main archival sources are the Finnish manufacturers' archives in Suomen Elinkeinoelämän keskusarkisto (ELKA), as well as the Israel State Archive, and the Central Zionist Archive. These archives contain drawings, photographs, minutes from business meetings, correspondence, international agreements, and contract drafts. Furthermore, the Finnish National Library's digital archives provide extensive access to digitized journals, newspapers, commercial booklets, and product catalogs. The digitalization of the Israel Film Archive and Israel National Library also allows searches in data in different languages as their depositories scope go beyond the Israeli material.

Architectural archives come in a wide variety of forms and content types. The technical development during the last decades has highly transformed the work both within the archives themselves as well as how research in their contents can be conducted [1]. Today, architectural archives are understood as more than an entity devoted to preserving the work of well-known architects, focusing more and more on acknowledging the often fragmentary nature of the trails of papers left behind within the practice of construction. Even the term "architectural archives" is questioned due to the often highly diverse type of materials preserved, opting, for instance, for broader terms as "project archives", as suggested by Riccardo Domenichini [2].

One challenge of the architectural archives is the wealth of data often available, which within more traditional architectural research might lead to a focus on the usage of the pictorial material, bypassing the other primary sources and the data they contain [2]. In the case of administrative architects and development companies, the data is ever more diverse, especially in colonial settings or in international trade, often spread over several countries [3-5]. Another challenge is posed by situations where data is missing or was never produced or sorted in the first place, as for instance regarding camps or temporary settlements [6].

Common research perspectives today consist of documentation of company histories, how partnerships or networks contributed to facilitating orders and projects, conflicts expressed in the correspondence between agents and the mother company, or post-colonial perspectives on the existing data. In the case of Finnish houses in Israel, the research deals with company archives, local government archives and the type of collected data typical for administrative architects. To extract relevant information, it is beneficial to adopt a methodology which connects a multitude of source types, as economical documents, correspondence, minutes from meetings, registers of conflicts and newspaper articles, as well as memory records and oral stories, not just focusing on the drawings [3-7].

In the project, the first step was to create a chronological understanding of the design process and the import/export to bring information on the temporal aspects of the work. Here, we will highlight some of the examples of the design process as case studies. The next stage adds data from all the different types of sources that are available, as well as contextualizing the finds with historical data. This will contribute to creating a comprehensive description of the planning process. The sources are analyzed through close reading of the archival documents to understand the historical context surrounding the official discourse on the import and export. The drawings, photographs and visual material are subjected to architectural – or visual analysis, which specifically searches for signs of the design process decisions in the material product.

2. PREFABRICATION IN FINLAND AND THE EXPORT INDUSTRY

In Finland, industrial prefabrication of wooden houses began in the late 19th century. During the first decades of Finnish independence, the 1920s and 1930s saw a new development of prefabrication methods as well as companies within the trade [8, 9]. From the beginning, the main market for Finnish prefabricated houses was global, and the trade routes established in the 1890s continued to be important throughout the main parts of the 20th century. The trade with the Levant developed during the inter-war decades and Finnish manufacturers were continuously reported to exhibit and sell their houses in 1930s British mandate Palestine, mainly trading with the country's Jewish community [10-12]. Trade contacts were mainly based on interpersonal relations, and these were the foundation for the intensified trade between the governments and Jewish organizations after the Second World War and the founding of the state of Israel in 1948 [13].

The main difference in the trade during the post-war decades compared to previous trade was the centralized coordination of manufacturing. In 1940, twenty-one companies joined together and founded the Puutalo Oy sales organization to streamline the production and sales of Finnish prefabricated houses. Due to the wars between Finland and the Soviet Union between 1939 and 1944, and the following war reparations Finland had to pay, the Puutalo organization became the coordinator of the wooden housing industry's part of the reparations and developed formalized collaboration with the Finnish government [9]. This gave the organization easy access to participation in large-scale international trade deals. Until the end of the 1950s, most of the company's production went on export due to the struggling domestic economy. However, thanks to its connections to the government, the company participated in the national reconstruction after the war, mainly regarding planning and development of suitable building types. Another leading organization involved in the trade with Israel was Suomen Puurakenteiden Myyntiyhdistys, founded in 1944 by six companies which left Puutalo and started their own organization [14]. The organization simplified its name in 1950 to Myyntiyhdistys Puurakenne. In early 1956, Puutalo Oy and Myyntiyhdistys Puurakenne merged due to the dramatically deteriorating market for prefabricated wooden houses due to a halt in exports to the Soviet Union [9]. A third company involved in the Israeli trade was the Pelkkatalojen Myyntiyhdistys, which was formed in 1949 and had four members in 1951 [14]. Since the company was described by the Finnish press in 1954 as a small company with mainly domestic clients in contrast to Puutalo Oy or Myyntiyhdistys Puurakenne, it is possible that the negotiations with Israel failed [15].

3. OPPORTUNITY AND DIPLOMACY IN FINLAND'S HOUSING EXPORT TO ISRAEL

Following the mass immigration, the Israeli landscape was dotted with various kinds of temporary dwellings, like the *Ma'abarot*, New Towns, *Kibbutzim* and, *Moshavim*. While tents were common in the beginning in many places, they were later replaced by *Zrifim* (Shacks) of *Zrifonim* (Small Shacks), *Badonim* (structures made of cloth), and *Pachonim* (metal Shacks). These buildings were distributed by the government and the Jewish Agency, as well as by public housing companies like Amidar. The need for housing on this massive scale posed a great challenge to the new Israeli government, and to the Jewish Agency, organization that was pivotal in the founding of Israel (and was still powerful in the first decade of the state).

As a new state facing mass immigration and a housing crisis, Israel was struggling to build mechanisms for the provision of houses to fulfill what was described by Allweil as a «state citizen contract during the first years of Israeli sovereignty» [16]. This kind of contract, which tied state policy and housing, was not unique to Israel [16], though in Israel, the creating of new a government and the political and diplomatic of housing import, created, as we will show, mechanisms of multiple participants.

The archive material shows there was not one governmental or non-governmental body responsible for the import of the houses to Israel and their distribution, there was also not one guiding hand and decisions were made through negotiations and sometimes in response to immediate needs. The new Israeli government had a Planning Department in the Prime Minister's Office, but the issues of imported housing were navigated by different ministries, from the Foreign Ministry which was dealing with the diplomatic side of the import of prefab housing, to the Ministry of Labor with its Housing Department and others. The government also used other organizations such as Amidar, a governmental housing company which helped in the management of the housing. Since Israel was a new state, there was still the involvement of pre-independence Zionist bodies dealing with the issues of housing in the new country. An important pre-state organization dealing with housing was the Jewish Agency, which had a great impact on the issue also in the first decade after the founding of Israel. Another organization which preceded statehood was the Jewish National Fund, which was active in building settlements. The correspondence in the archives reveals many different participants in the import of the houses from Finland to Israel, including also private companies and agents who worked with the different authorities in the dealings [17]. The files in the ISA (Israel State Archive) show the involvement of different governmental bodies to name a few: the Planning Department at the Prime Minister office (for example file ISA 2762/ג-21); the Foreign Ministry and Israeli delegations abroad (for example file ISA 2369/ג-13); the Ministry of Labor, Housing department (for example file ISA 2369/ג-13) and others. The involvement of the Jewish agency can be traced among other places in the files of the CZA (central Zionist archive) where correspondence also about the JNF and other organizations is kept (for example, file S14-168). Examples of the involvement of private agents include the Jakob A. Lewison and company firm (correspondences appear, for example, in file ISA, 432/ג-31).

Anticipating the need for housing a growing number of Jewish immigrants, the Jewish Agency was negotiating with Finland's prefabrication industry and authorities already in 1946, two years before Israel's independence. The agency was in contact with the Finnish delegation in Istanbul concerning the purchase of houses which they called "Finn-Houses" [17]. The producing company was most likely Myyntiyhdistys Puurakenne since their telegram address at the time was "Finn-Houses" [18]. The Jewish Agency continued to be active in settling the newcomers to Israel after the establishment of the state in 1948. However, after the founding of the state of Israel, the interests of the Jewish Agency sometimes clashed with the interests of the government as the latter was looking to establish a trade based on the exchange of commodities with Finland, with which the new country signed its first international economic agreement in 1949.

The Finnish and Israeli governments were building an economic diplomacy to which the Jewish Agency dealings seemed to be a threat [19]. The Jewish Agency policies caused friction with the Israeli government as an act of a «state within a state» [16] and this was seen related to the agency's housing import dealings, which caused significant uproar at the Israeli Foreign Ministry as it was thought to risk Israels' relations with Finland. In 1951, this led Moshe Sharet, the Foreign Minister, to write to Levi Eshkol, Treasurer of the Jewish Agency (later Israels' prime minister), about the damage done to the country's diplomatic relations due to the Agency trade of the prefabricated houses with Sweden. Sharet wrote «In the development of the export to Sweden and the rest of the Scandinavian countries (including Finland) and in the founding of all our trade relations… on barter trade we invested immense efforts», and «the separate dealing of an official institute such as the Jewish Agency […] ruins our all endeavors and make a mockery of us». «It's about time that the Jewish Agency will move from a de jure to de facto recognition of the state» [20].

The first trade agreement between Israel and Finland was reached in August 1949, based on parallel trade. The largest part of the Finnish export deal consisted of prefabricated houses, with an Israeli commitment to purchase 680,000 dollars worth of houses (which later grew to 720,00 dollars when the agreement was prolonged) and the Israeli largest export were citrus fruits and industrial components [21, 22]. The trade with Finland was based on separate dealings with Finnish companies and was not entirely directed by the Finnish government. It is a possible result of the lack of guidelines that Israel first did not trade with one of the major companies but rather with a wholesale company called Hero-Tukku Oy. It is unclear how the connection started, but in the preserved correspondence, Hero-Tukku offered to provide "semi-prefabricated houses", which must have been cheaper than the prefabricated houses required by the Finnish-Israeli agreement [23-25].

While Israel was dealing with Hero-Tukku, the larger timber sales organizations also showed interest in exporting to Israel. Puutalo Oy entered the Israeli market with the help of Jakob Lewison, a businessman from Tel Aviv who had experience in dealings with the Finnish timber industry. In 1949, Lewison wrote to the Israeli Ministry of Economy and Industry about the intention of Puutalo Oy to send a task mission to Israel to form a business "collaboration". The letter specified that the mission would explore which prefabricated houses would be suitable for Israel and announced the Puutalo Oy's intention to build a factory in Israel for the production of prefabricated houses, hospitals, schools, etc., with the possible help of the Israeli government [26]. There is no evidence that Puutalo Oy ever built such a factory or really intended to do so, but by 1951, Israel had become a major customer of the company. Pelkkatalojen Myyntiyhdistys also approached the Israeli authorities in November 1950. Pelkkatalojen Myyntiyhdistys negotiated with the Israeli authorities, but its offer seemed too expensive and "uninteresting" [27]. It is unclear whether the company gained any Israeli commissions, but since it was described in the Finnish press in 1954 as a small company with clients mainly in Finland, it is possible that the negotiation failed [28]. In 1951, Myyntiyhdistys Puurakenne also approached Israel through an Israeli-Finnish representative who was urging them to order houses from the company [29]. This bid was successful, and the company exported houses to Israel in the following years.

In some cases, the companies' dealings with Israel were supported by people in the Finnish government. In 1951, Åke Gartz, the Finnish Minister of Foreign Affairs, who also was the Deputy Director of the Ahlström Oy company, which in its turn was a part of Myyntiyhdistys Puurakenne, offered Israel to increase the amount of "pre-fabricated houses in precut components", in a new trade agreement, to the sum of 1,000,000 dollars in exchange for a Finnish import of woolen tissues, raincoats, automobiles and trucks [30, 31]. Later, when the agreement for 1951-1952 was finalized, this sum grew to 4,000,000 dollars for "Prefabricated houses in components, prefabricated hospitals and schools", as it was mentioned in a secret protocol attached to the agreement. Israel's main export exchange was citruses and Kaiser Frazer cars, which were assembled in Israel and shipped to Finland.

While Israel was a major importer from Finland, the Israeli need for houses declined as the country's situation improved and permanent dwellings were built. In the trade agreement for 1953-1954, the quota for importing Finnish prefabricated houses was left open and now also building parts were included in this term [32]. The import of Finnish houses continued after this date, but according to the records, the trade was much smaller. The efforts of the Finnish manufacturers to maintain the export to Israel continued in 1953 when Puutalo Oy participated in the Conquering of the Desert International Exhibition in Jerusalem, where the Finnish timber industry was represented, and Puutalo Oy presented a 62 m^2 house with four rooms, fully furnished with Finnish furniture [33]. The Finnish housing export to Israel was continuously supported by Finnish diplomacy. In the 1956-157 economic agreement with Israel, a secret clause was agreed that if Israel were to import prefabricated houses for foreign currency, it should offer to import first from Finland and guarantee Finland the "first refusal" [34].

The diplomatic and economic aspects of the trade in prefabricated houses between Israel and Finland had a crucial impact on the number of houses imported to Israel and their production in Finland. This also affected the design process of the early houses, and they were more or less developed through correspondence.

4. THE NEGOTIATION OF PREFABRICATED DESIGNS AND THE AFTERMATH OF TEMPORALITY

While thousands of houses were imported to Israel from Finland, tracking them in Israel is challenging. The houses were distributed by different government offices, the Jewish Agency, the Jewish National Fund, and organizations such as *Amidar*, which made it difficult to locate their locations. Furthermore, the houses were considered temporary, most of them were demolished after a few years, and the few that survived were scattered all over the country. The temporary nature of the houses also encouraged the Israeli importers to demand that the houses be bought without roofs or floors, which compromised their structural integrity and must have affected their durability and survival [35].

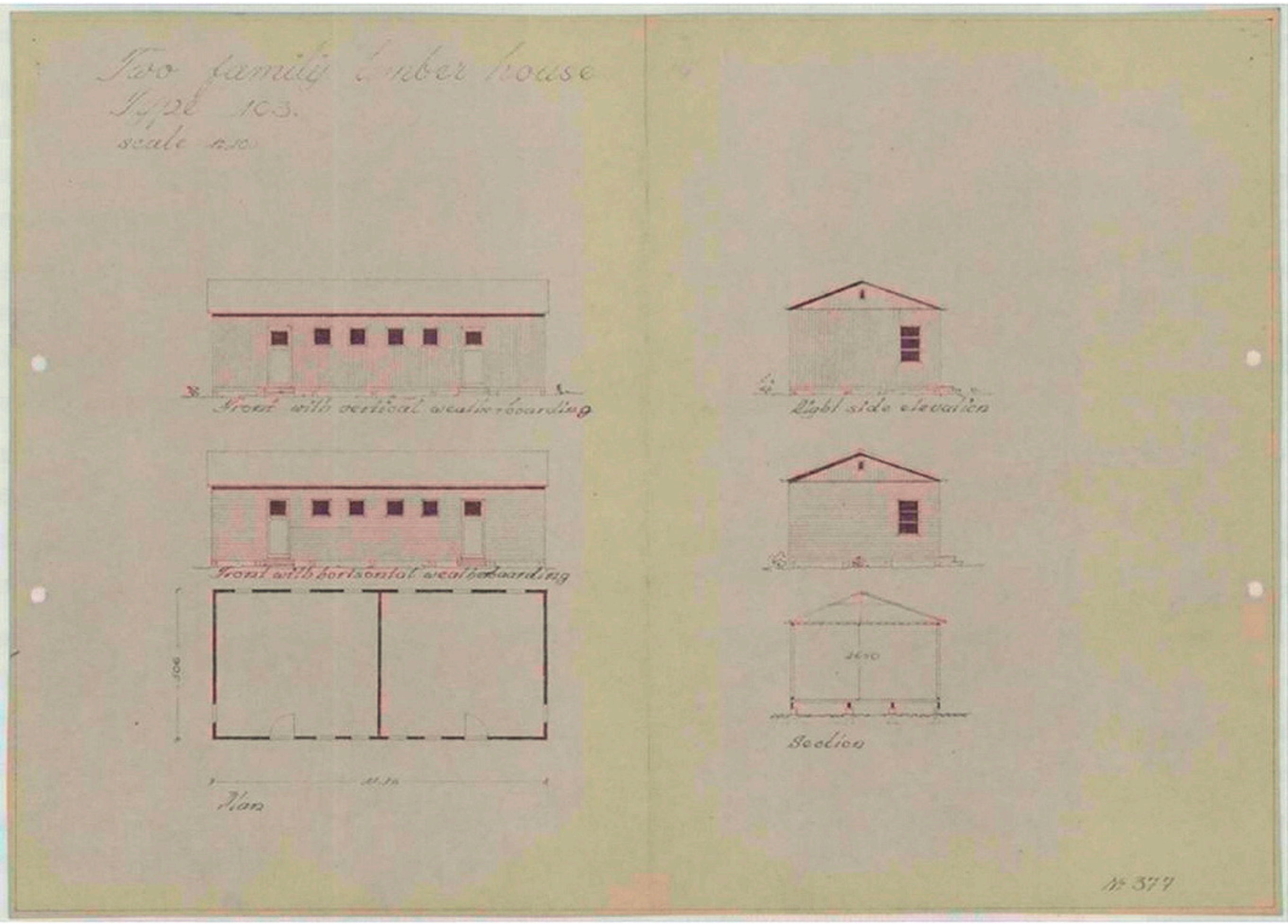

Fig. 1. *Pelkkatalojen Myyntiydistys, "Type 103", 1951. Source: Israel State Archive.*

While most of the houses did not survive, they did leave a paper trail in governmental and municipal archives, in memories of people, in old newsreels, pictures and different sites. One Finnish prefabricated building type that left its mark both on-site and in the archives was the two-family *Zrif* (hut), developed in collaboration between the Israeli authorities and the Finnish exporters. The initial design specification for a basic two-family *Zrif* was made by the Israeli Housing Department and sent from Israel to Finland, where both Pelkkatalojen Myyntiyhdistys and Puutalo Oy received it. The "type 103" was a simple wooden, unadorned shack divided into two one-room units with one entrance. Each unit was meant to house one family. To reduce costs, it was requested that there be no division inside the units (Fig. 1). The suggestion and drawings sent from Pelkkatalojen Myyntiyhdistys in January 1951 show a simple two-room house with no bathrooms or kitchen areas. The building had two doors with small windows, and four windows on the front elevation. The company also offered two options for positioning the boards of the outer walls, one vertical, the other horizontal. Two larger elongated windows were fixed, each on the side elevation. The house was to stand detached from the ground on stilts with a wooden floor. The Pelkkatalojen Myyntiyhdistys wooden house, which was meant to be constructed of timber, must have been considered too expensive, since the company sent another offer in which the houses would be built with a method called "Pe-Te" consisting of plates of pressed wood wool [36, 37].

Puutalo Oy also received the "type 103" specifications and sent their offer, and by February 1951, houses were ordered from the company for the sum of 460,000 dollars [38]. Puutalo Oy designed two options, renamed "type 840p" and "type 840s", both remarkably similar to the previous Pelkkatalo timber design. The "840p" (Fig.

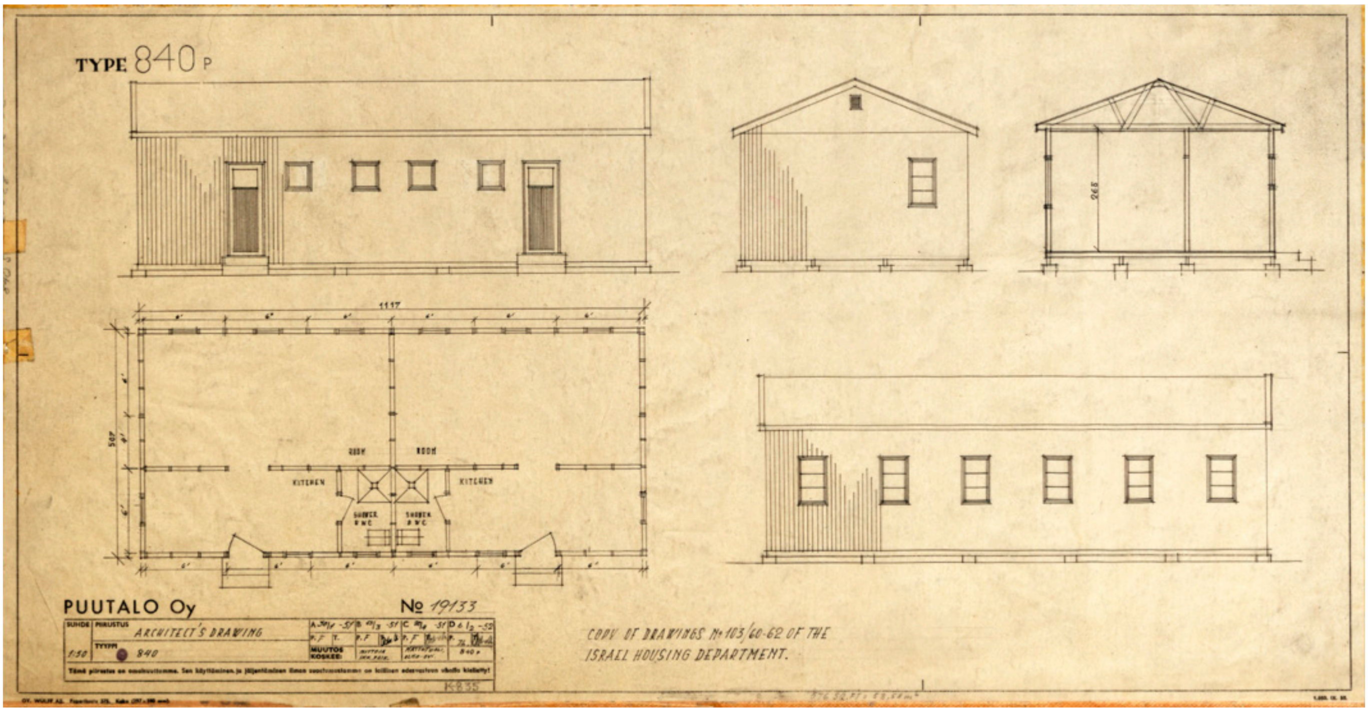

Fig. 2. *Puutalo Oy, "Type 840d", 1952. Source: ELKA Archives.*

2) was designed to stand on stilts with wooden floors, while the "840s" was designed to be placed on a concrete platform, eliminating the need for a wooden floor and allowing the Israelis to save on the import of wooden floor materials. After the commission was secured, the "type 103" was further developed. The letters do not include information on this, but the drawings can be analyzed to describe the fine-tuning of the design process. In the 1952 version of the "type 103" by Puutalo Oy, each of the rooms had gained a small entrance area, a division of the living space, a small bathroom with a shower and toilet, and a small area at the entrance was designated as a kitchen but with no fittings. The design changes to the "type 103" were most likely related to the function of the house, since it was meant to provide temporary housing for longer periods, and this required utility rooms [39].

A *Ma'abara* to which the "type 103" was sent was Amishav, erected near the city of Petah Tikva and later incorporated into the city itself. This was part of a rebuilding of the *Ma'abara* in 1952. This rebuilding was celebrated in an Israeli newsreel, which announced that these *Zrifim* replaced the tents where the inhabitants had lived before [40]. In the same newsreel, one can see several types of houses, among them the "type 840p". The arrival of the Finnish houses in Amishav must have been seen as a more enduring solution for housing. The area where the houses were built became known as the "*Zrifim Finnim*" (Finnish huts) neighborhood and it is still remembered on a plaque at the local Tiferet Israel synagogue. The move into the *Zrifim* was considered a move into a more permanent public housing policy and came with a price, as the inhabitants had to pay a deposit and a monthly rent, and if they could not do it, they had to take a loan. In Amishav, the *Zrifim* housed 1300 families in 1953, mainly from Iraq but also from Romania, Iran, and Yemen, amongst other countries [41]. The cramped existence in which whole families lived in one room in a *Zrif* and ongoing neglect by the state turned the Amishav into a slum in the following years. In 1963, 11 years after its construction, the "*Zrifim Finnim*" neighborhood was up to demolition as a newspaper wrote that «Amishave is still neglected», commenting that at times, up to fourteen family members were cramped in one *Zrif* and that there were houses which still were not connected to the sewage system there were no paved roads, and even the clinic was not connected to electricity [42]. The simplicity of the types used to build "*Zrifim Finnim*" and neglect were the reasons why most of the *Zrifim* in Amishav were demolished, leaving only a few heavily altered ones that still exist.

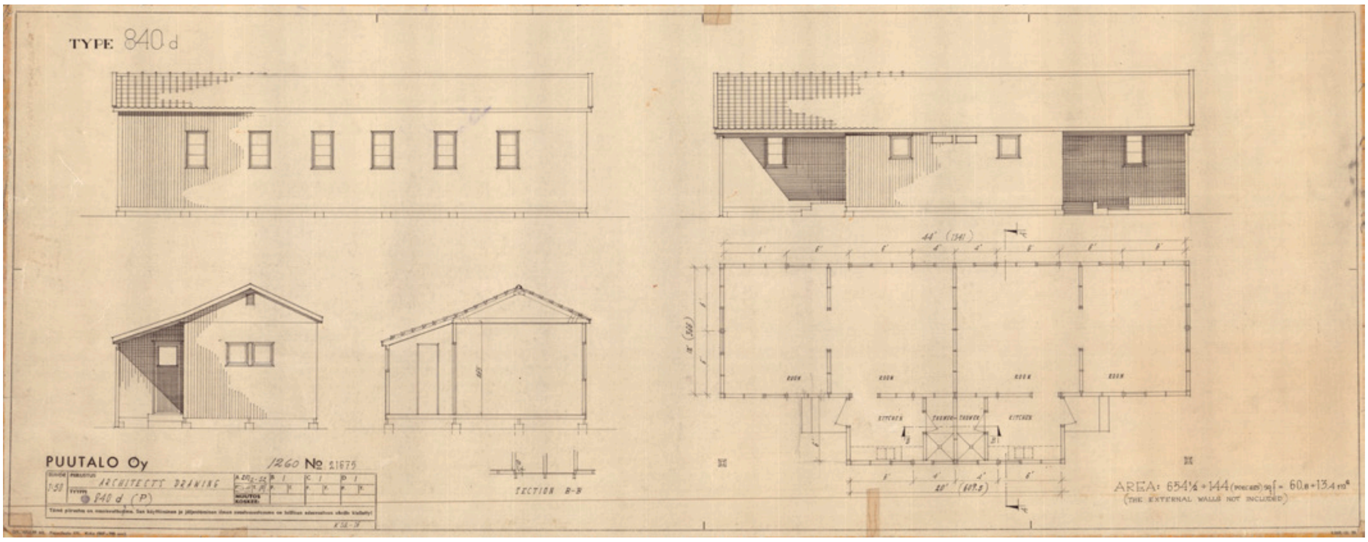

Fig. 3. *Puutalo Oy, "Type 840d", 1952. Source: ELKA Archives.*

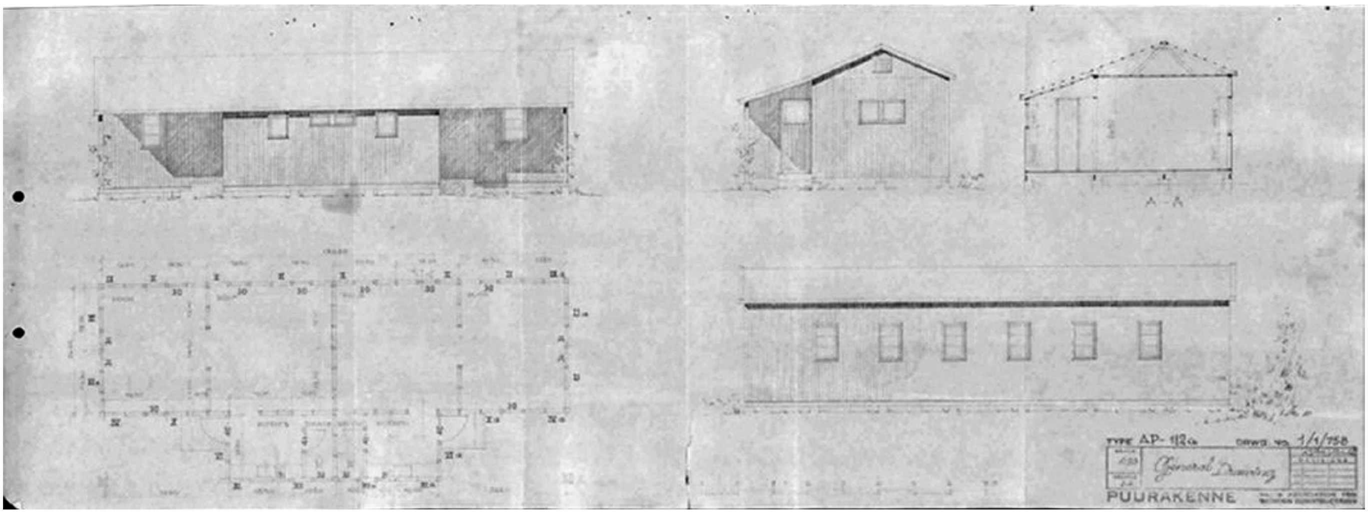

Fig. 4. *Puurakenteiden myyntiyhdistys, "Type AP-112a", 1952. Source: Israel State Archive.*

Another example of a two-family house that was distributed in Israel through two companies was a design that was manufactured in Puutalo Oy as part of the 840 series and was marked as 840c. This type had two units, each with one room, and the "sub-type 840d" had two rooms. From the outside, these two types were identical, built on stilts. They each had a kitchen area and a shower area which projected out of the middle of the entrance façade with small, shaded areas on each side. The houses were planned with no toilets. The back façade was similar to the "840s" and "840p" types, but the side façade had a horizontal window instead of an elongated one. This type was also designed according to Israeli specifications and a similar version of it was designed by Myyntiyhdistys Puurakenne with one type almost identical to the Puutalo "840c", called "AP 111a", and another similar to" 840d" called "AP 112a" [43]. The differences between these types and the Puutalo ones were that the "AP 111a" had only four windows in the back façade and that the *Puutalo* types had an elongated attic ventilation shaft while the Myyntiyhdistys Puurakenne ones were squarer shaped (Figs. 3 and 4).

In *Kibbutz* Sde Boker, which was built in the Negev desert, a "*Zrif Fini*" was erected in 1952, not far from the famous *Zrif* that was built as a home for Israel's First Prime Minister, David Ben Gurion. According to archival sources, this *Zrif* was a double-family house with "one and a half" room in each unit, and from a contemporary

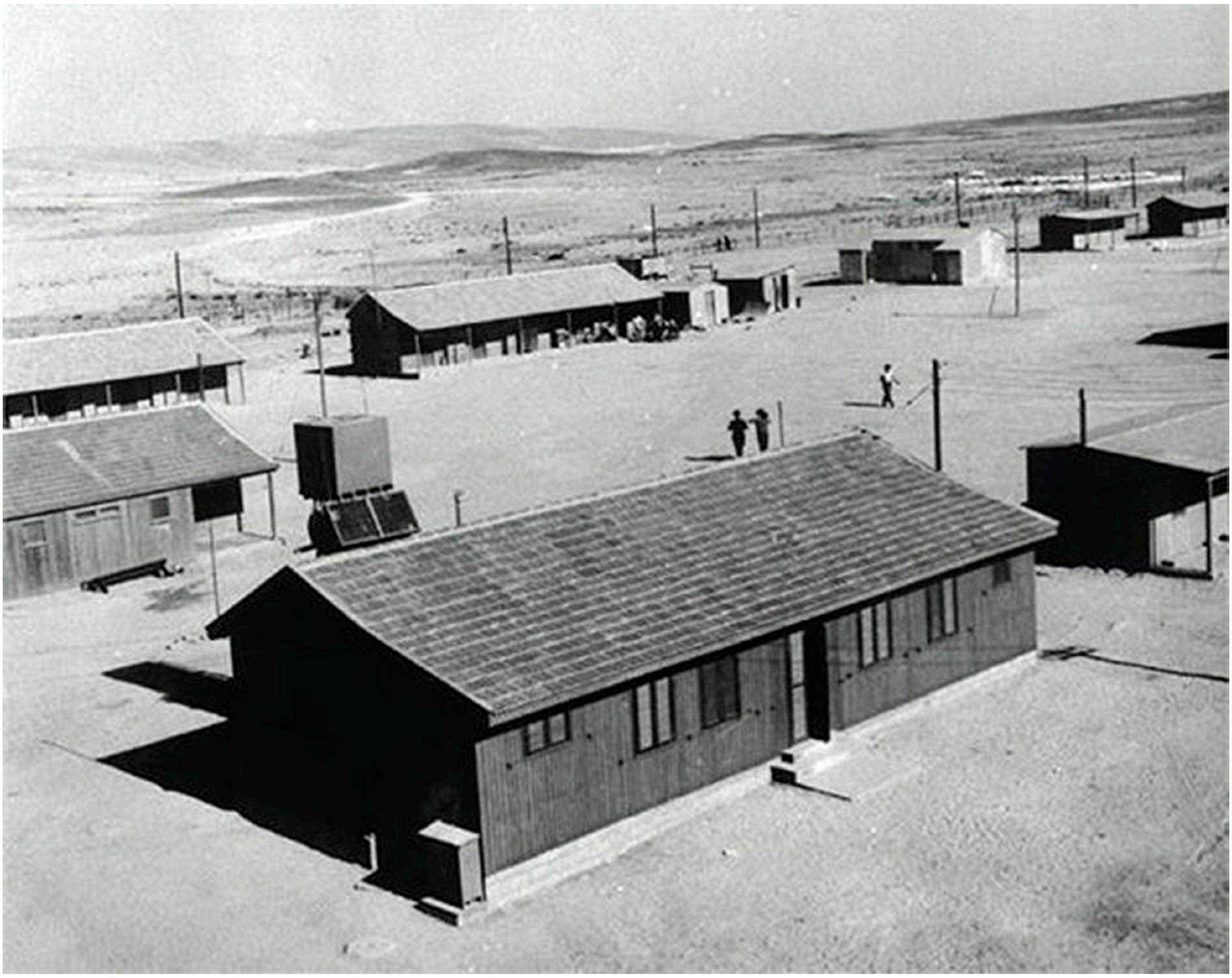

Fig. 5. *Werner Braun, Sde-Boker, 1953. Source: KKL-JNF photo Archive.*

photo, we can learn that this was a Puutalo Oy "840d" or Puurakenne "112a" [44] (Fig. 5). This instance shows the difficulty in tracing the distribution of the different houses since, without a photo of the side façade, we can't trace the manufacturer of the building. It also shows that the distribution of the houses was sometimes random, and houses were sometimes sent individually and were temporary in most cases (Ben Gurion's *Zrif* is an exemption). They were part of a temporary planning of the site where they were built. At the time, the housing in the *Kibbutz* was usually without kitchens and private showers; the arrival of this house to Sde Boker was a unique circumstance that made its tracking through the photos fortuitous.

The story of both the *Zrifim* of Amishav and Sde Boker, which are only two of many cases, reflect how designed building types that were made as mass housing solutions could be manufactured on demand by different companies, and how the architecture of temporary housing demands research in different forms of documentation especially in cases when the buildings themselves are not preserved anymore.

5. CONCLUSIONS

Built as temporary solutions, prefabricated houses in crisis areas are usually of ephemeral existence. In the case of the architecture of the Finnish houses exported to Israel, this is evident in the transitional nature of their existence as transit houses in transit camps for people in motion. The heritage of these houses is, therefore, elusive, and their premeditated disappearance challenges the evaluation of their story through the research of existing architectural objects. The nature of this architecture thus demanded the research to turn to available documentation, building a research methodology following examples by Crinson, Mansion-Prud'homme, and Carboni based on combining snippets of information in various types of sources. The wealth of archival material, only a fraction of which we could include in-depth here, of correspondences, drawings, official papers, newspapers, and movies, allows a new reading of the story of the Finnish housing export to Israel and the impact of dealings and bureaucracy on designs and their effects. If we would have stayed within the traditional sources in architectural history, such as main company archives or just drawings, a perspective challenged by, for instance, Domenichini, the complex dialogue involved in planning and executing the projects in Israel would not have been possible to unveil. The "design by correspondence" process provides valuable lessons on planning housing in crisis areas and what the main objectives of governments, agencies, manufacturers, or inhabitants in these situations might be. The research in the political background and scope of the import of Finnish houses to Israel highlights how the need for bilateral deals between countries to upkeep diplomacy, while keeping the budget low at all costs, stresses the limitations in the design process of the shelters. In all documents, the materiality of the houses, the money, the practical issues, and trade are underlined. However, the ones who rarely are discussed in the available sources are the inhabitants. In general, the times when the house types were changed to better accommodate daily tasks and hygiene, there are no traces in the archives of the reasons or discussions preceding the design changes in the material. The end user got a place to live but could most likely rarely influence the design or level of comfort initially provided. These processes offer a glimpse into the mechanism of mass housing and shelter design in a period of crisis, which it is possible to learn from when planning shelters for future crisis housing.

When dealing with this case study, it becomes evident that the architecture must be understood through the complex diplomatic history between the two countries during the years immediately following the end of the Second World War. The growth of the Finnish industry and the formation of companies brought forth and transformed the local timber industry into a global exporter, with different companies as players in its market. The housing crisis in Israel in the first years of state turned Israel into a major importer of Finnish houses, and the effect of local politics, bi-lateral diplomacy, and economy defined which houses arrived, their quantity and the period in which they arrived, while political power struggles in Israel effected their arrival. The negotiation of trade and diplomacy affected the architectural production and its implementation in different places such as Amishav and Sde-Boker, which in turn affected the inhabitants' lives before bringing about the disappearance of most of these houses. The learning of the bureaucratic and political mechanisms of industry and international trade in the Finnish-Israeli case reveals the importance of learning this history to understand the management of design and application of housing in times of crisis.

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LAVENO STREET HOUSES BY MARCO ZANUSO. AN OUTSTANDING EXPERIMENT IN LIGHTWEIGHT PREFABRICATION

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Abstract

The paper focuses on one of the most interesting experiences in Italy about light prefabrication, developed by the Milanese architect and designer Marco Zanuso (1916-2001), a major protagonist at the national level in the debate on building industrialisation, together with the company FEAL (*Fonderie Elettriche Alluminio e Leghe*), an important Italian enterprise developing steel construction systems and producing aluminium building components. In the first half of the 1960s, Zanuso experimented with the VAR/M3 prefabricated system produced by FEAL for school buildings and tested its application to two housing complexes in Milan. Using this system, Zanuso built two apartment complexes, both in Milan one at Laveno Street (1960-1963) and the other at Solaroli Street (1965-1967), now Coari Street. The first of these two projects is especially significant for its experimental approach and the formal result achieved, which was favourably received by critics at the time but is still little studied today.

Keywords

Marco Zanuso, FEAL, Laveno Street Houses, Lightweight prefabrication.

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1. INTRODUCTION

In Italy, after the World War, the industry significantly developed mainly in the mechanical sector, but the building practice remains primarily tied to traditional masonry construction methods. Even the most modern and advanced concrete technology grows, in fact, in a substantially handcrafted manner, which «does not entail an industrial conception of building construction but stands as an evolved version of masonry work» [1].

In such a context, the use of steel, which had characterised some important experiences in the pre-war period, retains its episodic character, even if there are also experiments for a revival of metal construction. Due to the expansion of the steel industry and thanks to the promotional activity carried out by lots of magazines, among them *Costruzioni Metalliche* published since 1949, a greater awareness of the technical possibilities offered by light prefabrication spread in the 1960s. These changes lead to a series of important realisations by well-known designers, from workplaces to commercial buildings.

At that time, we face the development of two strands in metal construction research. The former is directed towards the study of the curtain wall, considered a typical element of modernity; the latter, on the other hand, attempts to pursue an Italian line characterised by a form of the expressive potential of structural steel skeletons.

Unlike the international framework, Italian designers start exploring metal construction as a technology with specific characteristics and a linguistic field only from the end of the 1950s, mainly in office buildings. For the first stand, there are a series of exemplary works, such as the *Centro Direzionale Eni* by Marco Baciagalupo and Ugo Ratti (1960-1962), that remained for years the largest steel building constructed in Italy, and the ESSO headquarters at EUR (*Esposizione Universale di Roma*) by Luigi Moretti (1961-1965). There are also less important examples, but significant at the same time, including the RAI Management Centre by Francesco Berarducci and Alessandro Fioroni (1961-1965) and the INA (*Istituto Nazionale delle Assicurazioni*) complex by Venturino Ventura (1960-1961). These buildings, where the main structure and the façade are made of steel, are flanked by others, such as the office building in Via Torino by Adalberto Libera (1957-1958) and the Pirelli skyscraper in Milan by Gio Ponti (1955-1960), for which the frame structure is in concrete, and all façades in a glass and aluminium curtain wall. To the second line of research, closer to constructive realism and characterised by structural expressionism, we can list works such as the *Rinascente* in Roma by Franco Albini and Franca Helg (1957-1961), the ADISU (*Azienda per il Diritto allo Studio Universitario*) headquarters (1967), also in Roma, by Enrico Mandolesi and the office building in Piazza Meda in Milan by BBPR (1969).

The exponential population increase at the beginning of the 1960s determined the political and social urgency to build many schools in a short time and at a low cost [2]. Therefore, the Ministry of Education launched a public programme to adopt alternative construction techniques to develop lightweight prefabricated dry-mounted systems. In 1960, the XII Triennale di Milano set up the *La Casa e la Scuola* (The Home and School) Exhibition, promoting several collateral initiatives, including the *Competition for the study of industrialised elements for elementary school buildings*.

The prefabrication topic, which was already widespread abroad, start to be discussed by the major designers who, in these years, establish various partnerships with some enterprises (Disertori-SALVIT, Magnaghi-Terzaghi-SNAM, Albini-SECCO, Minoletti-HOLIDAY, Pellegrin-BENINI, Pellegrin-Pea-MONTEDISON, Valle-VALDADIGE). The design challenge of prefabrication begins: it gives rise to a series of interesting experiments. Industrialisation quickly extends from school buildings to residential buildings, where steel frames and light metal components were not employed, but heavy prefabrication with concrete panels on the French model was employed. The only notable exceptions among the numerous *INA-Casa* Plan construction sites are the Prà district in Genoa (1960-1961) and the CECA (*Comunità Europea Carbone e Acciaio*) district in Piombino, Livorno (1963-1967), both built by the steel company Italsider for its employees. The synergy between Marco Zanuso and FEAL (*Fonderie Elettriche Alluminio e Leghe*), leading to the realisation of the houses in Milan at Laveno Street and those at Solaroli Street between 1960 and 1965, is particularly significant. Using the prefabricated VAR-M3 System developed by FEAL for school buildings, Zanuso is one of the first architects to use light prefabrication for a residential complex, paving the way for the debate on open-cycle building industrialisation with metal components that would only develop in the following years.

2. FOR INDUSTRIALISED CONSTRUCTION: MARCO ZANUSO AND FEAL

After the war, Zanuso was interested in industrial prefabrication within the debate promoted by the MSA (*Movimento Studi per l'Architettura*), publishing in the first issues of *Domus* magazine, together with Paolo Chessa, three articles titled *The prefabricated house*. In these writings, Zanuso and Chessa declare a clear programmatic purpose to renew building methods according to the possibilities offered by industry: «[…] we cannot longer think of construction as modelled, cast, conglomerate – the two architects write – but assembled. We must think of construction elements, prefabricated in the workshops and mounted on the building site using exact and well-defined jointing pieces» [3]. The focus is therefore on the «ready-to-assemble element», which provides for the home «an organisation of transport and assembly as for any other industrial product, such as cars, aircrafts, boats» [4]. The adoption of the first seven years of the *INA-Casa* Plan inhibits and interrupts the debate on building industrialisation, promoted by several Milanese architects and partly tested in the well-known QT8 (*Quartiere Triennale 8*) district. Despite this, at the *Convegno del progresso edile*, held in Milan in April 1953, Zanuso relaunches the idea of an architectural design approach based on the *industrial model*. In his intervention, the Milanese architect declares his aim to establish a replicable *principle* that has «as broad a validity as possible in adhering to similar requirements» and also states that «the house is an object of use» [5]. During the same year, Zanuso has the opportunity to visit some schools in England built by the county of Hertfordshire following prefabricated and modular systems. This trip represents for the Milanese architect a revelation about the potential of building industrialisation. The travel notes include sketches of the building systems adopted in some of the English schools built in those years, including the Templewood School in Welwyn Garden City (1948-1950) [6]. Zanuso remains particularly impressed by this experiment in social architecture by using industrial methods, and the following year, he writes an article for *Casabella* magazine about the school planning experience in England. By publishing in the magazine the *punt system* which is a simple, modular structural scheme, consisting of pillars, main beams and punts (elements with which the roof is constructed, alternating with simple closure panels), designed by the engineer Ove Arup Zanuso is aware of a functional way of building, not based on finished elements and their assembly, but on «a constructive simplicity, a structural evidence, materials economy and especially a compositional flexibility» such as to confirm his conviction that industry can «take part in architecture as a propulsive energy of new forms and new compositive freedom» [7]. In this way, Zanuso renews his interest in architecture, which is closely linked to industrial design and building industrialisation matters. However, the Milanese architect believes that industrial construction should not be limited to standardized buildings but should be oriented towards open prefabrication that, through many combinations and a wide dimensional range of mass-produced components, can provide an efficient and sufficiently adaptable approach to building.

Zanuso finally has the opportunity to implement these intentions through relationships he establishes with engineer Giovanni Varlonga, a member of ADI (*Associazione per il Disegno Industriale*) since 1957 and founder of FEAL founded in 1945 in Milan, which initially produced die-cast joints and later expanded production into building components (door and window frames, handles, false ceilings, movable walls, radiators, roofing and façade panels). For the innovations brought in the field of construction, FEAL excels among other companies and, in the 1960 award edition of the *Premio Compasso d'Oro*, it receives an honourable mention for the up-and-down window frame and is also awarded for the aluminium radiator *Thermovar*. Varlonga is involved, already in the 1950s as an industrialist and designer, on lightweight prefabrication: at the X Triennale in 1954, FEAL had, in fact, participated with the *Industrialised Vertical House Element*, designed with engineer Fabio Fratti of the company's Technical Office and in collaboration with architect Ippolito Malaguzzi Valeri (Fig. 1). In later years, FEAL begins intensive activity in exhibition construction, reaching international notoriety, and patents several metal building solutions (Fig. 2). In the mid-1970s, at the top of its economic success, FEAL comes to own three operating divisions: Components (to manufacture the components in its two plants in Milan and Pomezia), Construction (to design civil and industrial buildings), and Plants (to set up industrial complexes for production). Other than Salvit of Milan, FEAL becomes the leading company in Italy to develop open-cycle lightweight prefabrication, developing in the late 1950s the VAR-M3 dry modular system (Fig. 3). The VAR-M3 system, then modified and commercialized until the 1980s, uses a 30 cm base module on which all other components are sized in multiples and submultiples. Zanuso plans to test the feasibility of applying to housing construction the VAR-M3 system, employed until then for school buildings, checking «its versatility in responding to a need of architecture, for richer and more complex volumetric articulation, with the possibility of being used with different materials and coexisting with other complementary building systems» [8].

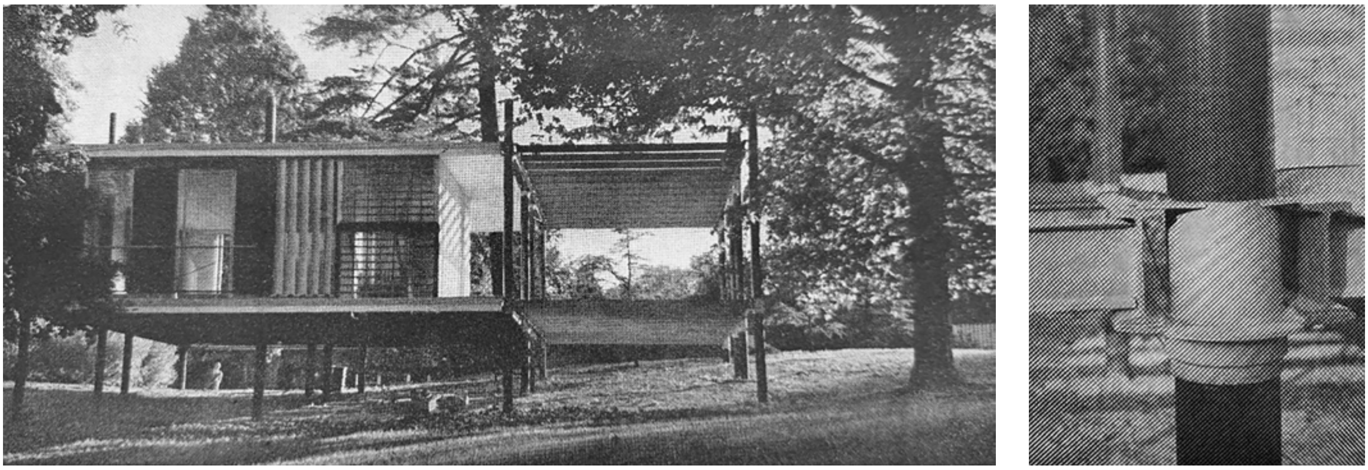

Fig. 1. *Right: Industrialised Vertical House Element at the X Triennale in 1954, designed by FEAL. Source:* Casabella *203. Left: Detail of Vertical House Element at the X Triennale. Source:* Casabella *203.*

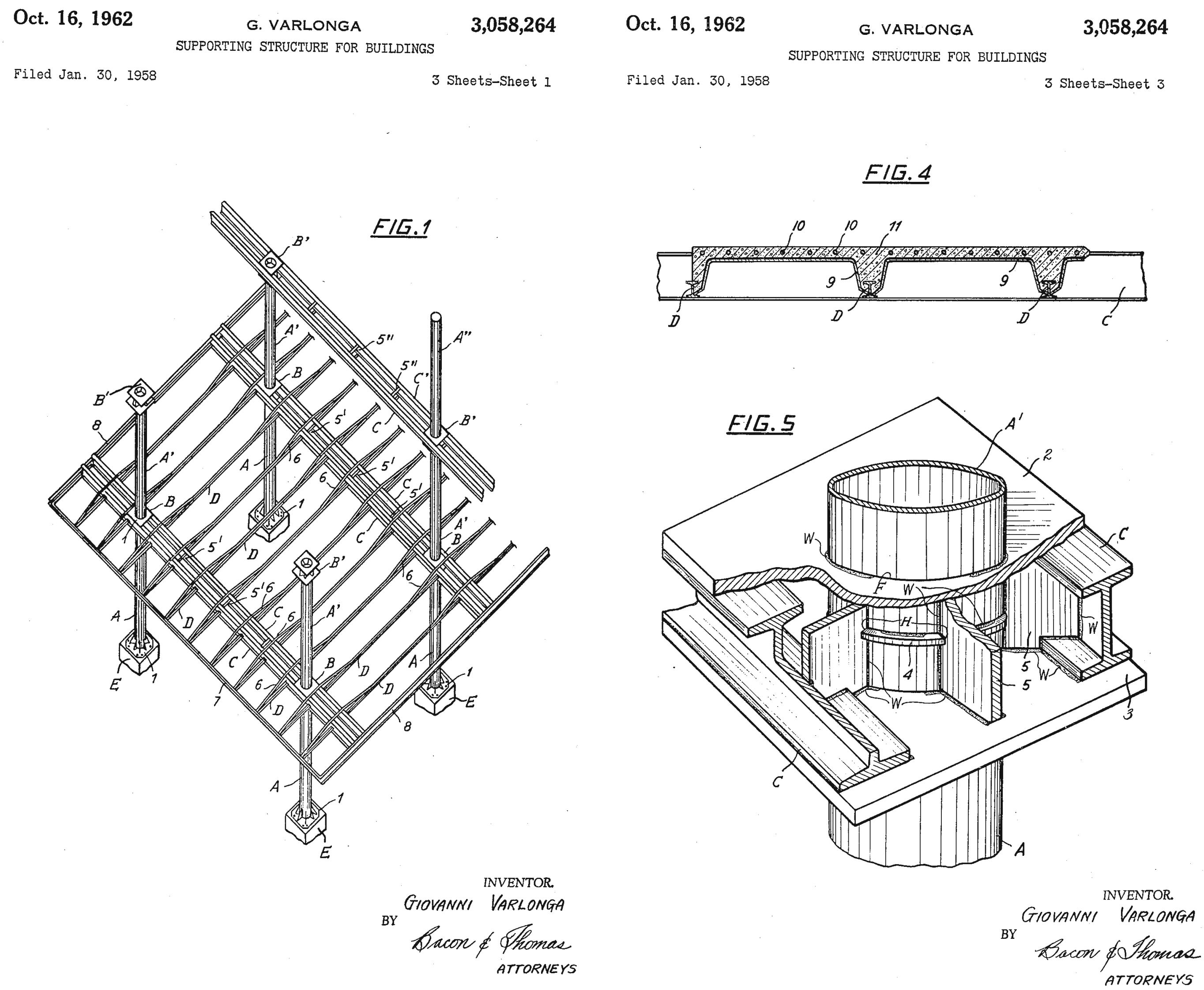

Fig. 2. *Patents of the load-bearing steel frame structure. Source: Google Patents.*

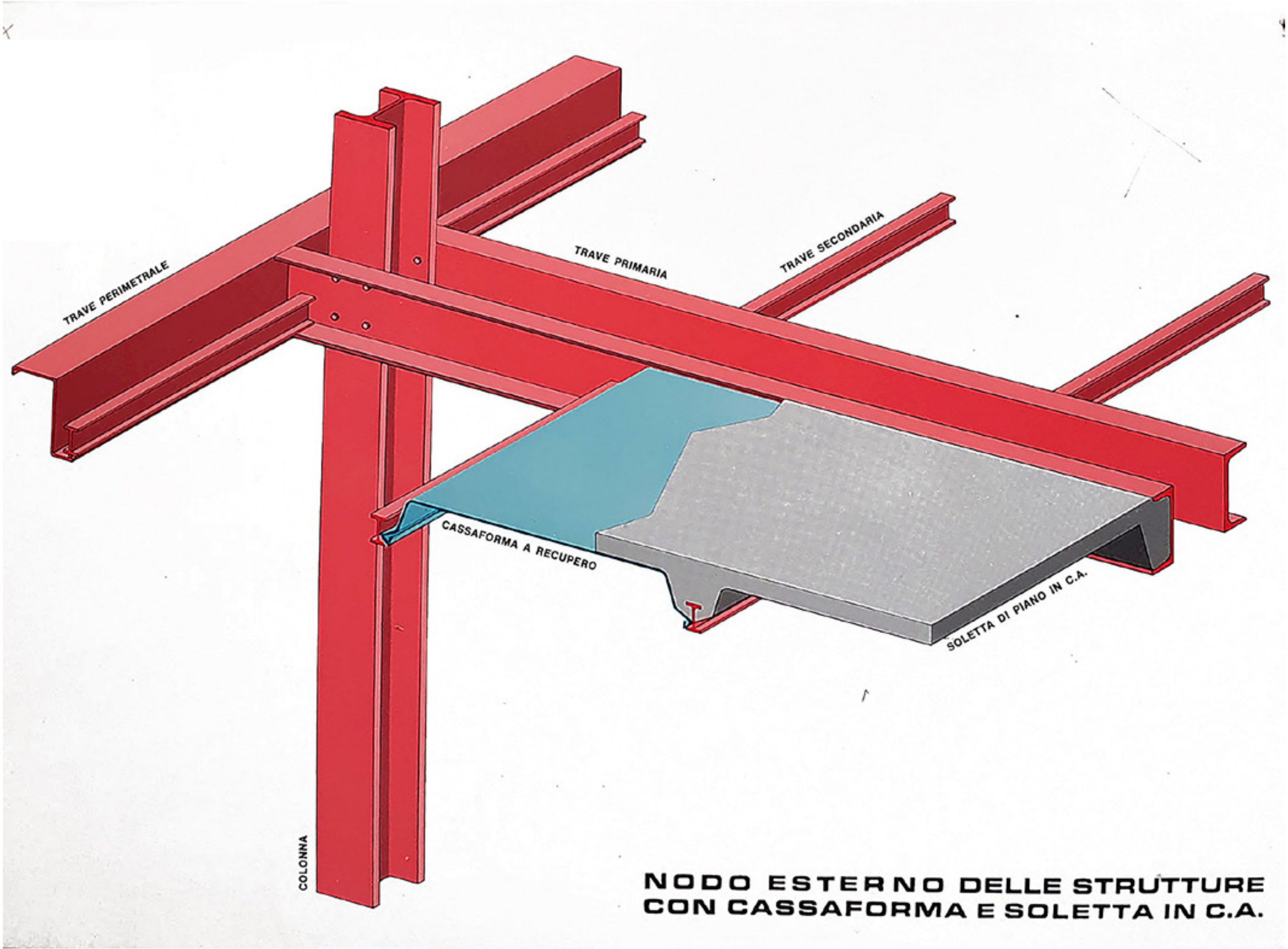

Fig. 3. *VAR/M3 system steel structure. Source: catalog, Var M3:* sistema coordinato di edilizia industrializzata*, n.d. [published after 1975].*

3. LAVENO STREET APARTMENT COMPLEX: A PROTOTYPE FOR MASS-PRODUCED LIGHTWEIGHT PREFABRICATION IN HOUSING

The project for FEAL Houses at Laveno Street fits fully into the debate on building industrialisation relating to low-cost and social housing, especially rooted between the 1950s and 1960s in the Milanese context. In the municipality's deeds, it is pointed out that the publicly owned building area is granted «for the construction of social and affordable housing» to be assigned to the members of the Edilvar cooperative.

It is important to premise that the theme of affordable housing already interested Zanuso at the end of the 1940s when he designed several affordable houses: the best known of them are those built for veterans in the QT8 district in Milan (1947-1948) with Roberto Menghi. Even in the second half of the 1950s, as a municipal councillor, Zanuso worked on social housing initiatives, presenting reports and a motion to the city council in 1960 on the housing problem [9]. Although he is by now an established designer and architect with many projects in progress, in these years, he takes part in one of the many urban planning projects of the *INA-Casa* Plan, the largest urban development programme promoted by the Italian government. Indeed, together with Luigi Caccia Dominioni, Alberto and Gian Paolo Valenti, he designs the *INA-Casa* Vialba I district in the northern suburbs of Milan between 1957 and 1960. However, the standardization and prefabrication hypotheses advocated by Zanuso and other Milanese architects since the immediate post-war period clash with a situation still characterized in the 1950s by construction techniques that remain craft or semi-craft-based. Despite being the most important social housing experiment in Italy, the *INA-Casa* Plan has been conceived to increase employment, requiring a high labour input for building houses and excluding the widespread use of prefabrication. This *anti-industrial* approach finally seems to be overcome, at least in part, at the beginning of the 1960s, when Milan is the scene of some political changes and sees a more concrete technological development in the field of construction due to some important initiatives. The ever-increasing population growth affecting the metropolis since 1951 and the consequent need to provide housing become the main issues for the city council. In 1962, Piero Bassetti – budget councillor of the first centre-left council elected in 1960 with Gino Cassinis as mayor – entrusts the IACPM (*Istituto Autonomo Case Popolari di Milano*) with a four-year plan for social housing, expecting to build 34,000 flats and approximately 120,000 rooms. A year later, the Municipality of Milan also approves the PEEP (*Piano per l'Edilizia Economica e Popolare*), which set out the location of sixteen public housing projects in peripheral areas of the city, including the Sant'Ambrogio district, the Gallaratese completion, Gratosoglio district, Missaglia district, the Olmi district and the Quarto Cagnino district. In May 1955, on the IACPM's initiative, the CRAPER (*Centro per la Ricerca Applicata ai Problemi dell'Edilizia Residenziale*) is also established, with the aim of investigating the urban, social, economic, productive and technical issues of social housing. A fundamental contribution to the debate on prefabrication is provided by Giuseppe Ciribini's studies on using the production and organisational methods of industry in construction. Due to Ciribini's dense relationship network with French institutions, the IACPM, in order to cope with the construction of social housing in a short timeframe, stipulates an agreement in 1962 with several building firms (including Mbm Meregaglia, Sicop, Fintech, Sepi, Romagnoli) holding French patents for heavy prefabrication. Already used for grands ensembles, these French heavy prefabrication systems – such as Balency, Barets, Camus, Coignet, Fiorio, and Costamagna – are now being used for the construction of the new housing districts in the Milanese suburbs [10, 11].

Therefore, if research and practical applications are moving towards heavy prefabrication, in which France is the most important reference point, the all-Italian experimentation of light prefabrication conducted by Zanuso and FEAL appears to be countertrend and particularly innovative. In fact, the Milanese architect opts for a more flexible building industrialisation that is compatible with the Italian small business and does not need overly burdensome investments. Precisely in the Laveno Street Houses, one of the first experiments in Italy on lightweight prefabrication in housing, we can see Zanuso's commitment to exploring «the margins granted to expression by the adoption of a prefabricated structure», as well as «a tendency to bring the problems of design back to the exclusive dimension of technology» [12].

Zanuso is probably in charge of the two buildings at 6 Laveno Street in early 1960 (Fig. 4). In October of the same year, an enquiry on industrialised construction, entitled *Investigation at FEAL*, is published in *Stile Industria* magazine, with contributions by Gianni Varlonga, Giuseppe Ciribini and Marco Zanuso. In his intervention, the Milanese architect credits FEAL with a courageous

a)

b)

c)

Fig. 4a-b-c. *FEAL Houses complex views. Source: Archivio del Moderno, Fondo Marco Zanuso, Balerna.*

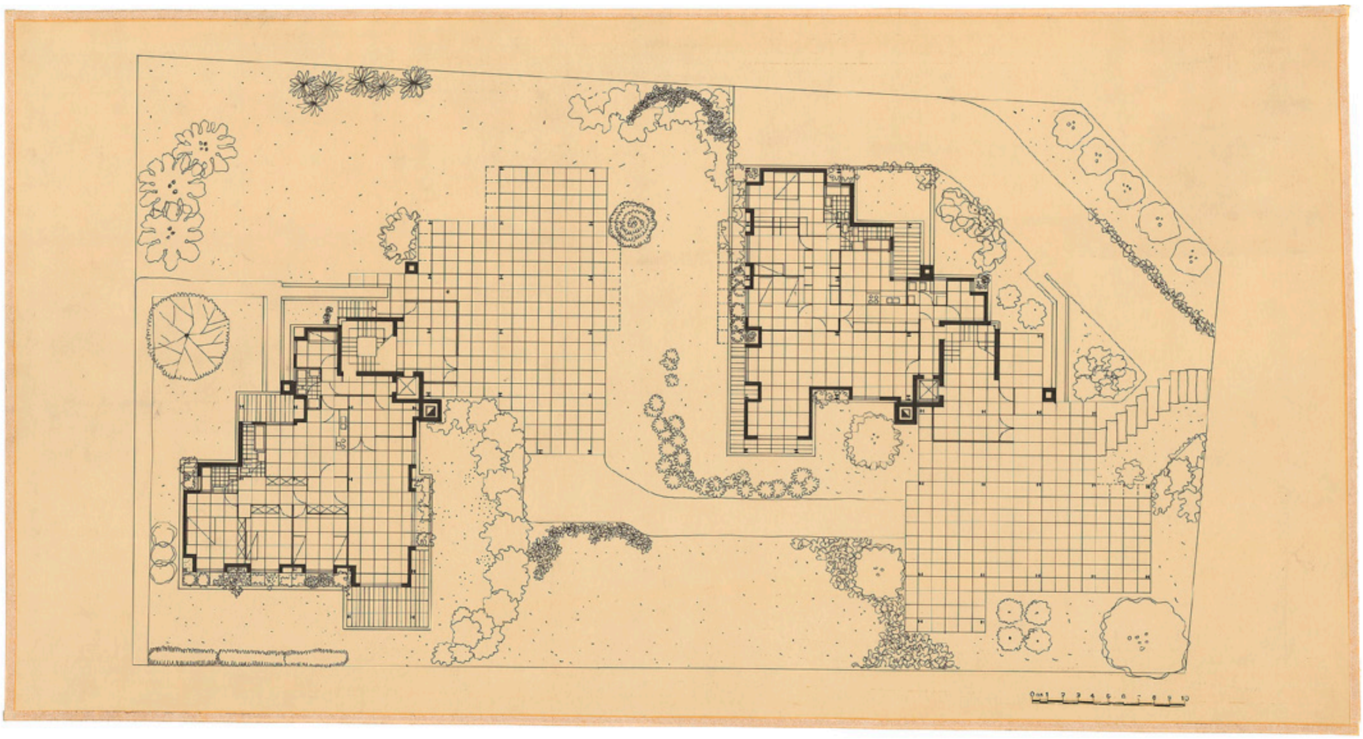

Fig. 5. *FEAL Houses on Laveno Street floor plan. Source: Archivio del Moderno, Fondo Marco Zanuso, Balerna.*

commitment to the problem of modular coordination and building industrialisation. «The experience gained on each construction site, which usually comes to be lost, has been gathered here – says Zanuso – in a wealth of experimental data such as are an industrial complex can condense. Every rabbet, every seam, every joint has been tested, modified and led to a point of perfection that is the only guarantee of a product» [13].

From documents kept in the Archives of the City of Milan, we learn that the developer and owner of the plot at 6 Laveno Street is the Edilvar Cooperative, with engineer Fabio Fratti as president in charge.

In April 1961, the Municipality and the Cooperative sign an agreement to sell the land: two residential units are to be built within two years, and the apartments must be assigned only to members. Among others, Giovanni Varlonga, Fabio Fratti, and Marco Zanuso himself, who will move his studio there. As early as the first draft project, drawn up between January and February 1961, the twin buildings are set rotated 90° to each other, with access from the short side of Laveno Street. The buildings' perimeter is very jagged, and the two apartments on each floor, distributed by a concrete staircase, are arranged on staggered levels (Fig. 5).

The VAR-M3 system on a 90 cm module, triple the basic 30 cm module, is used in construction. The load-bearing structure is made of steel HEB 180 pillars and main beams made of two NP 240 C-profiles, to which secondary beams (double-T NP 80 profiles) are welded. The edge beams are bolted to the main beams, and on them, the curtain wall uprights (IPE 100 profiles) are fixed with galvanized steel plates, which support the brackets for mounting façade panels. The floors are assembled on the ground, with reusable aluminium formwork set up between the secondary beams for slab casting, then lifted with a crane along the steel columns, used as a guide, and finally bolted in place [14]. Fabio Fratti specifies that in Zanuso's project, the windows on the façade are up-and-down, while those on the loggias are two-sash sliding. Windowsills and light alloy frames are fixed to the uprights by special aluminium fittings [15]. The interior walls are realized with modular panels, consisting of two steel plate surfaces stiffened by metal profiles on the inside and finished with baked-on paint. The suspended ceilings are of the *Soundvar* type, also produced by FEAL, with 15 cm wide aluminium slats suspended from galvanised sheet metal rails.

Fig. 6. *Vico Magistretti, Office building at 22 Corso Europa, Milan (1955-1957). Source: Irace F, Pasca V (1999). Vico Magistretti architetto e designer. Electa, Milano. Photo © Gabriele Basilico.*

The VAR-M3 system is creatively used by Zanuso, who succeeds in the extreme compositional flexibility of prefabricated modules by adopting standard elements. In the project report, the architect himself recalls how he concentrated «on the modularity of the concave and convex corner joints» [16]. The layout of the uprights on the façade follows, with some exceptions, the 90 cm module, while the structure grid of the pillars fits a module of 30 cm. The pillars are offset to the 90 cm grid, allowing Zanuso compositional freedom to respond to the different functional needs of the floor plan. The structure's geometry appears at the portico level, where the columns are free and form a main span of 6 m and a side span of 4.8 m with intercolumniations varying from 4.2 m to 3.6 m. The different modularity between columns and envelope produces two different geometric layouts that create unexpected variations that are totally surprising in a prefabricated building based on a strictly modular approach. Besides technical and constructive experimentation, the Laveno Street buildings also reveal particular care in the use of materials and design of the façades, characterized by the vertical rhythm of uprights and openings. The main modification that Zanuso introduces in the VAR-M3 system concerns the prefabricated panel, 6 cm thick, composed of polyurethane insulation enclosed inside by a steel sheet and outside by an aluminium one.

The Milanese architect thinks of transforming a conventional curtain wall into a particularly textured wall face: he adds a natural stone slab (*piperino* grey trachyte) to the standard panel, with a glass wool cavity in between. The solution proposed by Zanuso thus blends lightweight prefabrication technological innovation with a close reference to the Milanese building tradition.

The VAR-M3 system's modularity hence characterises the two buildings, but at the same time, their image is not monotonous but instead is articulated in depth and height by the protruding volumes and voids of the balconies. Similar research on façade composition with prefabricated panels and expressive interpretation of the curtain wall can also be found in some contemporary works by Vico Magistretti. In the first case, reference can be made to the building designed by Magistretti at 3 San Gregorio Street in Milan (1957-1959), where the façade is marked by irregularly spaced pillars, clad in granite and rotated by 45°, and by a prefabricated concrete panel cladding with a characteristic burgundy-coloured grit finish (Fig. 6). As in the buildings at Laveno Street, the laying of the panels is irregular, while the particular colour solution is a successful reference to the brick wall of the nearby Lazzaretto. Additionally, in this project by Magistretti, it is interesting to note the vertical shape of the opening, which is likewise taken up in Zanuso's apartment complex. The use of such proportions is not an insignificant detail: these openings clearly differ from the typical rationalist window as seen in Milan in some buildings. The most known typical examples are Casa Rustici (1935) by Terragni, where the reinforced concrete frame enlarges the holes horizontally; the Palazzo Montecatini by Gio Ponti (1936); the famous apartment block by Asnago and Vender at Albricci Street (1939-1942/1953-1956), where windows keep the vertical aspect but with a less slender proportions, often emphasised by the vertical bipartition of the window frame; or the Case Albergo by Luigi Moretti (1950), with still horizontal holes.

On the contrary the windows at San Gregorio Street and those at Laveno Street find references in other buildings, such as *Casa al Parco* (1948) by Ignazio Gardella and Caccia Dominioni's house in Piazza Sant'Ambrogio (1949). However, the most direct reference is to Milano's historical and popular housing, often characterized by full-height windows with metal parapets and wooden shutters. Nevertheless, in their buildings, Magistretti and Zanuso focus on another opening type, smaller in width, which creates a more articulated and wavy composition. The shape is still rectangular, but the small size and very stretched proportions make these openings look like cuts engraved in the wall that recall Lucio Fontana's canvas with vertical slashes. In the Laveno Street building, these *arrow slits* emphasised by the proximity of the aluminium uprights, produce a particularly marked and original caesura, breaking the curtain wall's regularity. As far as the expressive interpretation of the curtain wall is concerned, an emblematic example is the building in Corso Europa (1955-1957), also designed by Magistretti, where the façade is punctuated by pillars, uprights and a vertical ribbon window (Fig. 7). The graphic layout of the

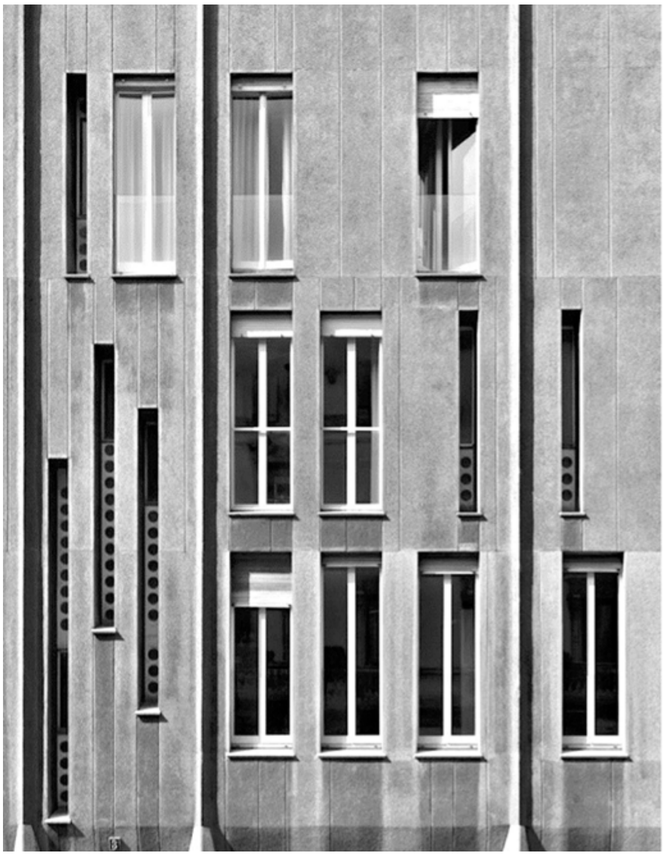

Fig. 7. *Vico Magistretti, Residential, office and cinema building at 3 San Gregorio Street, Milan (1957-1959). Source: Facecity scrool 2012. Photo © Pino Musi.*

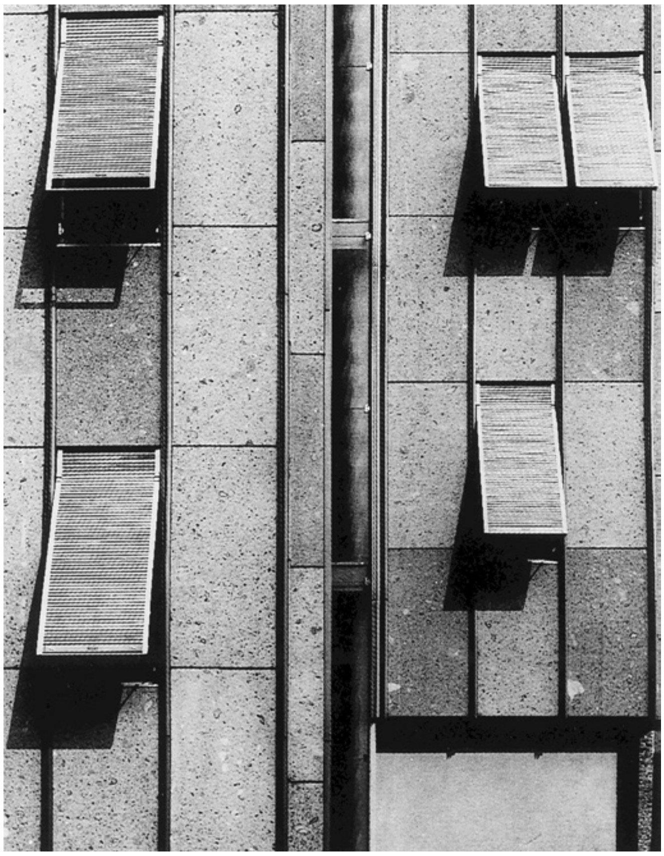

Fig. 8. *FEAL Houses detail façade. Source: Archivio del Moderno, Fondo Marco Zanuso, Balerna.*

openings is carefully studied, using construction solutions already on the market and employing standard window frames. Magistretti designed a module, repeated six times in each bay, with the glazed part in the shape of an asymmetric T (the two sidebands are of different widths) and two low areas at the sides in polished white granite slabs. The façade's dynamism, resulting from the vertical glazed bands and pillars, and the juxtaposition of various-sized windows in Corso Europa recall the vertical rhythmic scansion and window modules of the Laveno Street building. Although with different outcomes, these two projects belong to a broader line of research on the curtain wall topic, mainly experimented by Milanese architects. Interestingly, the appeal of curtain wall development in Italy came precisely from the world of industrial design. Some issues of the magazine Stile Industria at the end of the 1950s published extensive reports on the spread of the curtain wall in other countries, also delving into technical aspects and propagating Italian examples mainly by Milanese architect-designers [16-18].

However, the façades of Magistretti and Zanuso's buildings do not replicate the usual and anonymous curtain wall model widespread in other countries; they arise from specific experimentation and a particular project reinterpretation. Both examples are representative of an *Italian-style curtain wall*, as defined by Sergio Poretti, where the international language of the glass and metal façade «is subjected to such a minute reworking that it eventually turns into local dialect, enriching the variegated range of intonations of Italian modernisms» [19]. Indeed, although Magistretti and Zanuso use prefabricated elements, their buildings do not result from a simple assembly but are characterized by a distinctive compositional expressiveness in the façade design.

These considerations provide a better understanding of the original construction experiment carried out by Zanuso in the Laveno Street complex: the modern lightweight prefabrication technique is combined with the Milanese building tradition and historical reminiscences about parapets design of the terraces and balconies, which, resembling battlements, allude to the debate on environmental pre-existences arising around the Velasca Tower (Fig. 8). Despite the success of the FEAL Houses project, published in several magazines and awarded the prestigious national *IN/ARCH* prize for Lombardy region in 1966, Zanuso does not hide his regret for an interesting experiment that should have been continued «above all to explore the opportunity offered by the modular approach in the use of natural materials and dry assembly techniques» [8].

4. CONCLUSIONS

All efforts led by Zanuso and other architects, primarily Enrico Mandolesi, to promote lightweight prefabrication in housing were unfortunately unsuccessful. In the mid-1970s, due to the economic crisis, hypotheses about building industrialisation remain confined to a narrowly defined horizon. The use of steel by industrialised methods gradually decline even in those fields in which it has found wide use, while within industry, experimentation returns to the technological aspects, focusing on research and the use of new materials.

This epilogue does not detract from Zanuso's research on lightweight prefabrication, which – though isolated – represents an important milestone in the history of twentieth-century Italian construction.

Acknowledgements

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THE CONSTRUCTION OF A STEEL SKYSCRAPER IN GENOA. THE *TORRE SIP* BY BEGA, GAMBACCIANI, AND VIZIANO (1964-1969)

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Abstract

In 1964, the SIP Company entrusted Piero Gambacciani, Attilio Viziano, and Melchiorre Bega with the construction of the *Torre SIP* in Genoa, which was intended to serve as the regional company headquarters. Standing at a height of 105 m, the *Torre SIP* represents Italy's first instance of a skyscraper entirely constructed with a prefabricated steel structure. This paper explores the tower's history, spanning from its conceptualization to completion.

This essay delves into the pioneering industrial methodology applied to produce and realize its steel structure, starting with an overview of the skyscraper's contextual conditions and primary attributes. As a symbolic embodiment of progress in assembling prefabricated steel load-bearing structures, the tower stands out for the systematic and harmonious deployment of modern operational procedures.

In the design of the *Torre SIP*, the designers distinguished themselves by adeptly leveraging the potential of productive rationalization. Their accomplishment lies in creating a formally refined architectural artifact that transcends mere seriality while retaining strong linguistic connotations. By avoiding slavish adherence to technological coordination and pointless stylistic embellishments, the designers manifest a distinctly contemporary urban intervention, echoing the intent to position the building as "the last of a series and the first of another series".

Keywords

Genoa, *Torre SIP*, Skyscraper, Steel structure, Prefabricated structure.

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1. THE RISING CITY

In the 1950s, Genoa spearheaded various urban initiatives aimed at transforming the capital of Liguria into a thoroughly *modern* city. These transformations were made possible by the renewal opportunities presented during the city's reconstruction process, which became necessary due to the constant bombings during the Second World War. In 1953, the Technical Office of the city drafted the *Piano Particolareggiato di Piccapietra*, followed by the *Piano Regolatore di via Madre di Dio* in 1957 and the *Piano Regolatore di S. Vincenzo* in 1959. These plans served as implementations of the outdated 1932 masterplan *Piano Regolatore di massima delle zone centrali della città di Genova*, the outcome of a competition held two years earlier and updated in 1937 [1]. The recurring theme was integrating urban fabric gaps, preferably with newly constructed buildings.

Within the *Piano Regolatore di S. Vincenzo,* an area identified by the *Società Italiana per l'Esercizio delle Telecomunicazioni*, commonly known as SIP, was designated for the construction of a skyscraper intended to host the regional headquarters of the company. The commission was assigned to architect Piero Gambacciani (1923-2008) and engineer Attilio Viziano (1923-2011) in 1964. They initially worked at the urban planning level. The design and implementation of the project continued with the contribution of architect and designer Melchiorre Bega (1898-1976). Among the three, Bega was the only one with experience in the construction of tall buildings. Between 1956 and 1959, he completed the *Torre Galfa* in Milan, 104 m high, with a reinforced concrete structure concealed by continuous curtain wall façades [2]. The building integrated into an area characterized by an evolving skyline, including notable structures such as the *Torre Pirelli* by Gio Ponti (1952-1961), the *Torre Velasca* by Studio BBPR (1950-1958), and the *Torre Turati* by Luigi Mattioni (1958-1960) [3]. The *Torre Galfa* is a work that «wants to belong to the city to which it belongs, does not seek to nullify the pre-existing environmental conditions, and aspires to be part of plans and new aggregations that modern cities require» [4]. Numerous reviews, praises from distinguished colleagues, international recognition, and widespread approval among Milan citizens followed the completion of the *Torre Galfa*.

The situation in Genoa, where Bega, Gambacciani, and Viziano operated, significantly differs. Pier Carlo Santini wrote in the pages of the *Ottagono* magazine in 1970: «With its proverbial closures, with that sort of impermeability and even mistrust towards modern debate and any new order that may arise for the future, [Genoa] seems to have the power to sterilize, consume, and empty every condition of culture. Every event, in itself commendable, appears to hold promising prospects and implications for a different and better tomorrow» [5]. Moreover, the first and only tall building in the city center dates to the late thirties, a result of the provisions of the *Piano Particolareggiato di Piazza Dante* drafted in 1934. In 1939, the first of the two skyscrapers defining the new urban spaces was erected, 83 m high, and designed by architect Giuseppe Rosso. It was followed in 1940 by the *Torre Piacentini*, also known as the *Torre dell'Orologio* (Clock Tower), designed by architect Marcello Piacentini and engineer Angelo Invernizzi, reaching a height of 108 m. In the sixties, albeit of lesser height, tall buildings emerged as isolated episodes. Among them, the *Torre San Camillo*, built between 1960 and 1967 in the Piccapietra area by the Mor and Sibilla Studio, reached 75 m. Another example of similar height is the *Torre Villa Bozano*, located in the Quarto district in eastern Genoa, constructed between 1960 and 1966 by engineer and architect Luigi Carlo Daneri.

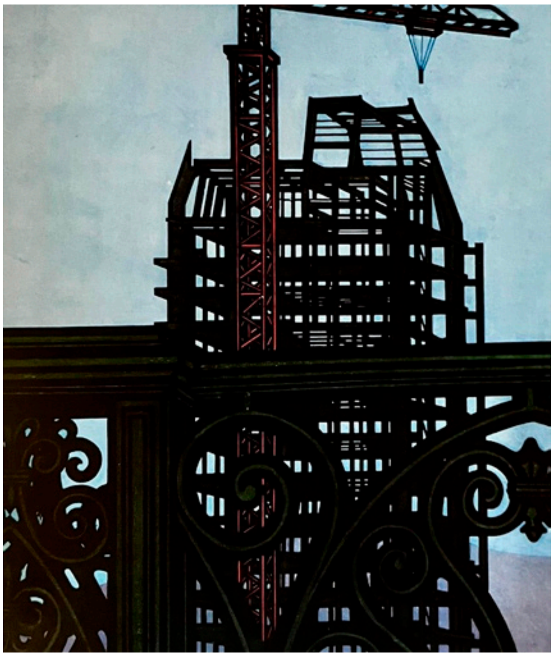

Figs. 1-2. *Photographs of the* Torre SIP *seen from Piazza Verdi and Via Fiume (1970). Source:* L'Architettura. Cronache e storia *174.*

The new *Torre SIP* would have emerged within a passage of the city that was both pivotal and controversial. In an article from 1970 published in the pages of *L'Architettura. Cronache e storia*, the designers clarified the contextual conditions at the outset: «The availability, at the time of the decision, of the area at the end of Via S. Vincenzo, where it opens into the large tree-lined square [Piazza Verdi], condensed and aligned positive parameters: an area regulated by a detailed plan with provisions for a multi-story building; adjacency to practically all urban transport network lines; proximity to Brignole Station; easy pedestrian connection to Via XX Settembre - De Ferrari, still today the 'city' of Genoa» [6] (Figs. 1-2).

Despite the building's placement within this urban context appearing as a practically feasible solution without disrupting the surrounding city, the lack of a comprehensive masterplan makes the location of the skyscraper seem arbitrary to most. Not because it is an unusual typology, but due to the absence of a preordained urban logic, architects are only expected to place a sudden "skittle" of a hundred meters anywhere in Genoa [7]. Using epithets such as "skittle" for architectures that evoke other representations due to their strong and distinctive formal characteristics is a recurring phenomenon in Genoa. Consider the *Casa A* building in the *INA-Casa Forte Quezzi* district designed by Luigi Carlo Daneri and Eugenio Fuselli (1956-1968), referred to as the "snake" or the *Pegli 3* complex by Aldo Luigi Rizzo (1980-1986), nicknamed the "washing machines"; or even the *Torre San Benigno Nord* skyscraper by Skidmore, Owings, and Merrill (1992), which earned the moniker "pencil".

Therefore, while the skyscraper initially raises some doubts and hesitations within the local community, especially concerning the choice of its location at the end of the Via San Vincenzo, the reaction from industry specialists is different. The *Torre SIP* would indeed have been the first example in Italy of a skyscraper entirely constructed with a prefabricated steel structure, a «modern technology serving engineers, architects, and builders», as stated in an advertisement created by the external relations office of Italsider in 1970 (Fig. 3). These are years when the topic of prefabricated steel buildings is becoming increasingly important. In 1965, coinciding with the beginning of the construction of the *Torre SIP*, an article was published in the Italsider magazine highlighting the potential of this construction system [8].

A symbol of the "measure of progress" in the assembly technique of steel load-bearing structures, the *Torre SIP* would stand out for the regularity and harmony of modern and entirely rational operational procedures employed. These procedures could ensure, at the same time, a refined experimentation in technological and formal architectural



Figs. 3-4. *Left: the Italsider advertisement. Right: the cover of the book* Le città del ferro*, featuring the* Torre SIP *illustrated by the artist Flavio Costantini (1967).*

design. It is not surprising that, in 1967, Italsider chose an image depicting the peak phases of the *Torre SIP* construction site – created by the artist Flavio Costantini – as the cover of the book *Le città del ferro*, dedicated to ten Italian cities that host the company's plants [9] (Fig. 4).

2. ON THE TECHNOLOGICAL FEATURES OF THE TOWER

The existing literature on the *Torre SIP*, also known as *Torre San Vincenzo*, is relatively scant. While mentioned in the previously cited publications related to the architectural work of Melchiorre Bega, the building does not find a place in architectural history textbooks. There is also a lack of a specific bibliography on the work of the other two authors, even though Gambacciani, particularly in Genoa, has accomplished much. However, the skyscraper appears, albeit approximately, in various publications dedicated to contemporary architecture in Liguria and Genoa [10-13] or Italian architecture of the 20th century [14-16].

The primary sources are articles that appeared in newspapers or industry magazines, written in the years immediately following the completion of the construction. Renato Pedio's article published in *L'Architettura. Cronache e Storia* in 1970 was a valuable source for preparing this contribution. This article provides a meticulous description of the technological and formal characteristics of the tower, accompanied by historical images and technical drawings. It also offers insights from the architects of the skyscraper, providing direct testimony to their design process. Below, an attempt will be made to synthesize the aforementioned characteristics, outlining an overall framework essential for the subsequent detailed examination of the construction of the prefabricated steel structure, a focal point of this contribution.

The volume of the building consists of a 105-meter-high steel structure, including twenty-eight levels, of which twenty-five are above ground (Fig. 5). This structure emerges from a detached reinforced concrete base, standing 30 m tall and encompassing eight floors, six above ground. The lower levels of the skyscraper integrate with this traditional structure through a series of small cantilevers placed along the relevant floors of the skyscraper. The entire structural complex is found on a reinforced concrete slab with a variable cross-section ranging from 70 cm to 125 cm. The foundation piles have diameters between 600 mm and 800 mm, with average lengths of 20 m, supported on a bed of limestone-marble consistency.

For the tower section, the structure, constructed according to the project specifications, consists of four multi-story rigid frame structures, two of which have four bays and three with five. The distance between the columns is 3.90 m. This structure manages the entire complex of horizontal forces due to the wind. With a Y-shaped cross-section, the corner columns connect the perimeter frames in pairs, absorbing the predominant part of the stresses from the horizontal forces acting on the frames. The columns of these frames are made of HE profiles with a section that decreases in size from the bottom to the top.

The composite slabs comprise a system of primary and secondary beams with I-shaped profiles (HEM and IPE) that support the steel decking and the reinforced concrete cast-in-place on top, which is 8 cm high. The torsional stresses from asymmetric wind loads are managed on each floor by a perimeter lattice ring element made of IPE beams partially embedded in the slab.

Crystals, metals, and types of cement forming the cladding elements are selected based on appropriate intrinsic properties and compatibility to provide filtration or insulation against physical factors in relation to the needs of the interior spaces and the overall planned technological conditioning system. All floors are designed and constructed with a layer for electrical and telephone installations, with outlets arranged planimetrically in a modular grid subordinate to the coordination module (132.5 cm); the walking surface is provided in vinyl sheets. The internal space distribution is achieved with removable wall panels related to the support system for sound-absorbing buffer ceilings; all fixed walls are finished in wood or enameled steel panels, where they form chases for cable passage, and in vinyl sheets when they have a cement structure.

In summary, here are the quantitative data for the skyscraper: a total construction volume of 75,000 m^3, with 56,000 above ground; a total floor area of 21,000 m^2, distributed as follows: public interaction areas, 5%; tech-

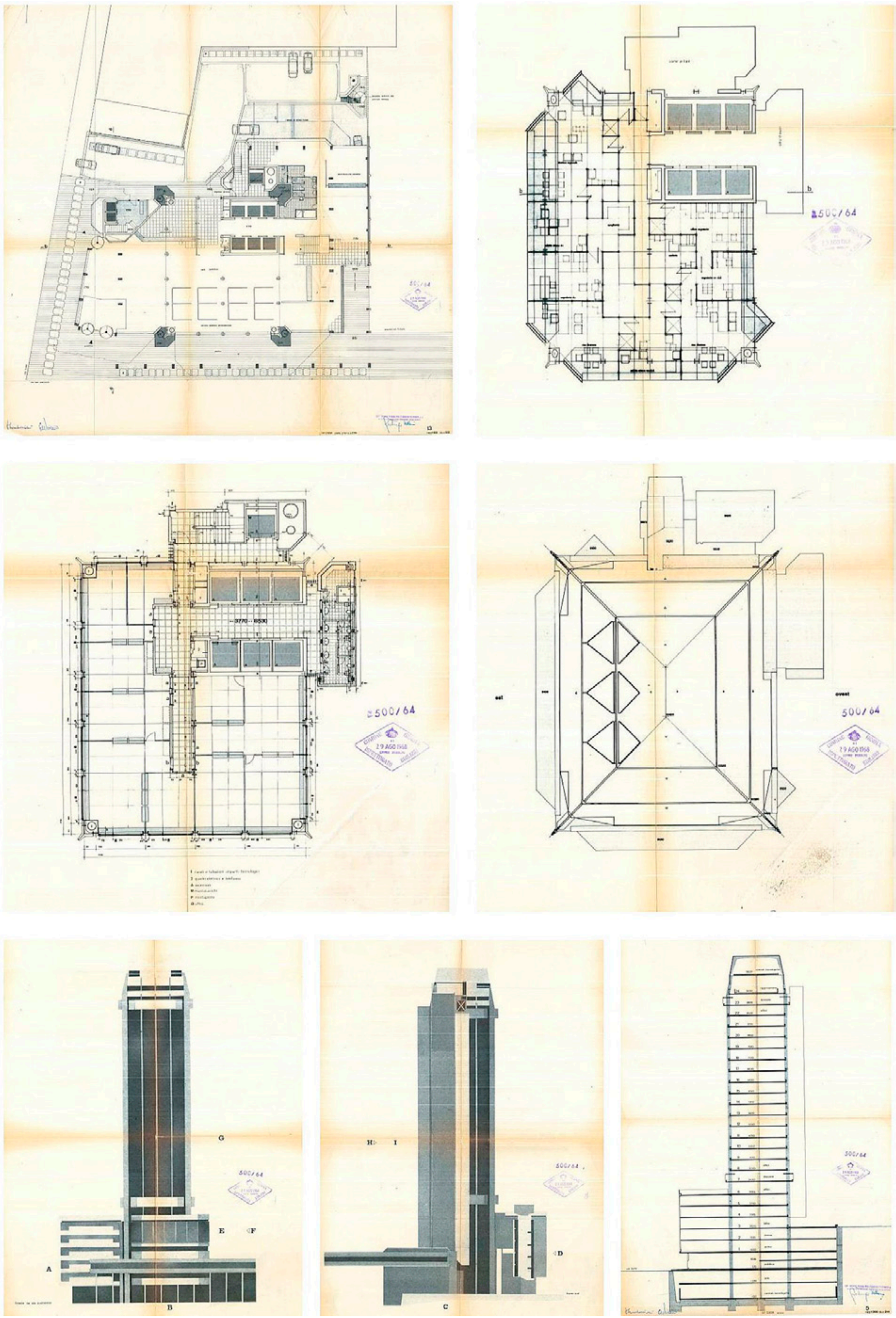


Fig. 5. *Project drawings. Top: ground floor plan and seventh-floor plan. Middle: type floor plan and roof plan. Bottom: elevation on via San Vincenzo, south elevation and section. Source: © Archivio Edilizia Privata, Comune di Genova.*

nical-administrative offices, 57%; sanitary facilities and corridors, 9%; vertical connections, 9%; parking, 9%; technological central offices, 12%. With a projection for an increase in the first decade of building utilization, it is designed for a maximum occupancy capacity of eight hundred people during full utilization.

In the vertical section, the distribution of functions across various floors is as follows:

- second basement: technological central offices;
- first basement: car parking;
- ground floor: public service;
- first floor: electronic center, cafeteria, kitchen, warehouses;
- second floor: electronic center;
- third to fifth floors: administrative offices and archives section;
- sixth floor: social and corporate institutions;
- seventh to twenty-second floors: accounting and technical offices;
- twenty-third floor: management and meeting rooms, secretariat;
- twenty-fourth floor: turbine motor-generator station.
- twenty-fifth floor: elevator machine room, electro generators, cooling towers.

3. *NASCE UN GRATTACIELO*: THE PREFABRICATED STEEL STRUCTURE

Almost nothing would be known about the design and construction of the steel structure, engineered by Riccardo Baldacci, if not for the considerable documentation work conducted by Italsider in 1968. They produced the movie entitled *Nasce un grattacielo (A Skyscraper is Born)*, capturing, for promotional reasons, the most significant moments of the construction of the SIP Tower, built by CMF (*Costruzioni Metalliche Finsider*) with steel supplied by Italsider. This movie is an extremely valuable original source from that era, the only one allowing for the detailed clarification of some distinctive aspects of this steel structure [18].

The movie provides fundamental preliminary data, namely the need and intention to give an industrial approach to constructing the skyscraper through the prefabrication of homogeneous elements produced in the factory and their subsequent assembly on-site. This serial production process allowed for an innovative and high level of productivity for that time. The documentary highlights individual parts of the structure being prepared in the carpentry workshop through a sequence of programmed operations and then moved steadily to the construction site, where they are assembled according to the project specifications.

The corner columns, conceived based on an interpretation of both aesthetic and structural motifs, are prefabricated in the workshop using a composition of custom-cut plates continuously welded to HE profiles with wide, parallel flanges. The base, which mirrors the star-shaped form of the column, is attached while the welding of its transverse ribs is in progress. Once on-site, the column is placed on the foundation slab in the designated position where the anchor bolts have been set; the narrator emphasizes «the simplicity and immediacy of the entire operation». The fabrication and subsequent installation of the other three corner columns proceed with a regular, coordinated work rhythm between the workshop and the construction site.

The installation then proceeds with one of the intermediate square columns on one side of the tower. The column consists of two HE beams, one of which is cut transversely in half and welded onto the web of the other. The dimensions of these columns, 520 mm x 300 mm, significantly limited in relation to the load, will decrease further as the building rises vertically. Simultaneously, the assembly of horizontal connections proceeds, which, proportional to the required section, consists not only of HE profiles but also of IPE profiles and welded beams. In 1964, the *Rivista Italsider* magazine published an article entitled *Travi per costruire* (Beams for Construction), detailing the specific requirements of IPE and HE parallel flange beams. According to the writer, these beams represent «a new contribution to solving the most challenging construction» [19]. During the lifting of an intermediate beam, the movie shows, at one end, a small balance set up for the worker who will perform the connection. Like all horizontal beams, this connection is made by bolting, first done with a manual wrench and

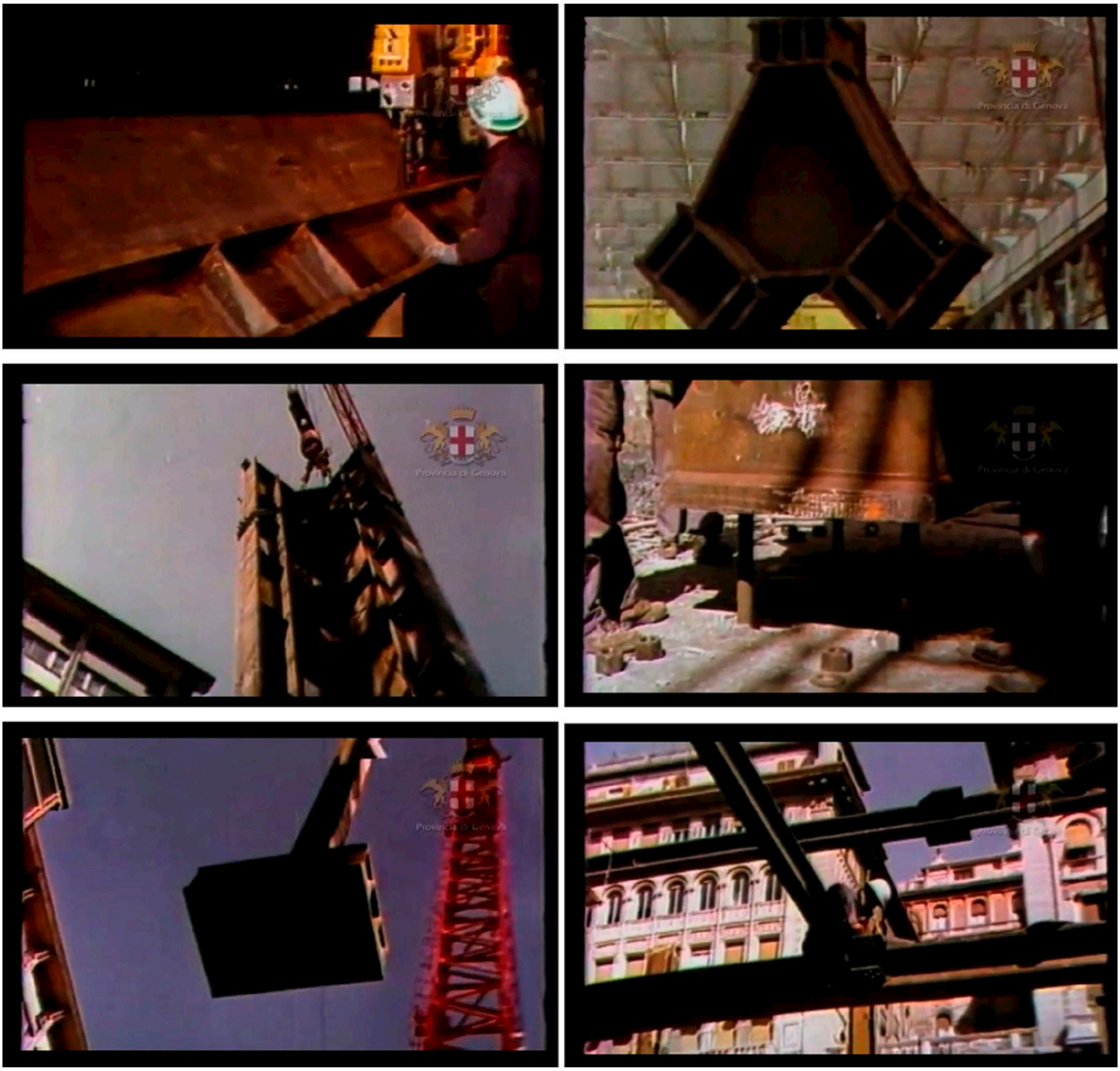


Fig. 6. *Frames from the movie* Nasce un grattacielo*: welding of the corner column and its base; the corner column lifted by the crane on site and the anchor bolts; an intermediate square column and the assembly of the horizontal connections. Source: © Archivio Audiovisivi, Città Metropolitana di Genova.*

subsequently with final tightening using an adequately calibrated automatic screwdriver (Fig. 6).

The process then involves lifting the triangular corner column segments, which are prepared on the ground and rigged for their movement, using a crane. The ability to use load-bearing elements of truly remarkable dimensions contributes to faster execution. These column segments reach a height of 14 m and encompass up to four building floors. The connection between the installed column segment and the new segment is made by welding the two matching ends, one of which is prepared in the workshop with a specific bevel to accommodate the welding bead.

In an extremely confined space, pre-assembly of structural units for sections of three and four stories is carried out at the construction site. The film shows the crane lifting a unit that covers over 100 m^2 of façade. The narrator states: «The emergence against the sky of these robust and slender frameworks of new dimensions gives the precise impression that even construction in our country embraces the momentum of great technological transformations.

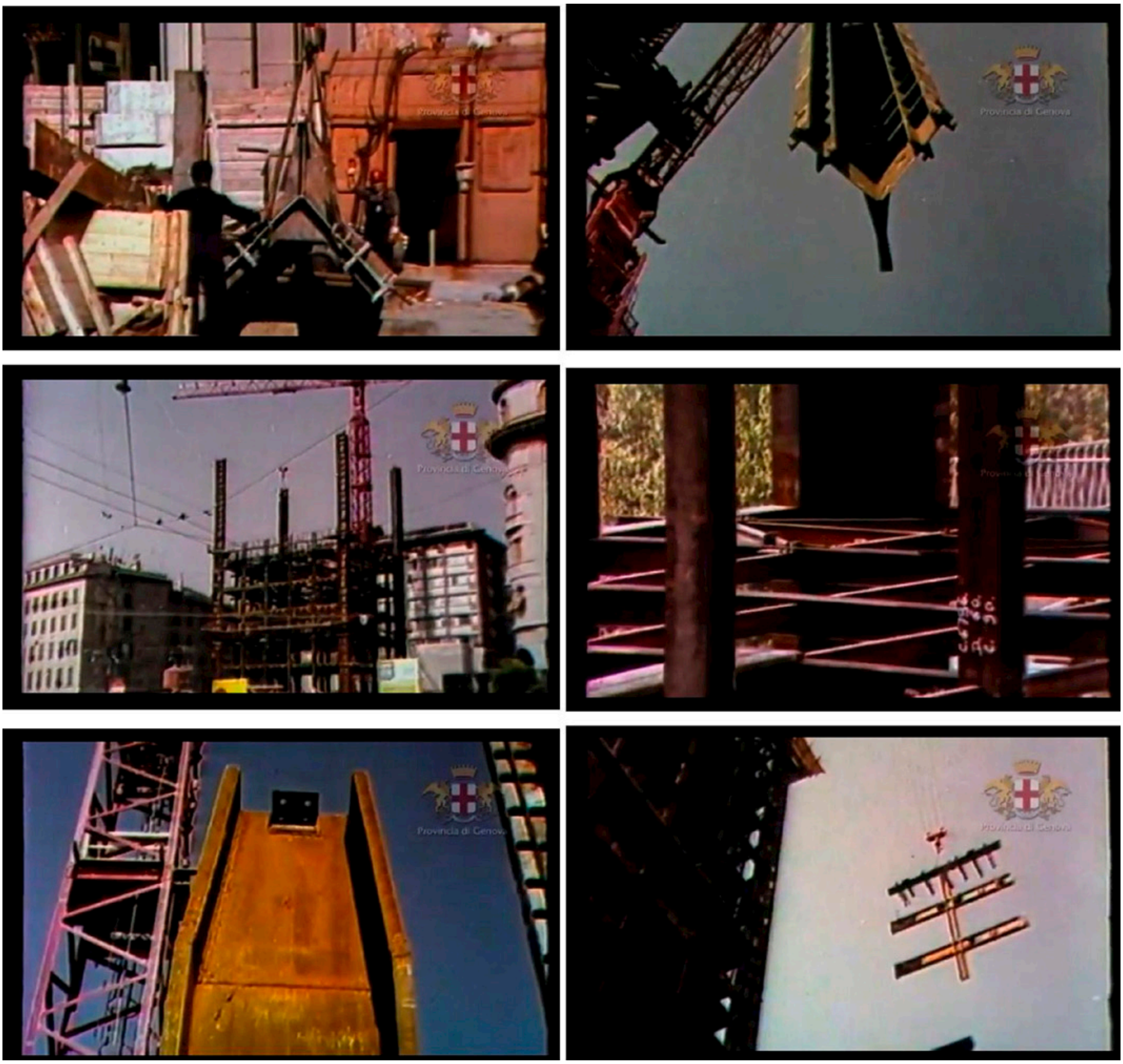


Fig. 7. *Frames from the movie* Nasce un grattacielo*: the segments of the triangular corner columns and their lifting; the tower under construction and the internal structural elements; reduction in the cross-section of an intermediate column and the lifting of a structural unit equivalent to 100 m*^{2}*. Source: © Archivio Audiovisivi, Città Metropolitana di Genova.*

With steel, it is possible to achieve an entire structural entity installed with a single crane lift, a task otherwise achievable with a variety of materials, excessive equipment uses, and a significant impact on time and labor».

To facilitate the integration of the unit into the structure, supports for service platforms used by assembly workers are attached to its upper beams. As the unit reaches its designated location, other work phases follow, such as joining the tower's internal structural elements. Plates with holes matching those already drilled in the side columns are welded to the ends of each beam in the workshop; the fastening is done using bolts. The structural elements for the stairwell group, which is planned as an attachment on one side of the tower, are also prepared on-site and placed continuously using the same assembly technique as the main core of the building. The insertion of the skyscraper into the environment becomes increasingly defined as the building rises; the tower begins to take shape in its proportions, integrating into the surrounding urban fabric (Fig. 7).

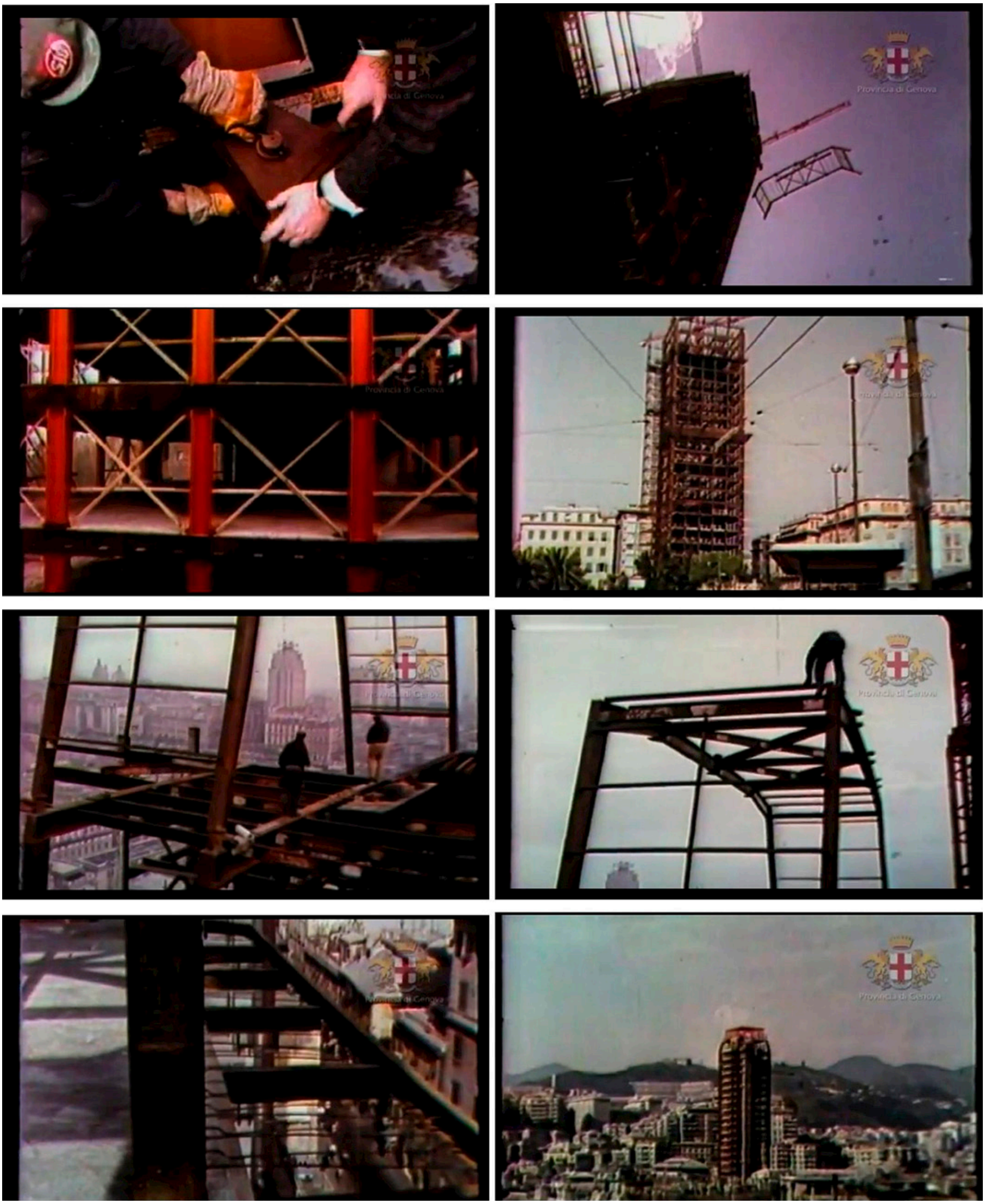


Fig. 8. *Frames from the movie* Nasce un grattacielo*: the hinge connection and the lifting of the portals; the installation of a portal and the bracing diagonals; edge beams made of steel profile for the cantilevers on the sixth and twenty-third floors; the steel structure completed with its pinnacle in the landscape of Genoa. Source: © Archivio Audiovisivi, Città Metropolitana di Genova.*

For the terminal part of the skyscraper, prefabricated units are employed on-site, consisting of two pairs of portals hinged at the base. The hinge constraint is considered the most suitable for addressing static and economic issues. The portals span over 16 m and a height of approximately 6 m. At the construction site, a pair of portals is prepared with the arrangement of connecting elements and the members for the roof installation; precise positioning is carried out with extreme accuracy due to the considerable size and extent. Diagonal braces are bolted to the upper area of the portal pairs, completing the load-bearing structure of the pinnacle; the assembly of a pair of portals takes about two hours. The pair of portals, resting on the underlying beams, is secured with bolts and then permanently fixed by welding.

The ample space inside the pinnacle will accommodate the air conditioning and lifting systems. Thanks to the high specific strength of steel, the load-bearing structure allows for the easy placement of heavy equipment at the top of the building. With the completion of the pinnacle, the tower will be ready to undergo finishing work. The external cladding will consist of prefabricated panels, which emphasize the continuous rhythm of the façade volumes, marked by two cantilevers located on the sixth and twenty-third floors, constructed with edge beams made of steel profiles and reinforced concrete slabs (Fig. 8).

The SIP Tower represents a unique milestone in the history of metal framing. In 1968, it made possible the creation of extremely linear and quickly executed joints with a limited footprint of structures, benefiting greater usable space and larger spans. Time and costs were also reduced: the assembly of the entire steel structure, unaffected by weather conditions, required 21,000 person-hours, ensuring a steady work progress. The entire unloading, assembly, and installation of the structure was accomplished using only one crane in a construction site area limited to just a few dozen m^2. Furthermore, the high strength-to-weight ratio of steel reduced loads on the foundations and, consequently, their cost.

Driven by an optimistic and innovative spirit, and perfectly fitting, are the words that conclude the documentary: «The ancient noble landscape of the city now welcomes, among its buildings differentiated by a history of many centuries, the strong and slender presence of the steel tower. It introduces into the traditional environment the essential imprint of dynamic and therefore enduring civilizations, namely the ability to consciously and harmoniously utilize the means made available by technological progress».

4. REMARKS AND CONCLUSION

Upon completing the structural steel framework, the need arises to personalize the structure. The designers, aware of the ineffectiveness of a symmetric architectural form within such a heterogeneous context, opt for a judicious differentiation of the tower's four sides. The modularity of the façade system allows architects to design the elevations using a variable use of cladding. Aluminum-glass panels, created with a self-supporting hinged system fixed at points to the structure, are employed in inhabited spaces. In contrast, cellular concrete panels hanging with an elastic system on the steel structure enclose service and distribution areas. Initially, the project developed by Gambacciani, Viziano, and Bega planned to place the distribution and service block on the north façade to provide the inhabited spaces with a view of the sea. However, the municipal offices did not accept this decision, and to emphasize the building's importance within the *Piano Particolareggiato*, the main façade must face Via San Vincenzo.

The tower appears to emerge from the ground, breaking through the base, with a front variously capped depending on the perspectives. This variability responds to an urban spatial intuition that metaphorically condenses in the building, which – quoting Pedio – «seems to want to take on, as much as it can, with a volumetric and figurative effort, the dynamics of the city» [6]. The gallery's ceiling is punctured to allow the angular load-bearing elements to slide through, highlighting the anchored-to-earth steel structure and emphasizing its measured and finished verticality. The *Torre SIP* does not seek a romantic reach for the sky; it is firmly rooted in the ground. Upon its completion, the tower asserts itself, with its well-defined volume, in the city's landscape (Fig. 9).

«If, on the one hand, – say the architects – given the current configuration of the city and the context in which

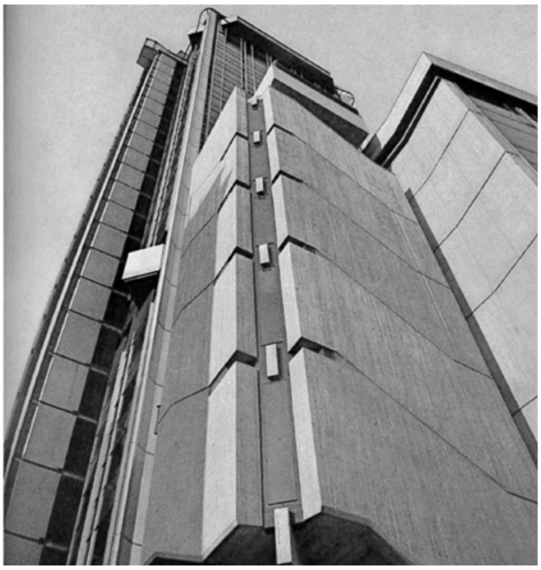



Fig. 9. *The load-bearing corner elements breaking through the base and cellular concrete panels of the distribution area. Source: © Archivio Edilizia Privata, Comune di Genova.*

it stands, the building represents a clear departure (aside from any superficial discussion about the need to refer, for any construction of quantitative commitment, to a manifest contemporaneity), a dialectic in the development of forms remains valid, where a building is both the last of one series and the first of another series» [6].

What distinguishes the work of architects Bega, Gambacciani, and Viziano is their ability to positively exploit the full potential of production rationalization, realizing an architectural artifact whose serial nature does not flatten its strong linguistic connotations. Going beyond a pedantic, albeit complex, technological coordi-

Fig. 10. *The* Torre SIP *(1970). In the background, Genoa. Source:* L'Architettura. Cronache e storia *174.*

nation and escaping with a personality from unnecessary styling, the architects create a manifestly contemporary urban intervention, choosing to graft architecture onto the city, making the building "the first of another series". Through the multiplication of cells and elements, following the canons of industrialization, the designers construct a formally qualified accomplished fact capable of also referring to the urbanistic solicitation, deepening the favorable elements of the situation and remedying planning deficiencies themselves.

Pier Carlo Santini writes about the *Torre SIP* just after the completion of the construction: «In Genoa, there is little talk of architecture, even though a lot is being built, at least at this moment. […] Dignity and correctness characterize the best cases. But there are no flights, even though the very recent SIP skyscraper seems to me to be an undeniable exception […]. Clear and simple as a crystal, as if to contradict the surrounding building modules, both near and far, this skyscraper is a new, recognizable, emerging episode in the Genoese urban landscape. Designers Bega, Gambacciani, and Viziano rightly thought that dimensionally distinct, the skyscraper had to assert an original architectural idea without succumbing to easy compromises or environmental flatteries. And the result is what it is, remarkable for what is right in the city» [5] (Fig. 10).

Acknowledgements

The documents related to the building permit can be consulted at the *Ufficio Visura Progetti, Sportello Unico dell'Edilizia, Comune di Genova*, to whom we express our gratitude for their availability and cooperation.

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PREFABRICATED LIGHT STEEL CONSTRUCTION. RESEARCH AND PROTOTYPES FOR HOUSING IN ITALY

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Abstract

The use of steel technologies in the residential sector was deeply influenced by Italian historical events and its distinct cultural background, resulting in limited and occasional outcomes throughout the peninsula. Pursuing a common thread that links the design and technical development of the steel house may provide an opportunity to understand the genuine involvement of Italian technological culture in technical innovation and to critically evaluate individual contributions.
Between the 1960s and 1970s, public and private bodies launched experimental and theoretical design research with a series of production initiatives. Numerous research institutes were established, fostering cooperative relationships between academic institutions and the private sector. Collaboration was encouraged between design teams, bodies, and firms involved in the production and promotion of steel, while some architects attempted to integrate the codes of prefabrication into an all-Italian code of planning geared towards aesthetics. Within the broader context of these activities, research and experiments concerning building prefabrication for residential purposes are examined in the paper, including both "programs" and "coordinated components" for which steel was used.

Keywords

Steel structures, Light prefabrication, Housing, Italy, Prototypes.

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1. INTRODUCTION TO THE LIGHT PREFABRICATION BETWEEN PROJECT AND META-PROJECT

In the 1960s, building industrialization was a prominent topic of discussion [1]. Due to the critical issues raised by the implementation of closed systems and the substantial demand for housing, the residential building sector was designated a privileged area for research and experimentation in the so-called "open manufacturing" [2, 3]. This operational strategy involved a variety of approaches, with the aim of providing answers to the primary "open questions" [4, 5]: the necessary and no longer deferrable adaptation of design techniques to the needs and critical issues posed by new production processes [6]; the development of an operational method that allowed the use of prefabrication system as a tool for enhancing production in the construction sector, with the clarification of the connections between typological models and construction; the use of traditional and innovative materials, in relation to the evolution of production and assembly techniques; the development of a correct relationship between architecture and industrialization to make coherent a new design practice, indeed «the only possibility of industrializing architecture without removing it from its range of artistic activity is not the application to architecture of industrial techniques already established and experiment, but the invention of a construction technique which, although considered to be fully autonomous, falls within the methodological scope of industrial technology» [7].

In this context, various research initiatives related to the industrialization of construction systems for residential purposes and the experimentation of steel, to validate its technical and appearance potential, pursued different directions [8]. The first one comprised a methodological and operational experimentation, wherein the "meta-project" was used not only as an ideological tool to oversee the entire design process across all phases, including conception, programming, production, and construction [9]. Alternatively, more strict design experimentation could be undertaken on the building component or components, with frequently divergent objectives and purposes [10]. The methodology proposed for the *Progetto di elementi edilizi industrializzati per la libera realizzazione di tipologie abitative* (Project of industrialized building elements for the free creation of housing typologies) entailed the incorporation of the definition of "meta-design": it was conceptually associated with "open manufacturing". It was conceived as a logical progression of prefabrication. The term "open" was considered as «the possibility of adapting to the mutability of circumstances, of absorbing external inputs and stress; consequently, an open system should be characterized by constraints of a nature that does not jeopardize its continuous change and adaptation. Therefore, the limitations that must be sought define the objectives as precisely as possible and not the means to comply with the technological adjustments while preserving the figurative nature of the various production categories» [11].

The methodology identified several theoretical tools based on this perspective. The first one was the theory of the "three freedoms", which encompassed the freedom to tailor the building to the user's requirements (flexibility), to incorporate it by the industry in the construction process, and to shape it (particularly its edges and overall appearance). This concept was used in the Clasp, the English system for the construction of schools with a steel framework employed in the postwar period. The second one was related to the "large module", conceived as the principal common factor from which the building's size derived. The third theory was based on the concept of "concentrated anomalies", which entailed the possibility of concentrating heterogeneous disturbance elements (such as ducts, vertical connections, and others) in a few vacant areas of the building. The fourth one was based on the notion of "adaptations", which referred to the possibility of incorporating non-system components, such as accessory components, into the building to be designed. The fifth theory comprised "categorical spaces", defined by ten productive categories [12].

The experimental research titled *Studio di un programma edilizio con impostazione integrale della progettazione, per edilizia residenziale dipendenti Italsider* (Study of a building program with an integral design approach, for residential buildings of Italsider employees) was grounded on a whole design approach, which, from a methodological standpoint, was able to regulate the entire program with the three phases of setting-up, preparation, implementation and also of starting a technical-operational collaboration among all the participants in the construction process [13]. The methodology involved a meta-design approach that guaranteed typological and functional diversity, unification and standardization of industrialized components, selection of construction systems, and adoption of modular coordination. They were based on building type through standard components (built of steel and reinforced concrete), following a specialization relationship linked to the role of the construction elements' set and the typological layout of the entire building. The design experimentation of the system based on steel components for residential and school buildings named Fly had a more ideological objective: to bring architecture back to its primary purpose of the technical culture of building. It sought to reunify architecture and construction «with a different method of analysis of the construction logic that can establish a different history, in which the emphasis on the individual element is replaced by the consideration of the building culture to study the process and not only the result» [14]. Therefore, research became the most suitable dimension for the project, a dimension of discovery, not invention. The design of prefabricated building systems was pursued with the intention of reaching technical-formal rules of the construction system: a network of resilient components of different types, each one corresponding to distinct structural functions, in which the solutions and technical methods of assembly imparted a "decorative" aspect, aimed at comprehending the logical conception of the construction. The structure was not only considered as a static tool but also an ordering criterion from which the objective and tectonic laws were identified [15].

Quite the opposite, the design research on the "steel brick" was based on a more strictly technical-economic vision for immediate usability. The open-cycle prefabrication process was elevated to its most extreme outcomes by developing a singular steel building component that was both modular and versatile, similar to brick in traditional construction [16]. From a production standpoint, this ensured significant degrees of freedom even during the construction/assembly phase of a building, despite the technical-mechanical repetition of industrialized components produced in series. The initiative to experiment with a single component and reduce the assembly phases aimed to evaluate the potential for triggering industrialization processes of building products that can be adapted to self-construction processes [17]. The study titled CREIG-ITALEDIL, namely *Studio per l'inserimento delle strutture e degli elementi costruttivi in acciaio nel procedimento costruttivo a ciclo aperto* (Study for the integration of steel structures and components in the open industrialized building system), aimed to verify, both at the design and construction-production levels, the potential advantages of "manufacturing by components" in steel, specifically the establishment of a unitary and integrated industrialized construction process that afforded a wide range of design choices [18]. The building organism was not the result of a predetermined mechanical procedure for assembling catalog components, according to technical-economic reasons, but rather a conceptual process in strictly architectural terms, which defined it as a collection of interconnected and related components functional to establish an "open system" [19].

2. *PROGETTO DI ELEMENTI EDILIZI INDUSTRIALIZZATI PER LA LIBERA REALIZZAZIONE DI TIPOLOGIE ABITATIVE*, 1966-67 (DESIGN OF INDUSTRIALIZED BUILDING ELEMENTS FOR THE FLEXIBLE CONSTRUCTION OF HOUSING TYPOLOGIES)

The design research, which was developed for the CECA-Finsider competition, focused on the design of housing units built at an industrial scale and was an opportunity for the application of the theory of "building meta-project" developed by the architect G.M. Oliveri, who headed the design group of the Nizzoli Architectural Office.

A dwelling of 110 m^2 was identified according to the group of users defined in the call, and it was set on a modular square grid with a side of 15 m. The design work included a "system engineering phase" for the development of subsystems that could be produced by different industries that shared the meta-project as a reproductive structure based on the regulations and an "industrial design phase" for the verification of technological, formal, and economic-productive needs [11].

In the subsystem titled the *spazio-struttura* (space-structure), the frame was composed of slabs with integrated beams and pillars [20]. The orthotropic reinforced slabs were sustained by vertical supports placed in the center lines of the modular texture. The structural grid was designed to accommodate building modular units, with a size of 1,575 m^3 (15 m x 30 m x 3.5), that could be joined to form a maximum of six units. The steel columns were available in two standard types, each with a different height and profile to support varying loads. The end plates, large or medium, varied according to their position, external or intermediate, in the spatial reference grid. The slab comprised 7 mm thick flat beams placed along the perimeter and two shells made of pressed steel sheet with a thickness of 15/10 mm, which were connected by welding and filled with an expandable concrete casting. This component could be built with various building options depending on the different architectural typologies and its location: the standard type, prepared in the fabrication shop with

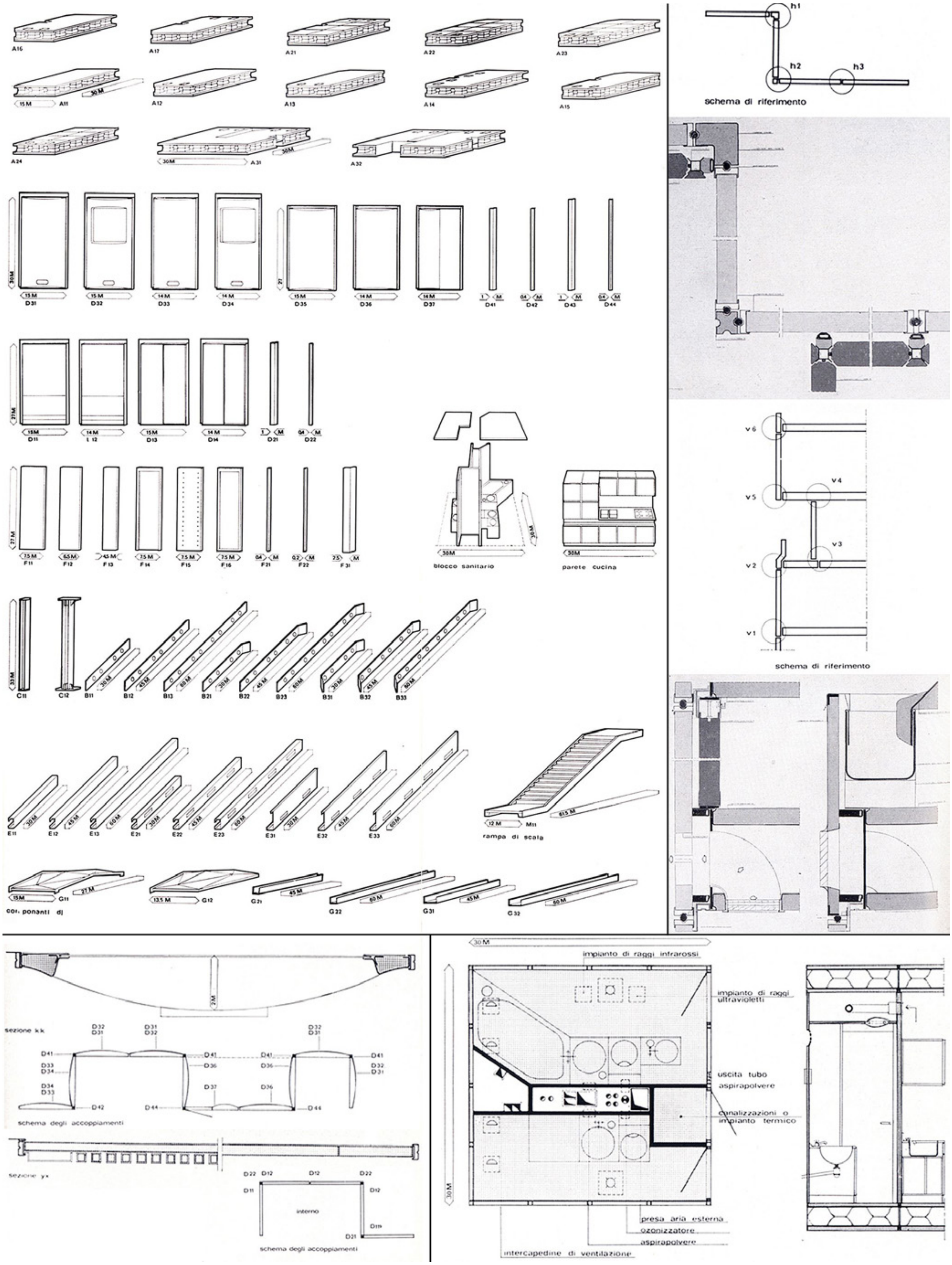

Fig. 1. *The building program developed by Nizzoli and Oliveri. Top left: the components' list. Top right: the vertical and horizontal joints for the façade panels. Bottom left: the diagrams of the possible panels' arrangement. Bottom right: technological features of the kitchen and bathroom units. Source: [12].*

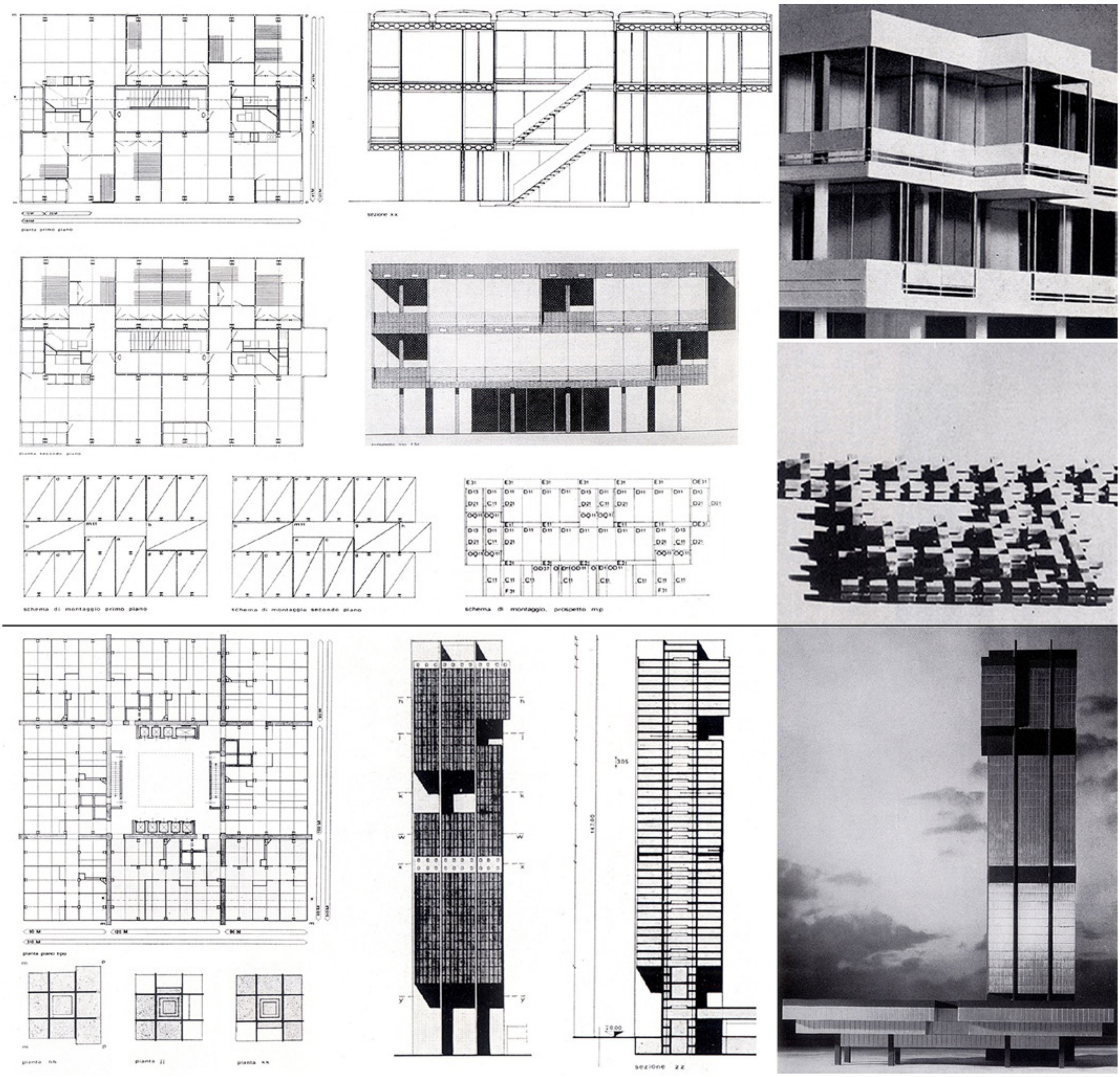

Fig. 2. *The building program developed by Nizzoli and Oliveri. Top: the modular layout of the housing block and its possible repetition in the urban arrangement. Bottom: the use of the same coordination grid for the tower typology and its architectural appearance. Source: [12].*

floor and ceiling, and the loggia-type variant, furnished of raised floor; the technological block-type, equipped with systems; the roof-type with the overlapping of molded plastic elements. The envelope subsystem included two versions of façade panels, built of pressed metal or plastic, with the same connection constraint along the perimeter. The façade panel made of plastic material was designed with a pass-through light to reduce the restriction of openings and enhance internal distribution flexibility (Fig. 1).

This construction system, which was also proposed for the expansion of a neighborhood in Bratislava, was used for multiple building typologies and displayed distinct design implications for each of them [21]. In the single-family dwelling, the criterion of distribution neutrality of the habitable spaces was experimented with, which was defined by the two horizontal components and the uniformity of the transparent envelope. The housing block typology involved using standard components of the building system and adapting additional components, such as the porch. The arrangement of the dwellings and the entire structure could undergo elevational changes in accordance with the kitchen's location and the interior spaces' arrangement, resulting in a distinct external perimeter.

In the tower typology, the central core was based on the concept of the "concentration of the anomalies", and it was built of reinforced concrete, allowing the suspension or the direct support of the eight dwellings characterized by the components of the building system (Fig. 2).

3. *STUDIO DI UN PROGRAMMA EDILIZIO CON IMPOSTAZIONE INTEGRALE DELLA PROGETTAZIONE*, 1960 (BUILDING PROGRAM WITH AN INTEGRATED DESIGN APPROACH)

Following the company's requirements concerning the construction of approximately 12,000 housing units for its employees, Italsider entrusted the CPA group, composed of the engineers S. Colombini and E. Mandolesi and the architect A. Libera, with the task of developing a residential building program. This study was validated in the pilot project of the Salivoli neighborhood in Piombino and executed in various phases. The first phase in 1960 was characterized by the use of two main housing typologies: towers and blocks. The dwellings' arrangement was based on a square module with a side of 3.20 m, which was suitable to guarantee combinatorial flexibility in the planovolumetric schemes, functional adaptability in the various shapes of the housing units, and the unification of the structure [22]. The selection of the module and the implementation of the three-dimensional reference grid also ensured the standardization of all technological components, including the functional blocks of the bathroom and kitchen.

The use of steel was the subject of both technical experimentations, encompassing the design of the building frame and other building components. Furthermore, the research was also carried out from the formal point of view on specific typologies, especially single houses and towers in the phase related to developing prototypes. In the verified prototype, the steel load-bearing frame provided for the unification of the columns and beams, as well as diagonal bracing and connection elements, and the unification of the slabs built off-site with reinforced concrete joists and hollow bricks.

The structure was characterized by athwart frames connected by the exposed beams on the façades, the bracing slabs, and the stairs. The athwart frame was divided into four spans, and HE 120 profiles were used for all its columns that had the height of the building at the far ends and the height of the building levels within, interrupted by the continuous beams. IPE 180 profiles were used for the main beams inside the building, and C-shaped 160 profiles were exposed along the perimeter, bearing the walls of the envelope and ensuring the connection between the athwart frames [13]. According to the structural layout consisting of a hinged frame, the bracing was composed of diagonal elements connected to columns and beams through hinged joints, ensuring the capability of the building to support the horizontal stresses (Fig. 3).

The building program involved the specialized use of steel for the construction of stairs, including a single type of ramp that could be customized to suit various building types. There were two alternative solutions: ramps with steel stringers featuring a free rise and tread made of prefabricated elements in marble grit and concrete or self-supporting ramps made of a single piece of folded steel sheet, with rubber covering for the tread. Both solutions were designed to be produced in the factory and assembled on-site after construction. The same choice of steel characterized the technical features of the windows, which could be shaped with a double or a single frame. The program provided alternative solutions for the walls of the envelope: the traditional type, with the use of separating space between the main layers of the wall that were innovative for the use of heavy or light prefabricated construction elements, respectively made of reinforced concrete panels or steel sheets, but also mixed solution (Fig. 4).

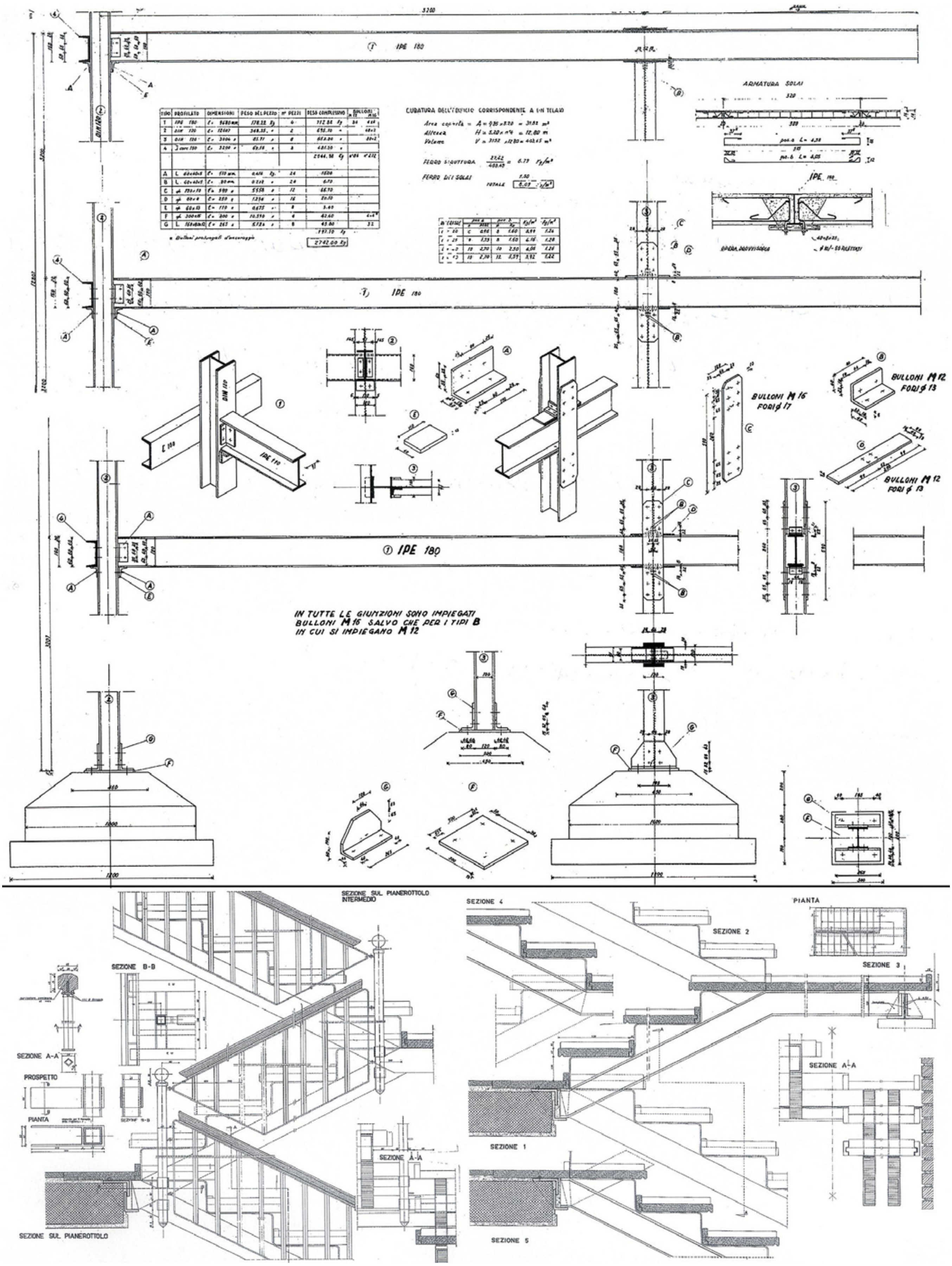

Fig. 3. *The building program developed by Colombini, Mandolesi, and Libera. Top: the typical hinged steel frame for the housing block. Bottom: the details of the staircase. Source: [23]*

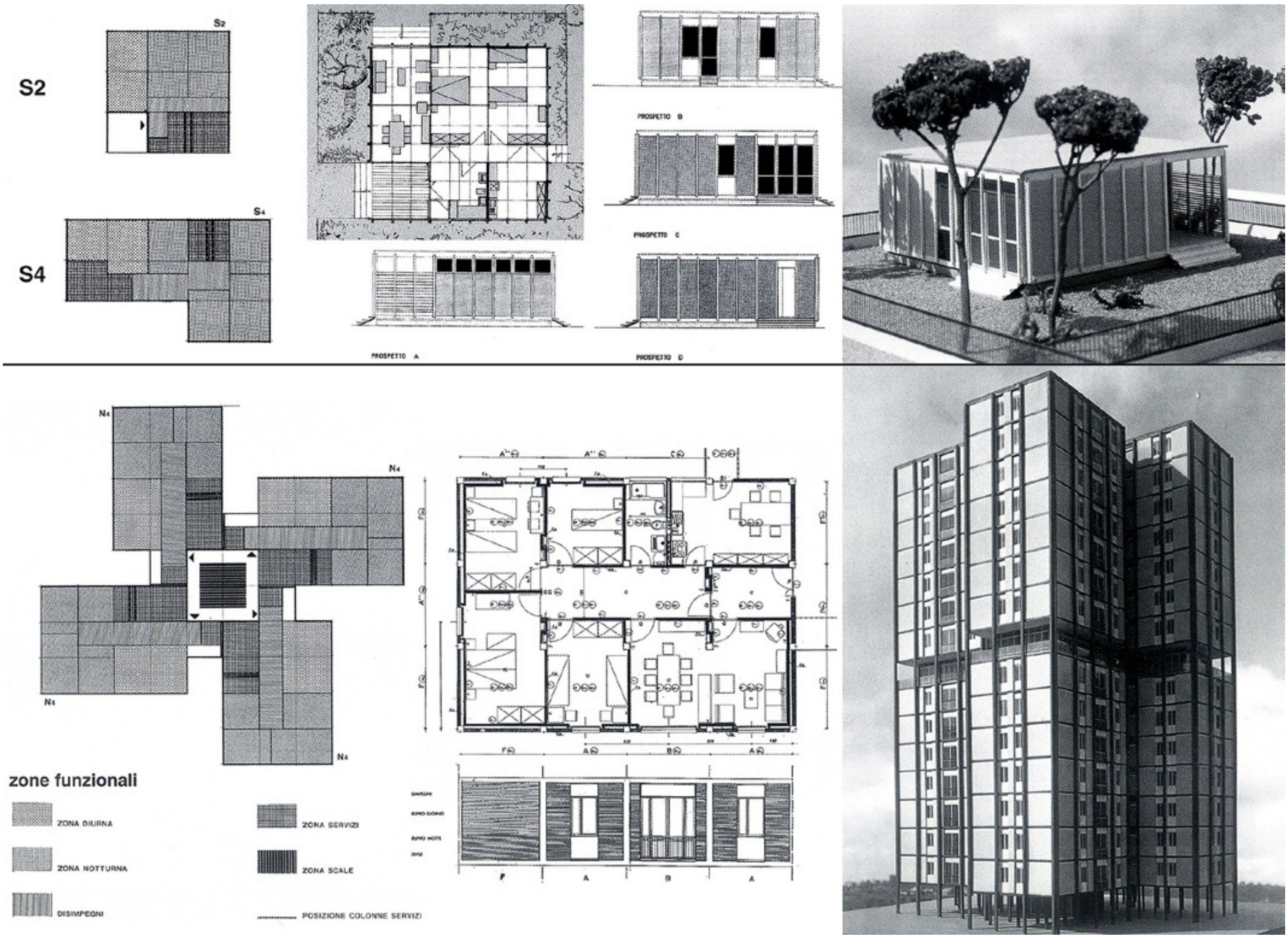

Fig. 4. *The building program developed by Colombini, Mandolesi, and Libera. Top: the single-family house with its modular coordination also displayed on the elevations. Bottom: the features of the tower typology composed of the arrangement of four dwellings. Source: [23]*

4. FLY CONSTRUCTION SYSTEM FOR RESIDENTIAL AND SCHOOL BUILDINGS, 1965

Designed by Angelo Mangiarotti, the Fly construction system aimed to introduce an entirely prefabricated lightweight construction system. The experimentation of the system was supported by a company that produced metal components for furniture; consequently, the modular spatial grid chosen by the architect to organize the internal spaces was set dimensionally identical to that of the furniture with module M equal to 96 cm x 96 cm. To guarantee a high demand for the construction system and consequently achieve adequate profits, the company decided to offer many prototypes to customers who could customize both the layout and the envelope, which was proposed in two versions, one with façade panels in concrete, the other in steel [24].

The Fly system allowed the creation of one- or two-story buildings that were also suitable for terraced house layouts. The steel structure, composed of tubes, had 4 to 6 M spans, depending on the layout. The position of the pillars was based on the modular grid, which also determined their alignment: the perimeter pillars were external to the modular grid, while the internal ones were aligned to longitudinal axes and juxtaposed to the main transverse trusses; consequently, the grid had a tartan pattern, to allow the insertion of spaces corresponding to the transversal dimension of the pillars. The foundations could be built on prefabricated reinforced concrete plinths or slabs with pre-finished flooring [25]. The upper floors were made of reinforced concrete and placed above a double frame of beams: the main ones were placed longitudinally and made up of U-shaped profiles and plates to compose rectangular tubes; the

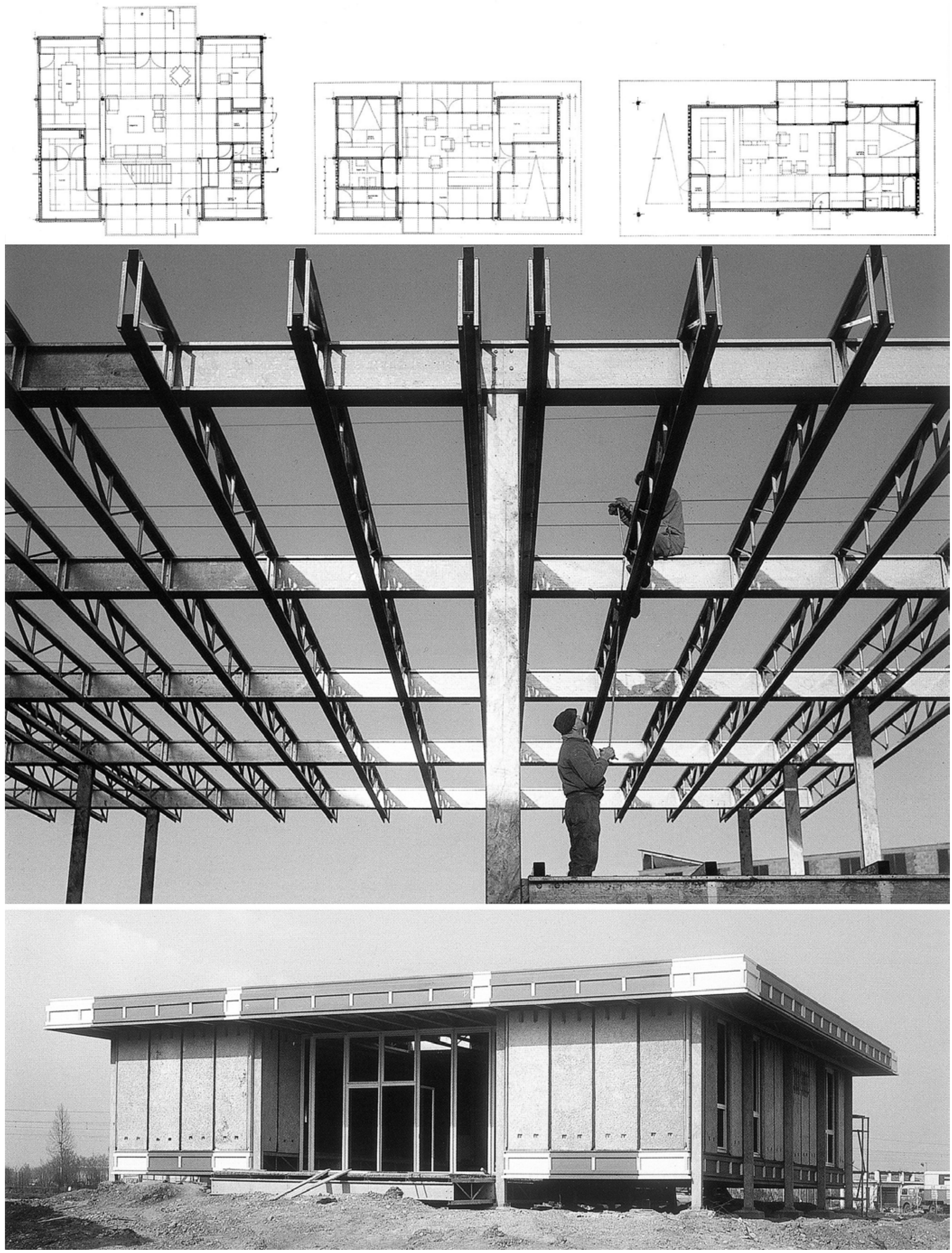

Fig. 5. *The Fly construction system designed by Mangiarotti. Top: the modular coordination of building system components for the arrangement of different types of dwellings. Middle: the assembling of the structure. Bottom: the prototype of the single-family house. Sources: drawings [24]; photos [15].*

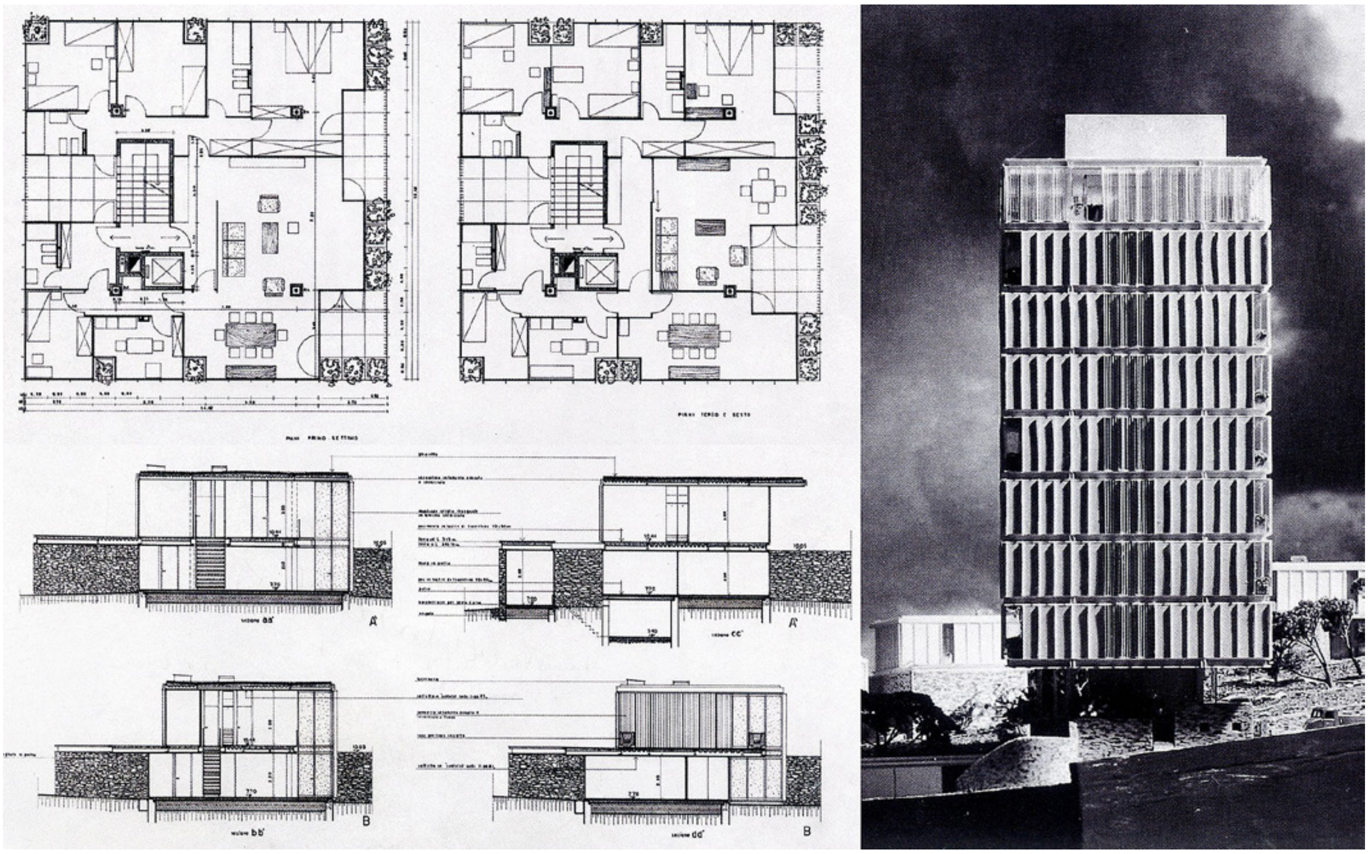

Fig. 6. *The Fly construction system designed by Mangiarotti. Top left: the plans of the tower with different arrangements of the living spaces. Bottom left: the two-story houses surrounding the tower. Right: the maquette of the tower. Source: [15].*

secondary ones were placed transversally and made up of flat trusses. Each of them had top and bottom chords juxtaposed to the primary frame to reduce the number of connections between the beams (Fig. 5). The decks, both on the roof and at the base, were entirely covered with metal sheets, which reiterated, as in a modern entablature, the length of each module of the tartan. Some prototypes were built for construction validation, but production of the Fly system was suddenly stopped due to economic problems (Fig. 6).

5. THE BUILDING SYSTEM BASED ON THE “STEEL BRICK”, 1971-1974

At the beginning of the 1970s, the *Consiglio Nazionale delle Ricerche* (CNR) financed an industrialized building program to produce housing at a proportional cost to the average per capita income. The study involved testing a building component patented by the engineer Michele Pagano, the “steel brick”. This experimentation took place within the *Centro Studi per l’Edilizia dell’Università di Napoli* (CESUN), directed by Pagano, without directly involving companies in the construction sector. This proposal for a modern industrialized brick was aimed at effectively guaranteeing the maintenance, at a conceptual level, of the relationship between the design, production, and assembly phases. It was conceived to allow a balance between freedom of design, adequate sizing of production cycles, and automation and technological unification for the assembly stage [26]. The element was a “brick” with a steel structure, measuring 60 cm x 60 cm x 30 cm, that could provide high thermal and acoustic insulation (Fig. 7).

During the prototype testing phase, another component of different dimensions was added to the first one: it measured 60 x 30 x 30 cm and was shaped to allow for corner connections between adjacent walls and the positioning of vertical elements inserted into a wall. The construction system was characterized by specific requirements: modularity of the spatial structure, adaptability and flexibility to different grids, high statically overdetermined, and reduction of the weight-ri-

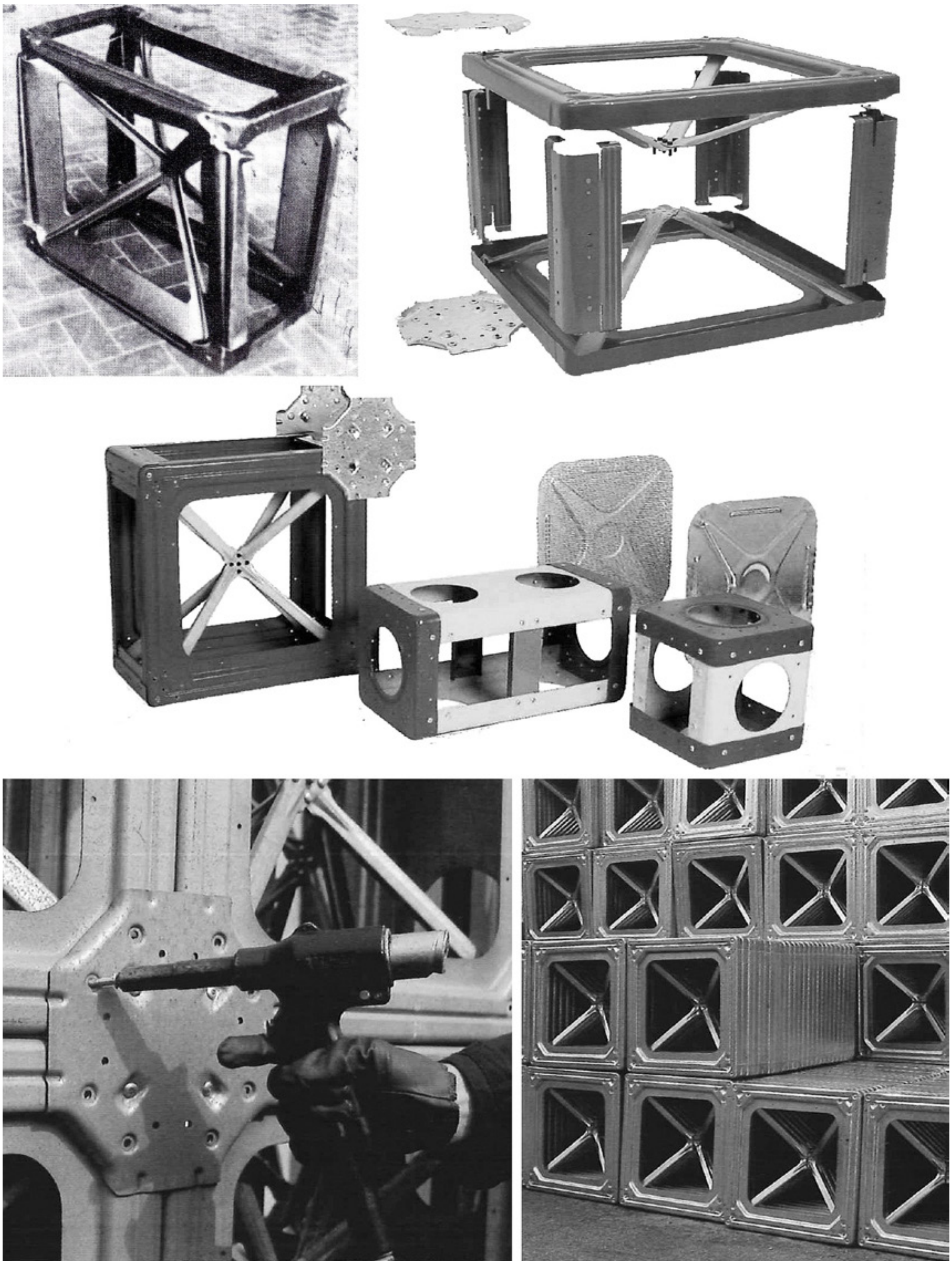

Fig. 7. *The steel brick developed by Pagano. Top: the first prototype and a focus on its metal components. Middle: the various sizes of steel bricks in the last version of the building system. Bottom: the use of joining plates and the ease of storing the metal components. Source: Archivio Michele Pagano.*

gidity ratio and the overall weight of the building. The brick was prefabricated in the factory by cutting "Spedo" type sheet metal (13/10 mm thickness) and molding frames, corners, as well as frames equipped with guides and fins. The assembly stage involved molding the half-brick on the chain of the cutting machine with cross bending, having the next half-brick rotated by 90°, bringing the two parts together, with a polystyrene panel in between, and nailing the diagonals in the middle. The two sandwich panels (sheet metal and hardboard) with an internal layer of polyester and resin were formed in multiple presses. The octagonal assem-

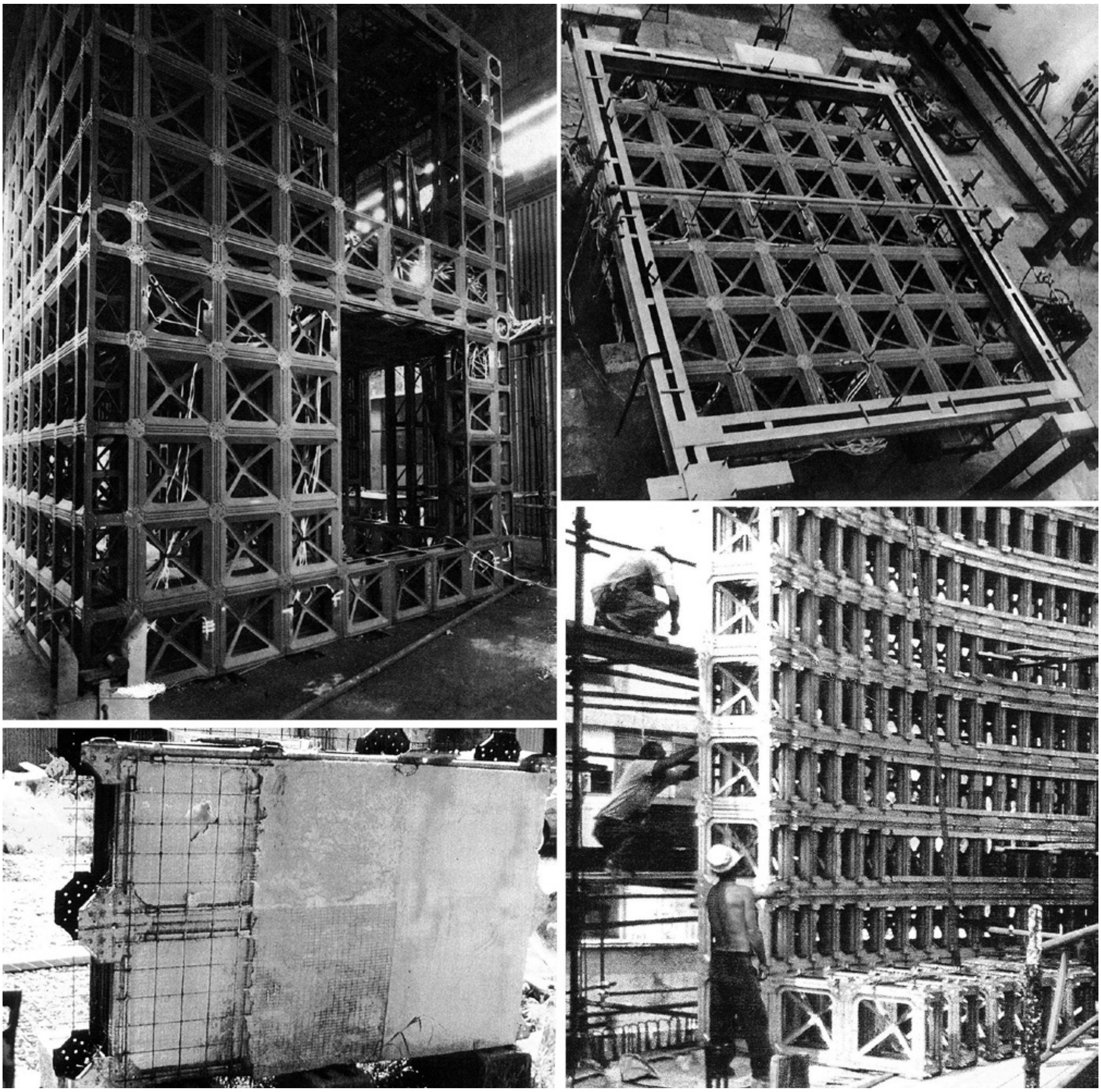

Fig. 8. *The steel brick developed by Pagano. Top left and right: the walls and slabs composed of steel bricks and tested in the laboratory of CESUN center. Bottom: a curved wall made of steel bricks and the mock-up of the wall. Source: Archivio Michele Pagano.*

bly plate was added to this component, with 4 nails, flat or angular, and the system-supporting skirting board in rigid expanded polyester [27]. The steel bricks, each one with a weight of 4 kg, could be placed side by side and mechanically assembled to form floor or wall elements (Fig. 8). Consistent with the objectives set, the research determined the cost based on the number of bricks per room (for a 28 m^2 room, approximately 158 bricks were needed) and the cost of the entire structure was estimated (800,000 *lire*).

6. STUDIO PER L'INSERIMENTO DELLE STRUTTURE E DEGLI ELEMENTI COSTRUTTIVI IN ACCIAIO NEL PROCEDIMENTO COSTRUTTIVO A CICLO APERTO, 1970 (STUDY FOR THE INTEGRATION OF STEEL STRUCTURES AND COMPONENTS IN THE OPEN INDUSTRIALIZED BUILDING SYSTEM)

The research was promoted by CREIG-ITALEDIL and entrusted to the group coordinated by F. Donato and E.

Piroddi together with E. Mandolesi, M. Grisotti, and G. Tardella. The first phase of the research highlighted the role that steel could have in prefabricated buildings. This analysis represented the starting point for a quantitative and qualitative evaluation of the components and areas of steel application in an Open Industrialized Building System. The evaluation also had to concern the methods of correlation between all the technical elements of the building in terms of combinability, based on dimensional coordination on a modular basis, and the design of the joints through coordination of connection capabilities. To guarantee the flexibility of the layout, the group coordinated by Donato and Piroddi introduced, among the technological characteristics of each component, the "degree of autonomy" that it could assume compared to the others related to it. For these components, the design is concerned with the product's characteristics and the production process, with a "redesign" approach of other components and other more complex technological elements [19].

The steel frame was designed starting from one of the components, a six or four-way "separated joint" (Fig. 8) based on which different classes of modular dimensions were defined (2x2, 2x3, for HE 100; 3x3 or 3x4 for HE from 120 to 200 and 4x4 for HE from 220 to 300); a subsequent step consisted of determining characteristics of the correlations between the node, the column, the beam, and the braces inclined at 45° degrees (Fig. 9). The objectives of integration and correlation inspired the design

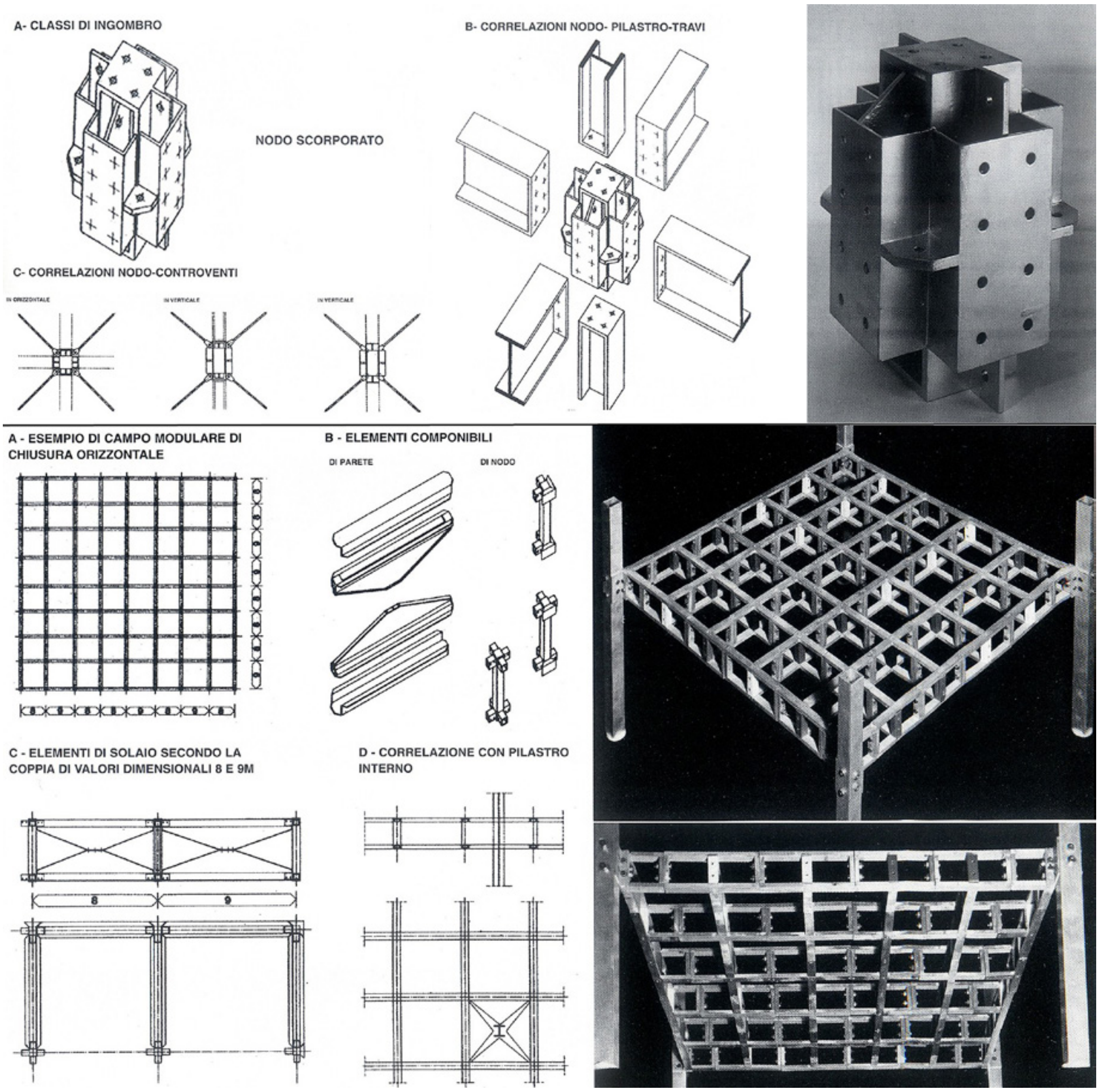

Fig. 9. *The steel components developed by Donato, Piroddi, Mandolesi, Grisotti, and Tardella. Top: the structural features of the joint useful for the connection of columns and beams. Bottom: the interlocking joists and diagonal braces of the grid slab. Source: [23].*

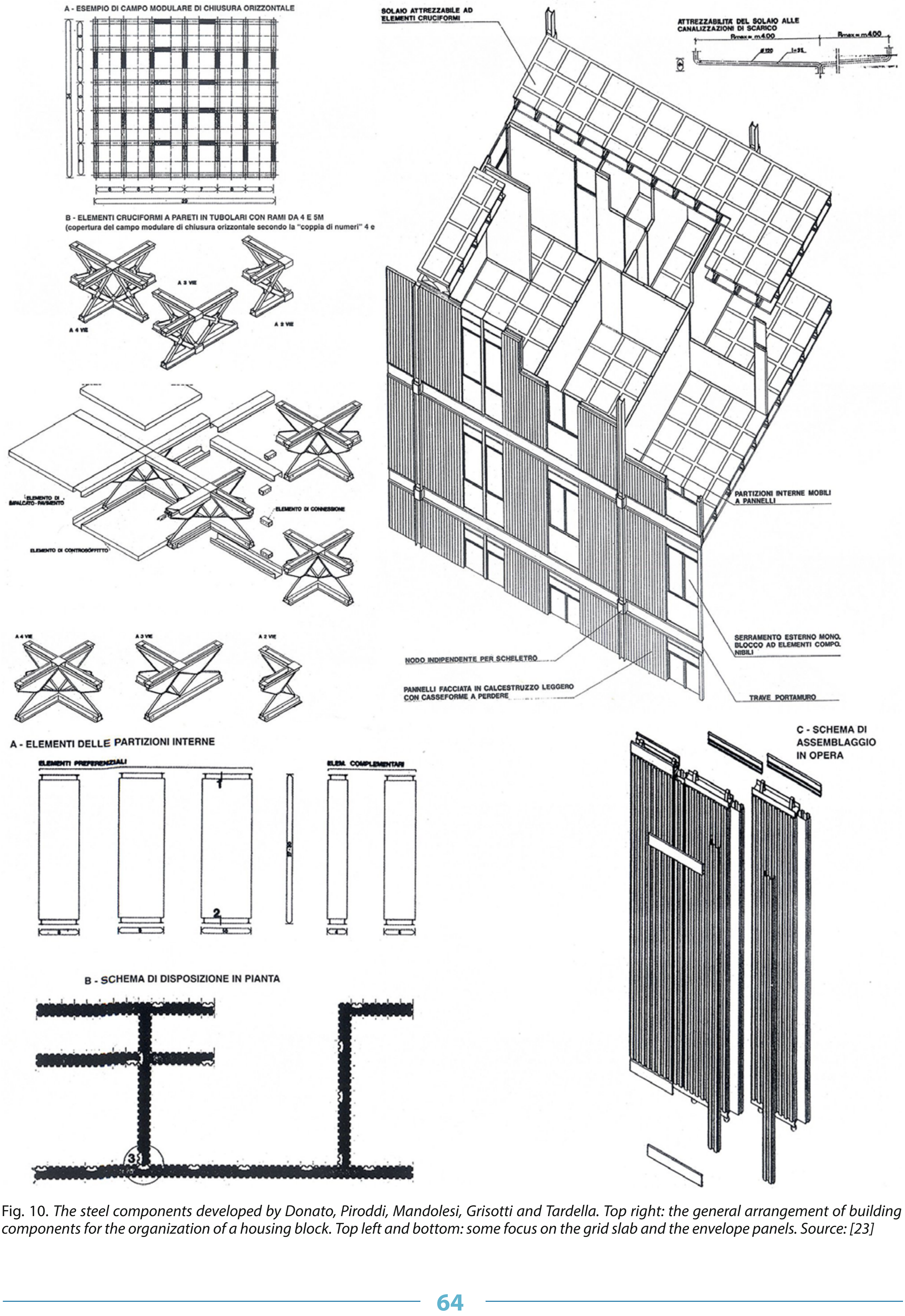

Fig. 10. *The steel components developed by Donato, Piroddi, Mandolesi, Grisotti and Tardella. Top right: the general arrangement of building components for the organization of a housing block. Top left and bottom: some focus on the grid slab and the envelope panels. Source: [23]*

of the floor component. It was supplied in two different technical-constructive solutions. The "slab that can be equipped with modular node and wall elements" consisted of cruciform steel elements consisting of a four-, three- and two-way node element, depending on the position in the structural grid of the slab and open-section columns. These elements were correlated to the technical solutions for the floor and suspended ceiling. The "floor that can be equipped with cruciform elements in galvanized steel" was made of cruciform elements and supplied in two versions: one made of tubes and the second made of sheet metal. These cruciform nodes were assembled using hidden joints, and, as before, the entire system could be correlated with the floor and suspended ceiling using dry assembly methods. Both slab solutions involved the modular coordination of the structural grid with the wall uprights (Fig. 10).

7. CONCLUSIONS

The reconstruction of the events linked to research for the prefabrication of steel construction systems is faced with the difficulty of finding documents and sources. However, this reconstruction shows how, around the theme of industrialization in the residential construction sector, the choice of a non-traditional material such as steel has shifted towards ideologically free, albeit culturally different, attitudes. This shift has favored some experiments that have investigated not only the technical-constructive but also design characteristics regarding some typological and stylistic models. In addition, the centrality of operational tools, imposed by the need to define a different design practice, ensured levels of overall quality of results, both in terms of product and process innovation, as demonstrated by the selected case studies, in the case of prototypes as well as in sporadic pilot project interventions.

Among the case studies, the proposal developed by the group composed of G.M. Oliveri and other professionals from the Nizzoli Architectural Office is an exception compared to the topic of the prototype reaching. Indeed, it only focused on the design of the construction system and its potential applications, which is different from the other examined cases, whose comparison leads to an assessment of the various levels of their diffusion. The prototype of structural components and their connections was achieved in the case of the CREIG-ITALEDIL building system, despite the direct support of a company specialized in the steel construction sector. In the case of the Fly construction system, the prototype development involved all the building components, even if were not related to the structure and the use of steel. Unfortunately, its functional flexibility, particularly envisaged for the construction of houses and schools, was not translated into its wider application. Another fate befalls the Italsider building system, which successfully overcame the prototype phase and was used in constructing the Salivoli district in Piombino, even though it represents its only result. The construction system based on the steel brick, which is an anomaly in comparison to the others as it involved a single component for the conception of an entire structural system, was the only one that was used for multiple applications, thanks to a longer-lasting experimentation, also pushed with the Irpinia earthquake of 1980. The steel brick was indeed employed for the related activities of reinforcement and reconstruction of the historic building heritage, as well as in new construction of buildings that were significantly distinct from the housing typologies for which it was initially designed, such as the church built in San Giorgio a Cremano between 1988 and 1989 [27].

The peculiarity of the construction system based on the steel brick is also reflected in some recent studies aimed at rediscovering its potential and verifying the overcoming of some critical issues that reduced its diffusion and application, mainly linked to the initial construction procedure, which involved the use of costly molds. For instance, the use of CNC machines opens up new production scenarios for this building component, which could allow for greater penetration into the construction market [28]. This continuity of experimentation cannot be found in the other examined cases, which remain unique. However, some experiments demonstrate the potential of steel structures that will be further appreciated, including the advantages of cold-formed steel profiles, as experimented by Mangiarotti and employed today for construction systems that can be adapted to various housing typologies.

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RAYMOND CAMUS' FIRST BUILDING SITES IN LE HAVRE, 1949-1953. A TESTING GROUND BEFORE CONQUERING THE WORLD

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Abstract

In just six years, the French engineer Raymond Camus achieved remarkable success. In 1950, he initiated the production of concrete panels in an abandoned warehouse at the port of Le Havre. By 1956, he signed a contract to export his heavy prefabrication system to the USSR (Union of Soviet Socialist Republics). The article describes Raymond Camus' pioneering projects in Le Havre. Between 1949 and 1953, Camus constructed 10 apartment buildings and 65 detached houses, employing his heavy prefabrication system. In 1949, he leased a disused hangar at the port of Le Havre to establish his workshop for casting concrete panels. The initial panels were crafted manually by unskilled laborers and transported by semi-trailer to the construction site of slot 17, where the first residential building utilizing the Camus system was assembled. Raymond Camus developed a comprehensive process, from producing panels in the workshop and their transportation to the construction site to assembling them into buildings. Within just nine months, Raymond Camus's firm succeeded in assembling the first residential building made from prefabricated panels. The construction efficiency quickly garnered a strong reputation for both Raymond Camus and his technology. Subsequently, he was commissioned to develop slot 21. His growing experience led to the construction of two more apartment blocks for the French railway company (SNCF – *Société Nationale des Chemins de fer Français*) and several single-family homes, further refining his techniques in both panel manufacturing and their technical design.

Keywords

Raymond Camus, Heavy prefabrication system, Concrete prefabricated panels, Housing, Le Havre.

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1. INTRODUCTION

The large-scale destruction in France caused by the bombing raids of the Second World War presented politicians, architects and engineers with a challenge to build a lot, quickly and with a scarce and unskilled labor force. Therefore, the technique of prefabricating residential blocks and assembling buildings from precast units was introduced as a remedy for rebuilding the destroyed housing stock.

Although the industrialization of the construction sector is rooted in the context of reconstruction following the Second World War, it should nevertheless be viewed as a part of a broader context. The technique of prefabrication is part of the debate on Modernity. Modernity was a set of ideas that loomed in Europe from the 1920s onwards [1]. It was based on discussions on accessible housing for the working class in Germany and France and inspired by the productivity of Henry Ford's assembly lines. So, in Germany, architects Bruno Taut and Ernst May made the first social housing developments, while Walter Gropius devised standardized components for building construction. In France, the architects Eugène Beaudouin and Marcel Lods, together with the engineer Vladimir Bodiansky, built apartment blocks in the cité de la Muette in Drancy (1934), where they experimented with a rationalized method of dry assembly of metal frames and concrete panels manufactured in a factory located directly on the building site.

The patents and companies of Raymond Camus, the French engineer originated from Le Havre, are part of this vast field of Modernity. In June 1948, Raymond Camus registered a patent for the construction of prefabricated apartment blocks. Camus explained that the originality of his invention lay in the industrial manufacture of large-scale elements so that "each element constitutes, in principle, an entire face of the wall of a room [2]. Camus writes: «What is a room? Four walls, a ceiling, a floor. Why assemble them from a thousand pieces when modern technology now makes it possible to easily manufacture these elements in a factory, and to transport, handle and assemble them with minimal effort? [3]».

Camus's invention made it possible to assemble whole dwelling rooms from six panels precast in a factory: four panels for the walls, one for the ceiling and one for the floor. Camus laid great stress upon the fact that the larger the components of a building were, the fewer joints were needed on the façade. According to Camus, a large number of joints leads to imperfections during assembly and requires excessive labor to assemble them.

In the submitted patent application, the façade panel is approximately 10 cm thick and consists of a reinforced concrete frame, which serves as a load-bearing structure, an external finishing layer (ceramic tiles, stone chippings), and lightweight concrete that fills the panel. The window frame openings are embedded in the mold when casting the façade panel. However, a thin façade panel does not resolve the issue of thermal insulation, so in the patent, Camus proposes assembling the façade from two rows of panels. The first row comprises façade panels, and the second consists of smooth panels facing the interior. The air gap between the two rows of panels acts as thermal insulation. Interior partition panels consist of a reinforced concrete frame and filler. Both sides of these panels are finished to allow for painting or wallpapering. During the pouring stage, door frames and electrical wiring are embedded in the molds.

The floor slabs between stories also consist of two panels. The lower panel is load-bearing, with longitudinal and transverse stiffeners, and one of its sides is factory-finished to serve as the ceiling for the room below. The upper panel, which is thinner, served as the floor of the apartment and was factory-finished with parquet or ceramic tiles.

2. AUGUST PERRET'S MASTER PLAN FOR THE CITY OF LE HAVRE

In November 1944, le *Ministère de la Reconstruction et de l'Urbanisme* (the Ministry of Reconstruction and Urban Planning), or MRU, was created to oversee reconstruction operations. The ministry's senior officials, such as Director of Construction Adrien Spinetta and Director of Architecture Pierre Dalloz, believed in prefabrication as a remedy for the housing crisis. In order to manage the reconstruction of the devastated cities, the MRU appointed Head Architects for urban reconstruction. Thus, Auguste Perret, a prominent specialist in concrete architecture and a proponent of the prefabrication system, was sent to Le Havre, a city badly damaged by the war. Perret designed a new general layout for the city, based on dividing the city center into rectangular lots (*îlot*) so that each lot accommodates 750 inhabitants per hectare [4].

In 1949, the *François-Ier* reconstruction cooperative, which owned lots 17 and 21, put the architects Henri Loisel, René Vallin and Raymond Audigier in charge of building housing there.

On each of the two lots, Henri Loisel integrated the existing buildings and placed four new houses aligned with the streets, forming a rectangle with a large courtyard accessible through the spaces between the buildings (Figs. 1-2).

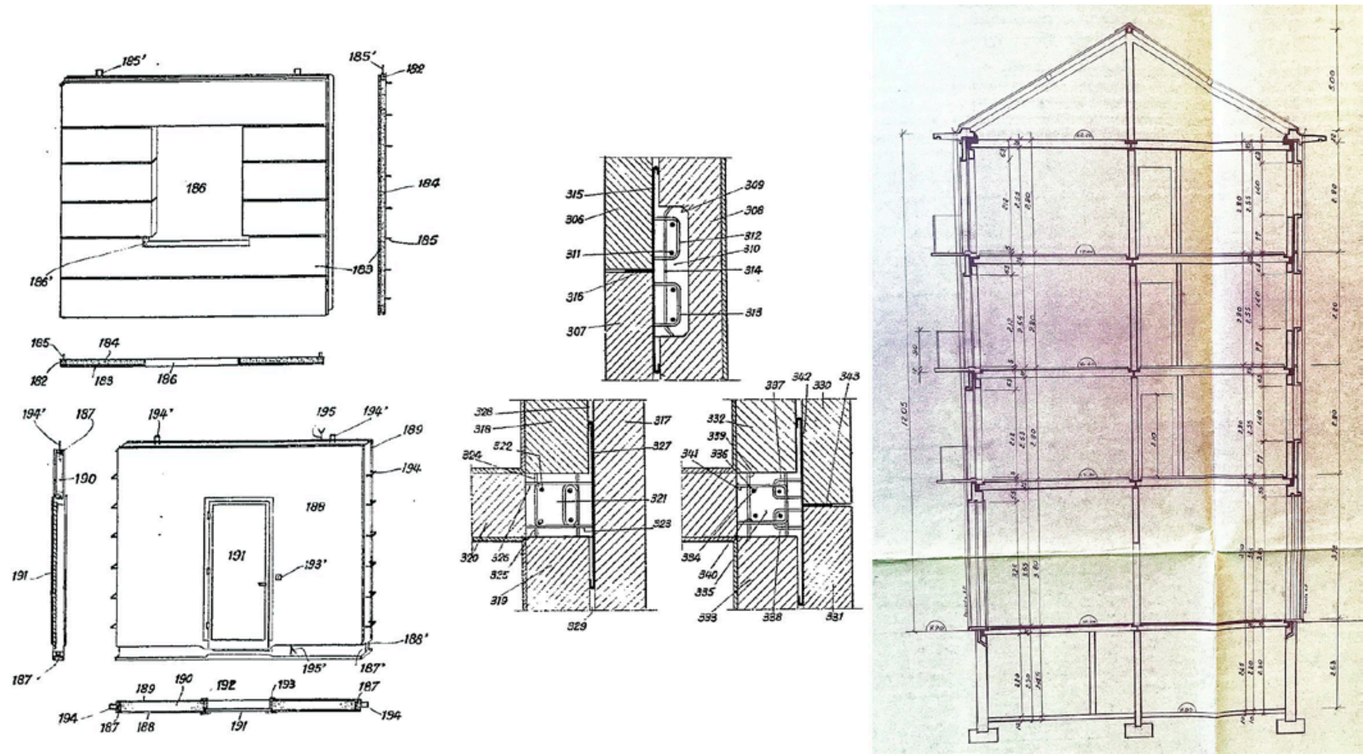

Fig. 1. *Left: drawings from Raymond Camus's first patent: façade and partition panels; horizontal cross-sections of the façade panels. Right: a transverse cross-section of residential Building A, Camus's first project in Le Havre. The drawings show that the façade is assembled from two rows of panels. Source: Patent N 1.009.676, requested on 16 June 1948, delivered on 12 March 1952. AMH, Fonds contemporain, demande de permis de construire, PC 587/49.*

3. PONT 6 AND PONT ROUGE - RAYMOND CAMUS'S FIRST PREFABRICATION FACTORIES

The construction company selected to build the apartment blocks on lots 17 and 21 was Raymond Camus' company; therefore, they were built using Camus's system. To manufacture the panels, in September 1949, Camus rented a disused shed in the port of Le Havre that the American army had previously used as a warehouse. Located in the *rue des Chantiers*, the shed was situated at the edge of Bridge no. 6, one of the structures linking the docks in the port of Le Havre, and so the factory was named "*Usine du Pont 6*" ("*Pont 6* Factory") [5].

By the time the new company, *Raymond Camus & Cie, procédés industriels de construction*, was registered, Camus had hired its first worker who cleared out the warehouse and cast a reinforced concrete base (a "table") onto which molds for the casting of panels would be installed, and next to the table, there were pillars onto which the panels ready for their final curing would be leaned, according to Camus's plans. In the span of three months, the warehouse was transformed into a factory, and around ten workers were hired, of whom only two were professional construction workers. Camus rented out a trailer and a tractor to transport the panels to the construction site, which were sold off by the American army (Fig. 3).

The factory equipment presented an assortment of rough-and-ready contraptions, and most of the tasks were performed manually. The hoisters used to remove the panels from the molds and otherwise handle them were operated manually, the concrete was carried by the workers in wheelbarrows, and the reinforcements were fabricated in the open air, right in the factory yard.

In December 1949, an application was filed for a construction permit for the first building situated on lot 17, the building "A" [6]. The construction began on Wednesday, May 3, 1950. Interviewed by the La Havre newspaper, Raymond Camus said: «I would just ask you to note that yesterday, on Wednesday, you took photos of bare foundation. Today, at 6 pm, half of the basement elements have been installed [7]».

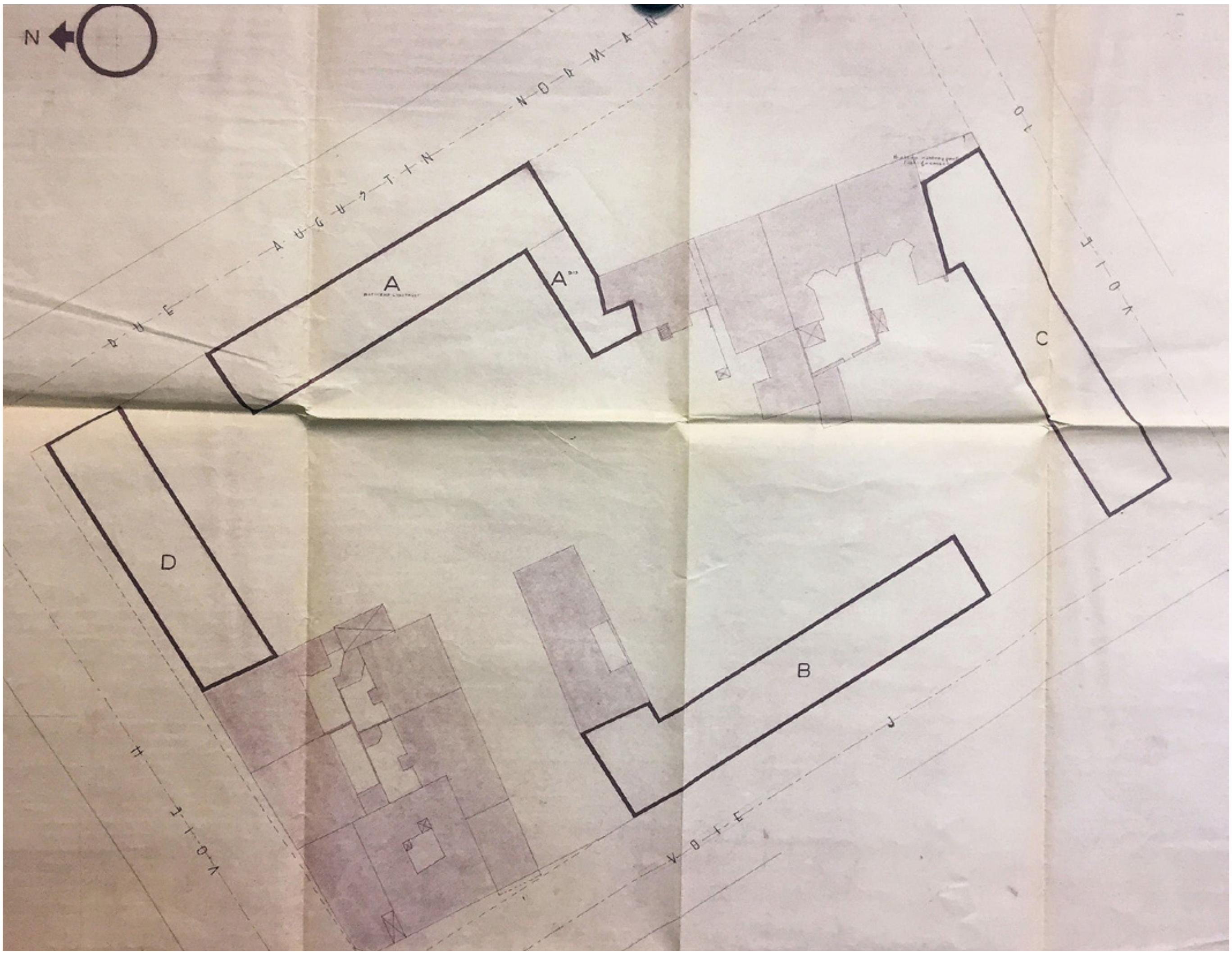

Fig. 2. *Henri Loisel, René Vallin and Raymond Audigier (architects), Raymond Camus (building contractor), Lot (Îlot) 17, Le Havre, general plan, drawing from the construction permit, 1950. Source: AMH, Fonds contemporain, demande de permis de construire, PC 587/49.*

In the architectural design of the first residential building "A", constructed according to the patent, the façade was made of two rows of panels with an air gap between them. However, upon starting the casting process, Camus abandoned this approach. Although two panels weigh less than one thick panel and are easier to maneuver in the factory and on-site, installing two rows of panels is more labor-intensive. Camus simplified the design by replacing the two rows of panels with a single sandwich-type panel that is 30 cm thick.

At the "*Pont 6* Factory", the panels for Building "A" were manufactured in layers in horizontal molds. The first layer placed at the bottom of the mold is the inner wall finishing: plaster for living areas or tiles for wet areas. Then, a layer of concrete was poured, reinforcement and insulating materials were laid, and another layer of concrete was poured. The outer wall finishing, reconstituted stone, was laid last.

The panels were left to dry in their molds for 48 hours. After that, they were removed from the molds and leaned against the pillars to acquire their rigidity (Fig. 4). After 4 to 5 days, the panels were loaded onto trailers and transported to the construction site, where a team of ten workers from Camus's company assembled the panels for Building "A". The 3.3 m x 2.8 m panels weighed four tons each, requiring the use of high-power lifting equipment.

Raymond Camus set up a complete cycle from molding units in the factory to their transportation and subsequent assembly at the construction site. He planned a timeline for the prefabrication of the components to match the progress of the construction; the components were stored and transported to the construction site in a

Fig. 3. *View of the "*Pont 6 *Factory" in 1949, with a trailer transporting prefabricated components to the construction site on lot 17. Source: AMH, fonds Claude Pagenot, photo 86Fi 0021.*

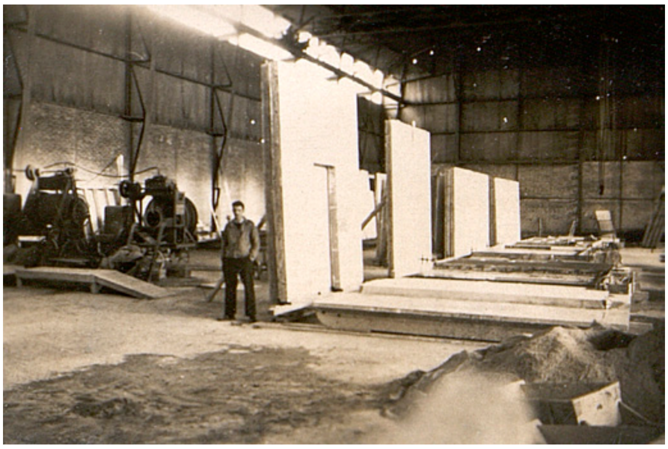

Fig. 4. *"*Pont 6 *Factory", the panels removed from the molds are drying, on the floor the concrete tables on which the panels are cast, around 1950. Source: AMH, fonds Claude Pagenot, photo 86Fi 0016.*

precise order. Each component had a reference number. Around 700 components were needed to assemble Building "A". Within a week, two apartments were assembled.

Building "A" is composed of 12 apartments laid out on three floors and 7 shops on the ground floor. Each apartment comprises three living areas: two 10 /11 m^2 bedrooms and a 15 m^2 living room. The service rooms include a kitchen, a shower room, a toilet and a drying room. The rooms are laid out around a corridor. The living rooms face the street, while the service rooms face the courtyard (Fig. 5). The roof of Building "A" is built using a traditional approach: a timber framework covered with tiles.

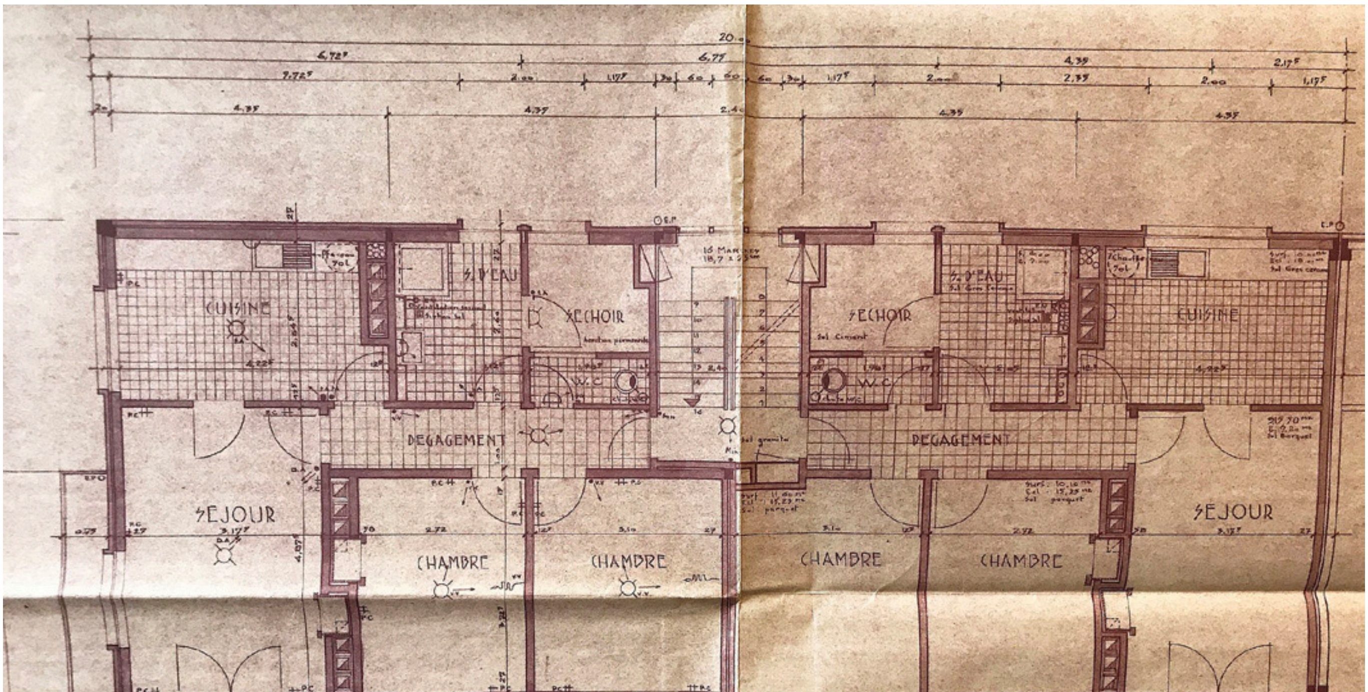

Fig. 5. *Lot 17, Building "A", plan of 3-room flats, drawing from the construction permit, 1949. Source: AMH, Fonds contemporain, demande de permis de construire, PC 1949/587.*

While designing the layout of Building “A”, the architects encountered large-scale prefabricated elements for the first time – the façade panels, the width and the height of a room. They left the joints between the façade panels visible and, to make them appear smaller, they opted for outer wall finishing, a tile pattern that gave the illusion that each large panel was made up of smaller ones. The protruding frames around the windows add diversity to the façade as a whole and create a “dialogue” that brings the joints and the outer finishing of the panels in tune with each other. The balconies placed on the sides and in the middle of the building emphasize the symmetrical composition of the façade. The vertical zigzag design of their metal railings creates smaller-scaled accents on the façade contrasting with the large concrete panels (Fig. 6).

On January 29, 1951, Building “A” was inaugurated in the presence of Pierre Courant, Mayor of Le Havre, André Marini, Director of the CSTB and Robert Le Chevalier, Chairman of the *François-Ier* cooperative [8]. Camus opened the ceremony and handed the keys to the cooperative’s chairman. Abbé Marie made a blessing, and the officials visited the apartments. In his speech, Courant spoke highly of the performance of the Camus system: «[I am] particularly pleased to see that thanks to the system used here, a rapid completion is possible, which ensures that future residents will have good and comfortable houses. On the other hand, this system makes it possible to employ non-specialist construction workers whose only knowledge is their own goodwill [9]». Le Chevalier expressed his satisfaction: «This system was offered by Mr. Camus, who is now able to build houses like this one in three months, according to HBM standards, and who personally supervised the laying of the eight hundred elements that form the building [9]». As *Le Havre Libre*’s correspondent reports, the occupants moved in on the very day of the inauguration: «The officials had barely made the round of the building when a movers’ van was already waiting at the entrance [9]».

The three other buildings constructed on lot 17 are buildings “B”, “C”, and “D”. The buildings are 4 floors high, and their interior arrangement is similar: two or three rooms facing the street and service rooms facing the courtyard. The façade panels of these buildings are decorated differently: they are smooth and have no tile patterns.

With the start of construction of the next lot, no. 21, in 1951, the production capacity of the “*Pont 6* Factory” was well exceeded. To cope with the increase in orders, Camus rented another shed in the port of Le Havre, situated this time next to the *Pont Rouge*. The “*Pont Rouge* Factory” was better equipped with automated hoisters and an overhead crane.

Lot 21 is composed of four rectangular 4-story buildings: “E”, “F”, “G”, and “H”. The houses contain 8 shops and 51 4- to 5-room apartments. The roofs of these four buildings are flat, and the smooth façade is composed of panels with visible joints (Fig. 7).

Fig. 6. *Lot 17, Building “A”, view at the end of the construction works, around December 1950. Source: Michel Camus archives.*

Fig. 7. *Lot 21, on the right buildings “G” and “F”, seen around 1955. Source: Société Raymond Camus et Cie: Architectural documents on some of the buildings built since 1949 using Raymond Camus’ system, promotional brochure, around 1960 (Natalya Solopova archives).*

4. 65 HOUSES IN ROUELLES LA POMMERAIS AND HARFLEUR BEAULIEU

The speed and quality of the construction process carried out by Camus on lots 17 and 21 earned his system a good reputation, and he was awarded a new contract, again working in a team with architect Henri Loisel, to build 65 individual houses on two sites in the communes bordering Le Havre: 34 houses in the *Pommeraie* district of Rouelles and 31 houses in the *Beaulieu* district of Harfleur. The construction permit was issued in 1951, and the houses were completed in 1953 [10]. The houses were built on behalf of the *Comité interprofessionnel du logement* (Interprofessional Housing Committee) [11].

It is important to stress that the patent registered by Camus in 1948 describes a two-story detached house measuring approximately 6 m x 6 m, with each of the four façades made up of four 3 m x 3 m panels. The detached houses in Harfleur and Rouelles, in essence, resemble the one described in the patent: two-story houses, each façade made up of four large panels – two on the ground floor and two on the first floor.

The only difference is that the façade is assembled from 30 cm-thick panels instead of two rows of panels with a gap between them, as it was supposed in the patent. The rectangular floor layout measures 8.5 by 6 meters. There is an entrance hall, a kitchen and a living room on the ground floor, three bedrooms, a toilet and a shower room upstairs. Each house is equipped with a garage and a laundry room. The ceiling height is 2.5 m. The façade has a very purist shape, cube-like with a flat roof. Exposed horizontal and vertical joints between the panels emphasize the minimalist look of the façade. They were assembled at a rate of three houses a week (Fig. 8).

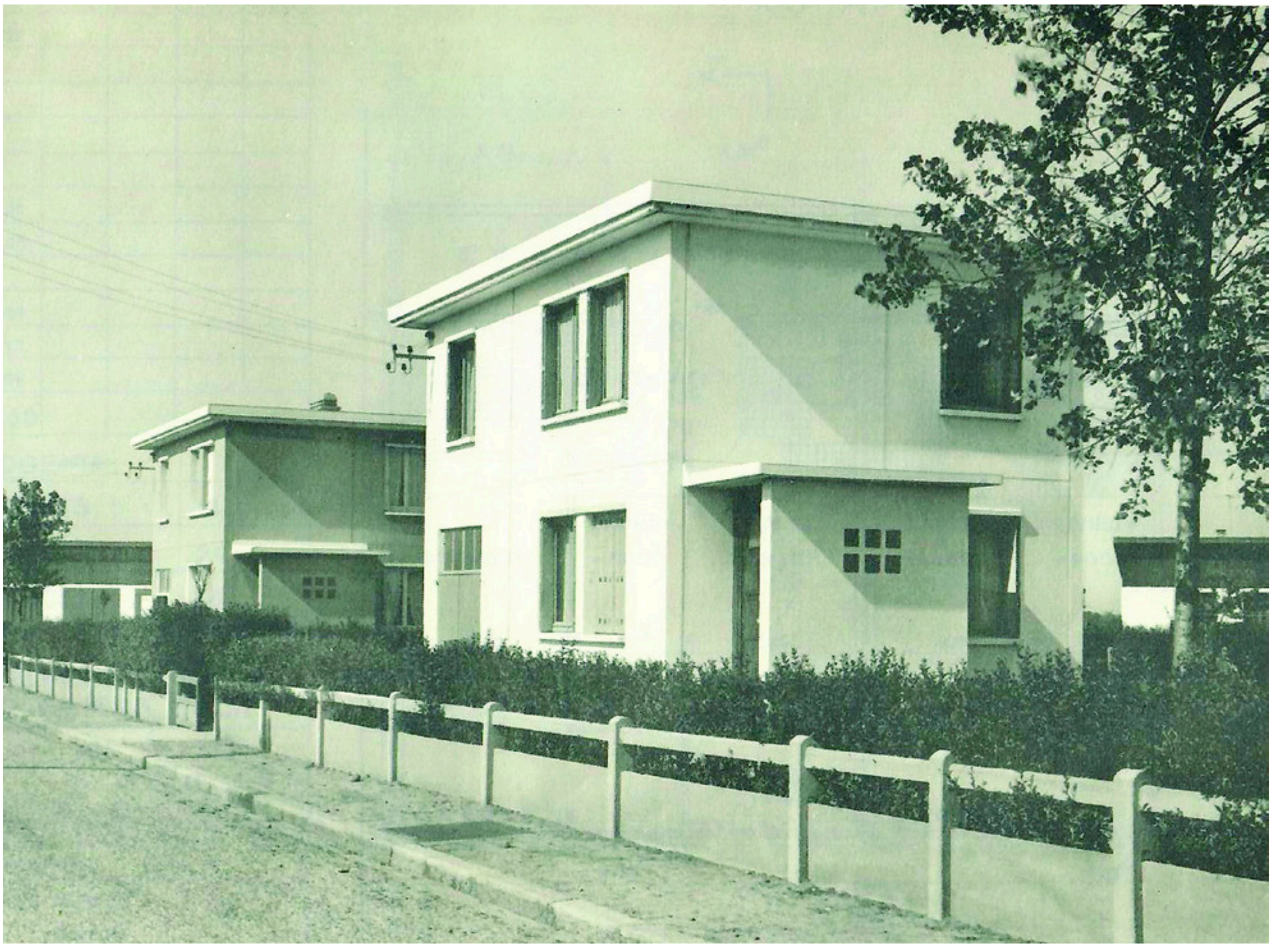

Fig. 8. *Individual house in Harfleur, photo around 1955. Source: Société Raymond Camus et Cie: Architectural documents on some of the buildings built since 1949 using Raymond Camus' system, promotional brochure, about 1960 (Natalya Solopova archives).*

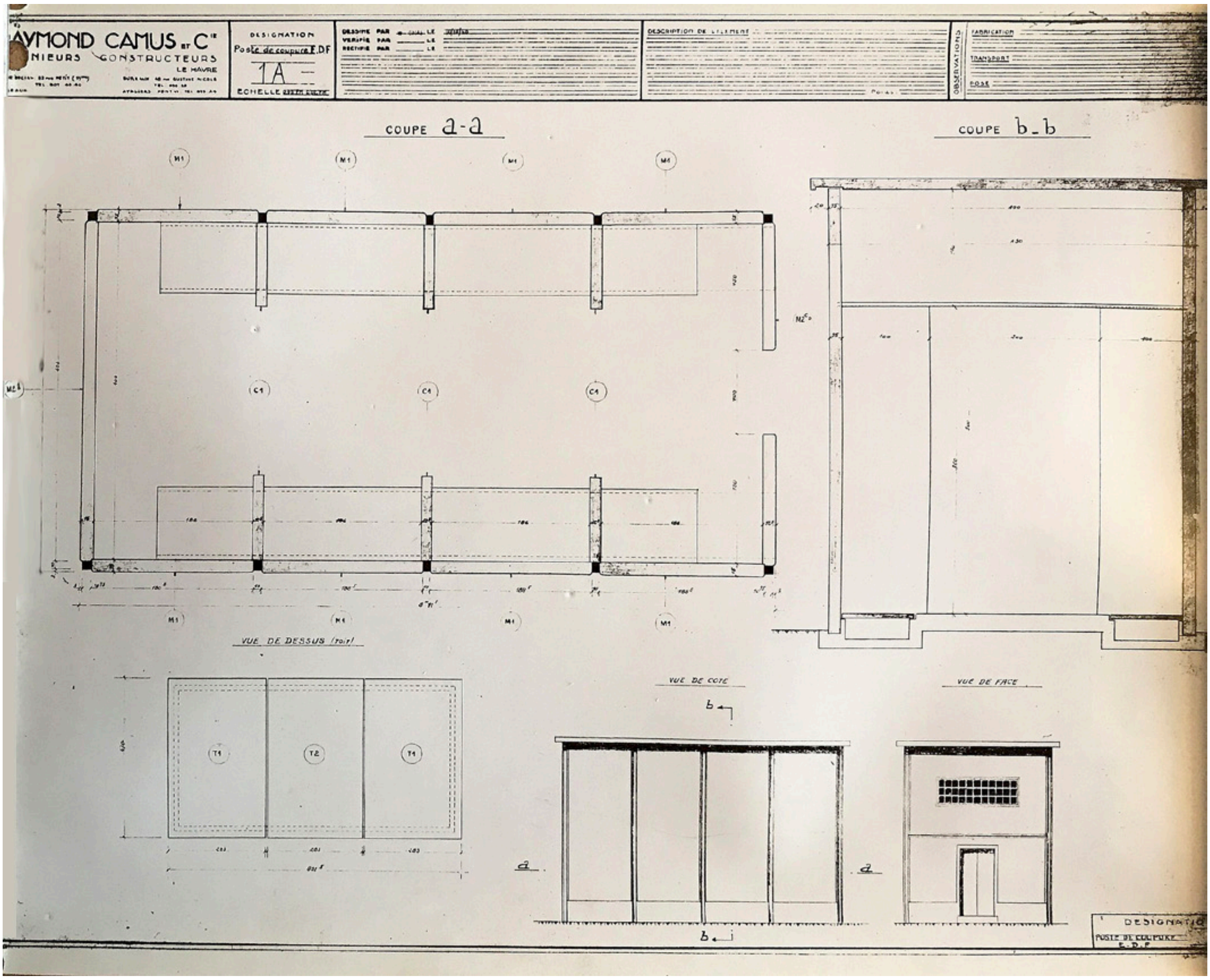

Fig. 9. *Electrical transformer substation. Source: Michel Camus archives.*

5. A SMALL STRUCTURE – A SHED FOR AN ELECTRICAL TRANSFORMER

Raymond Camus was playing a game to see how fast panels could be assembled. In the Pommerais district, a 35 m^2 shed designed to house an electrical transformer was erected in a single day. The shape of the shed was purist and the joints between the panels were apparent. Glass blocks above the entrance door added a certain finesse to the austere look of the façade (Fig. 9).

6. HOUSING FOR *SOCIETE NATIONALE DES CHEMINS DE FER FRANÇAIS* (SNCF)

The third and the last housing project built by Camus in Le Havre together with Henri Loisel, from May 1952 to October 1953, was the construction of 30 apartments for the SNCF (*Société Nationale des Chemins de fer Français* – National Company of the French Railways). They were allocated across two buildings in this way: 10 apartments on *Boulevard d'Harfleur* (since then demolished) and 20 apartments on *Place des Expositions*.

Loisel designed two rectangular five-storey buildings with flat roofs. The plan of each building reproduces the layout of lots 17 and 21: the building is 8.2 m wide, and the staircase serves two apartments per floor. Inside the apartment, the living rooms are separated from the service rooms by the corridor. On the façade, Henri Loisel experimented with contrasting rhythms: the vertical frames of the windows contrasted with the

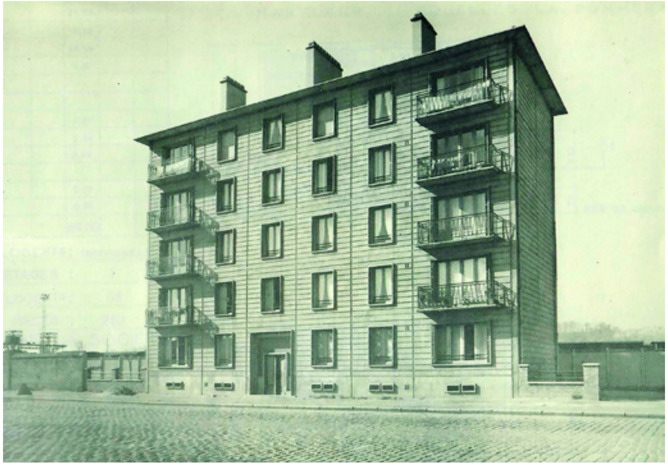

Fig. 10. *Dwelling house built for SNCF on Boulevard d'Harfleur (demolished), Le Havre, 1952-1953, view 1953. Source: Société Raymond Camus et Cie: Architectural documents on some buildings built since 1949 using Raymond Camus' system, promotional brochure, around 1960 (Natalya Solopova archives).*

horizontal pattern of the panels. The zigzag railings on the balconies gave these buildings a certain elegance; from an architectural point of view, the complex is the most successful of all those built by the Loisel-Camus team in Le Havre (Fig. 10).

Raymond Camus's first successful building sites in Le Havre, completed between 1949 and 1953, represent a short but favorable period for the French engineer. In four years, 209 apartments were built according to his system using an unskilled labor force. Camus tested and improved the design of his panels. He developed a complete cycle for the building construction chain – manufacturing of the components at the factory, transportation to the building site, and assembly of the components into residential buildings.

Once construction in Le Havre was completed, the Pont 6 and Pont Rouge factories were closed. From then on, Camus gets down to larger-scale projects. From 1955 onwards, the components factories using the Camus system were built in Montesson as part of the Paris Region program to build 4,000 dwellings and, in Forbach and Lens, to build housing for miners in the North of France and the Lorraine mining basin.

By 1956, at least four factories in France were already producing panels using Camus's technology. However, the design of these panels differed from the one Camus patented in 1948. In 1956, Camus signed an agreement with the USSR (Union of Soviet Socialist Republics) to

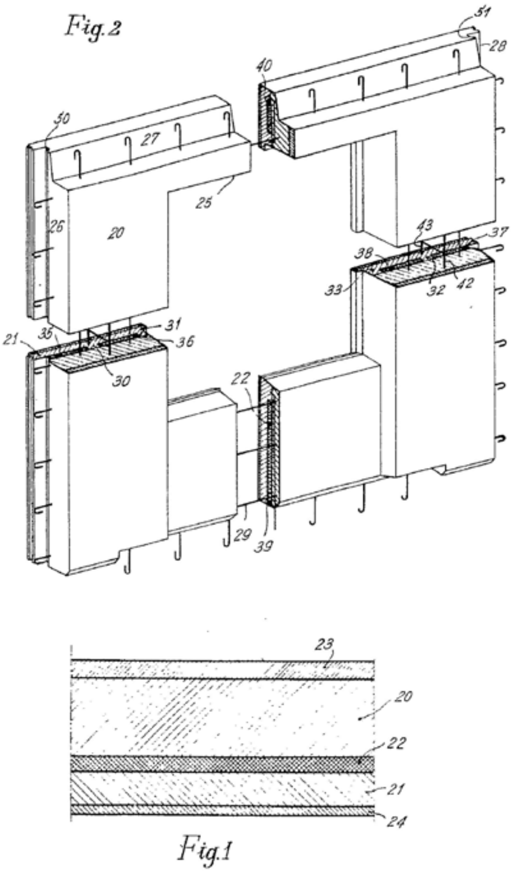

Fig. 11. *The horizontal cross-section and axonometric view depict the Camus panel, which he had been producing in his factories since 1954, but did not patent until 1957. Patent N 1.166.339, requested on 15 February 1957, delivered on 16 June 1956.*

transfer the technology for panel production, as well as the equipment for two factories.

The panels and their casting method needed to be patented urgently. In 1957, Camus filed a patent for a sandwich-type panel. The panel consists of three layers: the outer, thinner layer with a decorative façade finish; the middle layer, which is a polyester thermal insulation; and the third, load-bearing layer, which is thicker. The patent also details the production technology used in the factory. The panels are cast in heated horizontal molds that can be rotated 90 degrees. To speed up drying, the molds are covered with bells where water heated to 140 degrees circulates (Fig. 11).

7. CONCLUSIONS

Raymond Camus quickly transitioned from artisanal panel manufacturing in a port hangar in Le Havre to an industrial, well-equipped production process. Shifting the main construction operations to the factory, where the work process was not dependent on weather conditions and unskilled labor could be utilized, along with efficient production organization, yielded excellent results. The system Camus created, which integrated production, transportation, and installation of the panels, worked effectively. Entire housing blocks were constructed rapidly. The results were so convincing that the USSR adopted Camus's model as the basis for its own industrial housing construction system – room-sized panels produced and assembled by a single enterprise.

In the 1950s and 1960s, Camus's industrial construction system helped address the acute housing shortage. However, after seventy years, residential buildings constructed with Camus's panels no longer meet modern noise and thermal insulation standards. Moreover, the uniform panel housing developments have had a negative impact on both the city's architecture and its urbanism. Nevertheless, Camus's system remains a significant part of social and family history, as several generations have grown up in these homes. Camus's system is also an integral part of the history of Modernity in architecture, one of the most important periods in 20th-century architectural history.

Authors contribution

Conceptualization, N.S.; Investigation, N.S.; Resources, N.S.; Writing, Original Draft Preparation, N.S.; Writing, Review & Editing, N.S.

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PREFABRICATION BETWEEN TRADITION AND INNOVATION: THE FIRST NUCLEUS OF MIRAFIORI SUD IN TURIN

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Abstract

In Italy, the start of prefabrication and building industrialization experiences took place slowly and late compared to other European countries. The debate between the main workers in the construction sector and the representatives of the economic and political world on post-war reconstruction was oriented towards a substantial reconfirmation of traditional construction methods. Added to the productive backwardness of the Italian construction industry was the difficulty of supplying materials and the opposition of much of the academic and professional culture to the experimentation and introduction of industrialized systems. The problems posed by the severe housing deficit of the post-war and following years laboriously paved the way for the first national experiments with prefabrication and building industrialization systems. Due to the need to act urgently to contain construction costs – a relevant problem given the size of the housing problem – the rules of the 1963 Gescal were explicitly addressed to the use of industrialized and prefabricated construction systems. The Gescal years allowed Italy to start large-scale experimentation and application of prefabrication. Among the public interventions of the early 1960s, the construction of the first nucleus of the Mirafiori Sud district in Turin stands out for its peculiar, almost experimental dimension between tradition and innovation.

Keywords

Mirafiori Sud, Turin, Barets system, Borini, Gescal.

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1. A LOOK AT THE FIRST EXPERIENCES OF PREFABRICATION AND BUILDING INDUSTRIALIZATION IN ITALY AFTER THE SECOND WORLD WAR

1.1. THE EARLY EXPERIENCES

To contextualize the specificity of the construction experience of the first nucleus of the Mirafiori Sud district in Turin at the beginning of the 1960s, it is necessary to briefly recall some elements of the historical context and the state of the art of reference. In Italy, as widely documented by the literature in the sector [1], the start of prefabrication and building industrialization experiences took place slowly and late compared to other European countries. For a long time, the debate between the main workers in the building sector and the representatives of the economic and political world on post-war reconstruction was oriented towards a substantial reconfirmation of traditional building methods. The introduction of prefabricated elements on-site or off-site, which characterized most Italian building production from the end of the Second World War to the beginning of the

1960s, could almost still be defined as handcrafted. [2]. The very structure and organization of the construction sector companies were predominantly characterized by a low-skilled workforce, functional to a traditional and low-tech labor market. The difficulty in finding materials then compounded the productive backwardness of the Italian building industry – also in relation to the size of the destroyed building stock to be rebuilt – and the distrust of a large part of the professional and academic culture towards experimentation and the introduction of industrialized systems [3]. An example of this was the 1945 *Consiglio Nazionale per la Ricerca* (CNR) competition promoted by Gustavo Colonnetti. In addition to having the design of houses with prefabricated systems as their object, the competition was also open to semi-prefabricated systems [4]. More significant and relevant was the construction of the experimental QT8 district within the framework of the VIII Triennale di Milano (1947), financed by the Ministry of Public Works [5]. The only theme of the VIII Triennale, the first organized after the war, was dedicated to the house, as it was – as the catalog begins – «The most real, most heartfelt, most dramatic theme, which is the object of anguish, desire, and hopes for millions of Europeans…». Moreover, the number of Italian housing problems reported in the same *Triennale* catalog spoke clearly: the national need for housing spaces in 1947 was 12 million. The event entrusted to the direction of Piero Bottoni (assisted by Franco Albini, Lodovico Belgiojoso, Angelo Bianchetti, Ernesto Nathan Rogers, Ignazio Gardella, Carlo Rusconi Clerici, Gino Pollini) took up again with greater vigor and concreteness the theme of housing and popular economic construction already partly addressed in the 1936 VI Triennale, in which the urban plan of an experimental neighborhood had been presented on the proposal of the engineers Franco-Pagano, and Bottoni-Pagano-Pucci [6]. With the QT8 district in San Siro, the construction of five four-story buildings above ground with identical floor plans was started, built with different construction systems (the *Breda-Fiorenzi* with reusable sheet iron formwork, the *Gaburri*, and the *Ciarlini*) with prefabricated modular horizontal and vertical elements, assembled without scaffolding. The experience continued beyond the horizon of the VIII Triennale. In 1954, at the opening of the X Triennale and using the funding of the Ministry of Public Works, a second batch of seven multi-story buildings was built with the experimentation of the *Eliobeton*, *Forme Fioruzzi*, *Tenax*, and *Vlamark* systems. In the same years, the *Comitato Italiano per la Produttività Edilizia* was founded and led by Giuseppe Ciribini, which, in the context of the ECSC projects (European Coal and Steel Community), implemented the first organic initiatives in the field of building experimentation in Sesto S. Giovanni, Bagnoli near Naples, Milan with the Forlanini Quarter and later, in 1962, in Piombino. In the meantime, AIP (*Associazione Italiana Prefabbricazione per l'edilizia industrializzata*) was formed in 1957. AIP significantly promoted knowledge of prefabrication techniques already widely used abroad, especially in France [7]. Despite the debate triggered by the Triennale and the first experiences of buildings' prefabrication and industrialization in some Italian areas (especially in Milan and Lombardy region), the choices made by the Italian government for the vast program of public construction for the post-war reconstruction, privileged, at least initially, traditional construction systems that allowed for the absorption of part of the mass of unemployed laborer. The choices of the *Piano INA-Casa* (1949-1963) contributed to worsening the technological gap and the backwardness of the Italian construction industry compared to other European countries. At the same time, the strong economic growth of the 1950s and 1960s and the resulting immigration and urbanization phenomena, especially in the northern industrial cities, worsened the housing deficit. Faced with this situation, public building programs, due to construction cost-effectiveness and the urgency of solving housing problems, were re-oriented towards the use of prefabrication systems. Given the delay of the sector, patents, and systems – sometimes already outdated in their countries of origin – were purchased by Italian companies abroad and adopted with small variations [8].

1.2. GESCAL AND THE USE OF PREFABRICATION SYSTEMS

The *Gestione Case Lavoratori* (Gescal) and the rules to incentivize the acquisition of building areas for public and social housing with specific area plans in municipalities with more than 50,000 inhabitants of Law No. 167 set on April 18, 1962, initiated a change in scale and methods in terms of the extension and scope of public intervention. The Gescal established by Law No. 60, February 14, 1963 [9], constituted in a chronological sense the continuation of the *Piano Fanfani* (also known as *Piano INA-Casa*); however, its primary objective was not anymore the employment of workers, but the contrast to the severe Italian housing deficit [10]. Due to the need to act urgently by containing construction costs – which were considerable given the size of the housing problem – the Gescal regulations were explicitly directed towards the use of industrialized and prefabricated building systems. In the second seven-year-period of the *Piano INA-Casa*, the technical standards issued by the *Istituto Nazionale delle Assicurazioni* (INA) had already been drafted and modulated to achieve better dimensional coordination of the building elements in order to rationalize and improve the economy of the entire building process [11]. However, it was only with the Gescal that the first organic set of technical standards for public building in Italy was drawn up. This definitively broke with the traditional "artisan" construction practice that had guided the country's reconstruction until then. The 1964 technical standards for the execution of constructions, with special reference to design [12], while taking up many of the indications contained in the *Piano INA-Casa* dossiers, introduced the use of prefabricated building components and industrialized techniques with detailed rules for the dimensional and modular coordination of building elements. The Gescal years were the occasion in Italy for the first large-scale comparison with prefabrication techniques. The initial importation of patents and systems from other European countries, in particular from France, was followed by local modifications and experiments on the same systems (such as the versions of the Tracoba system by SIMET *Società Immobiliare Edile Torino* [13] or the version of the French Barets System used by the Borini company of Turin) [14]. These mainly were minor variations of the original systems; only in the following decade, in the 1970s, were diversified and more mature, highly industrialized technical solutions adopted, with results still much debated today [15].

2. THE EPISODE OF MIRAFIORI SUD DISTRICT: THE FIRST LARGE-SCALE EXPERIMENT OF PREFABRICATED HOUSING IN TURIN

The experience of building the first nucleus of the Mirafiori Sud district in Turin fits into the scenario briefly outlined above. The neighborhood located in the southern outskirts of the city, near the large FIAT Mirafiori factory complex (now Stellantis), represents an interesting example of public housing in the 1960s, both for the novelty of the almost experimental nature of the construction site, with the use for the first time in Turin of a heavy prefabrication construction system, and the large size of the public building project. The construction of the first nucleus of the neighborhood was still part of the interventions of the second seven-year period of the *Piano INA-Casa*. The construction was carried out between 1962 and 1967 on behalf of Gescal following a tender competition announced by the *Istituto Autonomo Case Popolari* (IACP) in Turin in 1962 [16]. It involved building 798 dwellings on a gross area of 550,000 m^2. The neighborhood in its definitive configuration – a total of 2,450 homes were planned for a construction volume of 1 million cubic meters – should have represented, in the intentions of the city administration, the new centrality of the urban expansion towards the south of Turin [17]. According to the tender notice, the competing companies had to provide a volumetric plan for the entire residential complex, including the subsequent construction of two more lots of approximately 800 homes plus the related services, in addition to the executive project of the first lot.

The tender's requirements left the possibility for competing companies to adopt or not prefabricated construction systems to realize the project. The company *Franco Borini, Figli & C.* won the competition with a project involving prefabrication techniques based on a system derived from the French Barets system. Jean Barets himself had previously illustrated its patent, of which Borini was the concessionaire, at the *Società degli Ingegneri e degli Architetti* in Turin [18]. The company had already used this same system to construct some school buildings [19]. The system was based on the prefabri-

Fig. 1. *Planovolumetric model of the Mirafiori Sud complex. Source: Gescal, IACP Turin, 1966.*

cation on-site of all vertical and horizontal construction elements: load-bearing wall panels, internal longitudinal bracing elements, façade panels, internal partitions, floors, stair ramps and landings, and other finishing elements. The thickness of the façade panels was 25 cm, with a height equal to the inter-story and a length varying from 3 m to 7 m. The water and electrical network plants were also integrated into the panels.

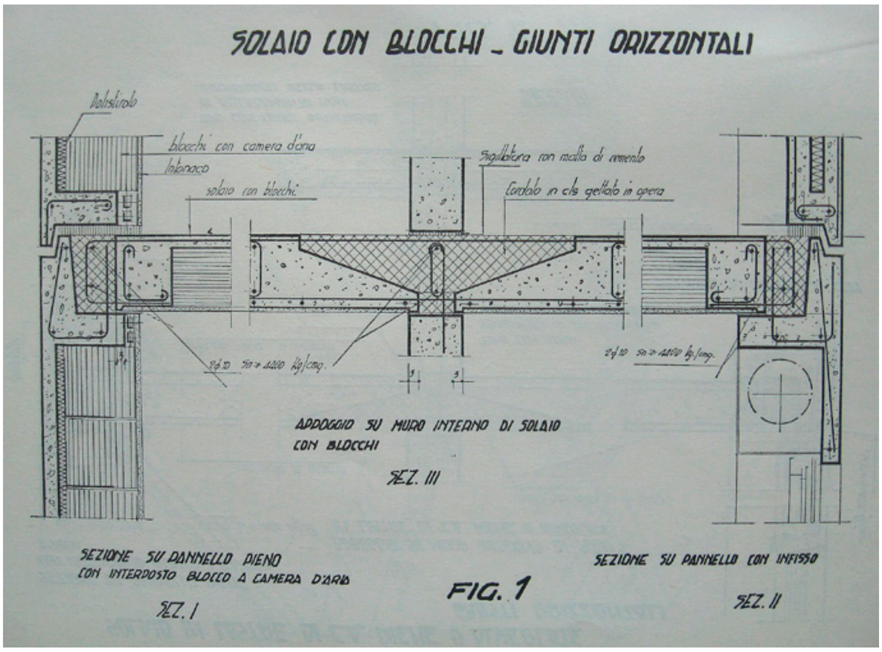

Fig. 2. *Barets system detail of slab section with horizontal joint blocks. Source: ATC archive, Turin, 1963-66.*

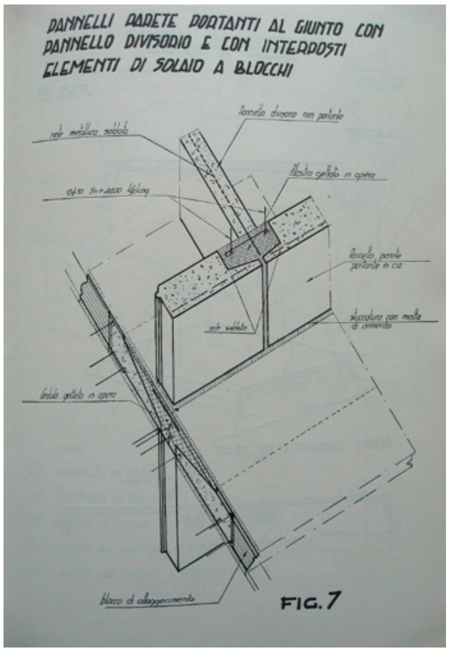

Fig. 3. *Barets system detail of the junction between the load-bearing wall panel, the dividing panel, and the floor elements. Source: ATC archive, Turin, 1963-66.*

2.1. ARCHITECTURAL AND FORMAL ASPECTS

The general and executive details of the construction of the lot were described in detail by Gescal in a small volume in 1966 [20]. A characterizing element of the architectural design, as stated by Gescal, was « that of grafting onto the structural normalization the typical elements of residential construction that were in such a relationship with each other that they could be reciprocally replaced without any prejudice, thus capable of creating a pleasant compositional variety of the façades». In essence, despite its structural rigidity, the system allowed for a certain compositional articulation by combining a few elements. This characteristic was essential for the containment of construction costs and duration. A fundamental characteristic of the system was the perfect overlap between structures and vertical supply and discharge ducts. The construction was carried out in close collaboration with the architects in charge, Mario Roggero, Ugo Mesturino, and Emilio Giay, the technicians of the prefabrication system and the company. For the construction of the 798 dwellings envisaged by the tender, 15 buildings were built, divided into three types of the same height and depth, characterized by different lengths (66.27 m, 95.29 m, 167.63 m), with seven floors above ground, plus a ground floor where the entrance halls, garages and cellars are located. The stairs were placed to serve two dwellings per floor. From an urban planning point of view, the buildings were arranged on the lot according to a comb-like pattern, with a central road axis from which secondary streets branched off at right angles. A distinctive and peculiar element was the organization of the construction site into three areas, with a single concrete mixing plant and the use of different formworks. The fifteen buildings were aligned on six parallel lines, so each part of the construction site served two lines, «since the total construction area is huge, it was more rational and convenient to place the molds near the buildings to be constructed rather than create a single prefabrication area with the need to move the large mass of prefabricated elements on-site». The concrete mixing plant was placed in a central position with respect to the three parts of the construction site. The production reported by Gescal was 28 cubic meters/hour «via double-traction dumpers with a pivoting tipper body, hydraulically controlled, with a capacity of half a cubic meter of concrete».

This layout arrangement allowed the concrete to be discharged directly into the molds without using conveyor belts, reducing costs, and rationalizing construction site operations. As regards the assembly phases, the foundations were built in the traditional manner. The first vertical panels were inserted into them, and the subsequent prefabricated vertical elements were attached. The connection was made using reinforced connecting pil-

Fig. 4. *View of the packaging and storage phases on the building site. Source: Gescal, IACP Turin, 1966.*

Fig. 5. *View of the building site during the assembly phases of the load-bearing panels. Source: Gescal, IACP Turin, 1966.*

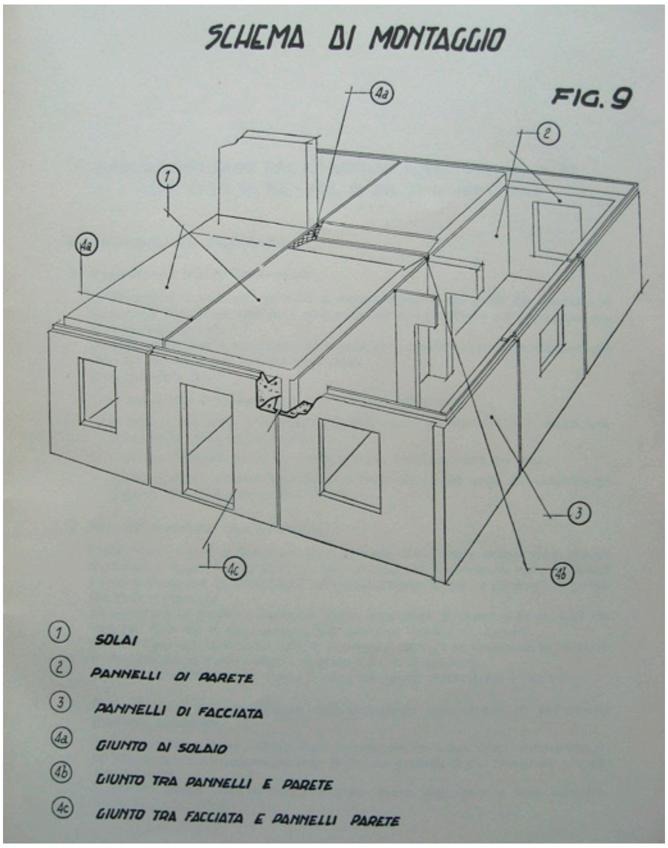

Fig. 6. *Barets system, general assembly scheme of the elements. Source: Gescal, IACP Turin, 1966.*

lars cast in situ inside special shapes in the panels themselves. A hot-applied gasket then protected the bottom of the joint between the panels. This was followed by the in situ plastering phase, which allowed the vertical connection to be closed. The partially prefabricated horizontal floors were laid on this structure, and the electrical plant, water, and sanitary system were installed. As for the finishes, a certain amount of care was given not only to the internal distribution and hygiene aspects of the apartments and common spaces but also to the formal ones, in the chromatic and material combinations: red stoneware for the stairs and landings, Botticino marble for the entrance halls. These elements still characterize the buildings almost sixty years after their construction. As for the external façades of the buildings, the use of prefabricated techniques influenced the choice of materials; instead of brick, traditionally typical of the Piemonte region, cement *granigliato* was preferred. The entrances were covered by reinforced concrete shelters, carefully designed and completed by small, boxed iron doors. The Mirafiori Sud complex was completed with the subsequent construction of two other nuclei, built with prefabricated construction systems between the end of 1966 and 1971 [21]. Alongside Borini, the second lot was awarded to *Compagnia Imprese di Prefabbricazione* (Co.Im.Pre), which used the *Costamagna-Skarne* system, and the third lot to *Società Immobiliare Edile Torino* (SIMET), and *Costruzioni Generali Ing. Recchi* (from now on Recchi), which adopted the industrialized Tracoba system. The system adopted by Co.Im.Pre was based on on-site prefabrication similar to the Barets system, which was improved from the point of view of finishing operations and some peculiarities of the assembly system. The Tracoba system adopted by Recchi marked the end of the experimental phase of these systems, perfecting the industrialization, seriality, and automation of the various construction site phases and operations.

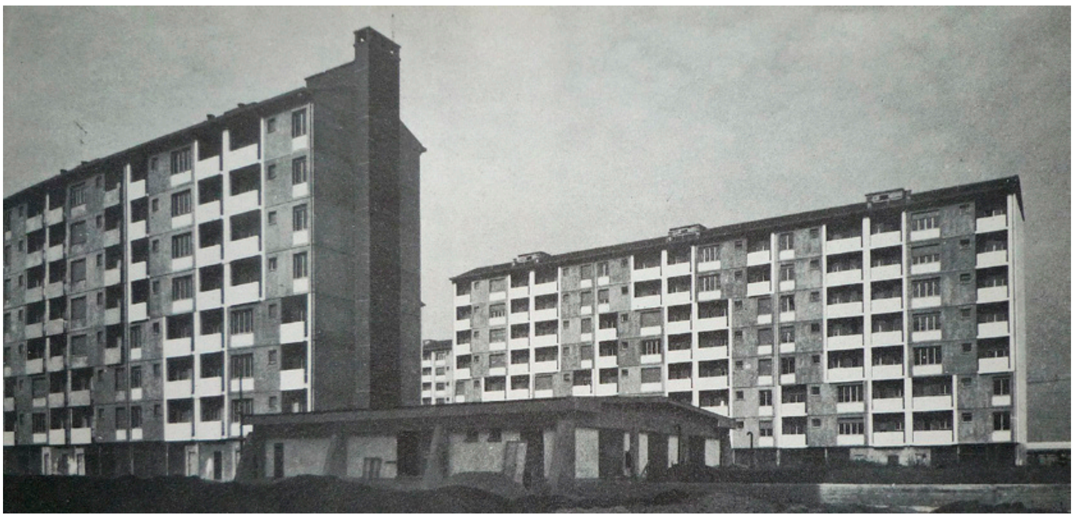

Fig. 7. *North-east view, thermal power station and buildings under completion. Source: Gescal, IACP Turin, 1966.*

3. METHODOLOGICAL AND FINAL CONSIDERATIONS

Some considerations led to the choice of identifying, through archival reading (ATC - *Agenzia Territoriale per la Casa* of Turin and Gescal IACP - *Istituto Autonomo Case Popolari*, archive of Turin, ASCT - *Archivio Storico della Città di Torino*, historical archive of the city of Turin), documentary materials and a single episode – albeit peculiar in size and aspects of the construction site – useful elements to enrich a general framework of the specificities of the Italian experience in the field of industrialization and building prefabrication in the post-war period.

The first one concerns the large size of this public building project and the change in the direction of policies and methods of public intervention in affordable housing in Turin, in addition to the impact it had on the urban layout and development of the city [22]. The social pressure caused by the massive immigration of laborers needed by the rapidly expanding manufacturing industry made it urgent to launch a social housing program that could provide a concrete response to the severe housing deficit, with sustainable costs for the public administration, already grappling with the still unresolved problems of reconstruction. Similar issues were also present in other large productive areas of the country, especially in the north. In nearby Milan, in particular, the IACPM (*Istituto Autonomo Case Popolari di Milano*) to meet the objectives of building social housing in a short time, stipulated, in 1962, an agreement with some construction companies (Mbm Meregaglia, Sicop, Fintech, Sepi, Romagnoli), concessionaires of French patents of heavy prefabrication, for the construction of new districts of low-cost and social housing [23]. In 1963, the Municipality of Milan, in implementation of Law No. 167 April 18, 1962, launched the *Piano per l'Edilizia Economica e Popolare* (PEEP), which defined the location of sixteen public building projects in peripheral areas of the city, including the Sant'Ambrogio district, the Gallaratese, the Gratosoglio, the Missaglia, the Olmi district and the Quarto Cagnino district [24]. Despite the similarity in the processes, the urban, historical, and socioeconomic characteristics of Turin were profoundly different from those of Milan. The orthogonal grid of axes that had guided and characterized the city's development from the Baroque period onwards was dismantled entirely in the 1950-1970 twenty-year period, by the location choices of the public building plans, with the creation of self-sufficient peripheral neighborhoods. The process had started with the first projects of *Piano INA-Casa*, in particular the Falchera neighborhood, on the northern outskirts of the city and the Vallette to the west, but it was the Gescal plans and buildings that caused a total break with the past in the settlement network and the typological and formal characteristics of the city's buildings. The doubling of the spatial and demographic dimensions of the city during the economic boom period occurred mainly through the new peripheral neighborhoods and in the subsequent welding between these areas and the historical buildings, in a condition of substantial deregulation caused by the lengthy approval times of the post-war master plan (which was approved only in 1959) and by the speculation dynamics [25]. It should be noted that Turin's building heritage had been largely destroyed (about 40% of the existing one) by the bombings of the Second World War. More than 50,000 people and families had been left homeless, and to these were added the evacuees and refugees, mainly from Istria, who had taken refuge in the city. The rapid economic recovery of the early 1950s, favored by the Marshall Plan from which FIAT benefited, significantly aggravated the problem of Turin's housing deficit due to the massive wave of immigration of workers arriving from all over Italy [26]. It is worth remembering that in 1971, at the end of the twenty-year economic boom, approximately 75% of those employed in the metalworking sector in Italy lived in Turin. The choice made at the central government level with the *Piano INA-Casa* to use traditional construction systems to start the great program of building reconstruction in Italy quickly became inadequate in the face of the worsening housing problem, especially in a city like Turin. The Mirafiori Sud residential complex, located next to the large FIAT factory (which doubled in size between 1961 and 1963, becoming one of the largest in Europe), arose in just a few years on mainly agricultural land, 14 km from the city center, also symbolically marking the break with the historic city and the spatial and economic transformation of the city.

Fig. 8. *The complex, east side, view from the surrounding agricultural fields. Source: Gescal, IACP Turin, 1966.*

The change in FIAT's production and dimensional scale strongly influenced the city's development, to which public urban planning and planning choices had to conform [27]. Gescal's interventions were, therefore, decisive in guiding the completion of public social housing programs using industrialized systems. The ambiguity and distrust of the professional and academic world towards the prefabrication and industrialization of buildings in the post-war period was overcome during the 1960s by a radical transformation of urban and technical concepts of social housing and by the methods and dimensions of public intervention, the results of which, in the various Italian realities, are still a matter of discussion today.

A second consideration concerns the technological aspect. Mirafiori Sud, the first nucleus of the neighborhood, factually testifies to the passage, the difficulties, and the uncertainties of design, techniques, and management between a traditional way of constructing based on a large use of workforce to an industrial and technological one with reduced use of personnel. Until then, prefabrication techniques had been used in Turin and Piedmont only for single buildings. The most innovative element was not only the design method, tied to the modularity and dimensional coordination of the panels and the rigidity imposed by the system but the organization of the construction site similar to that of industrial assembly lines and profoundly different from the traditional one. Traditional construction sites from which the workers and designers came. The Mirafiori Sud construction site clearly shows the difficulty of moving from the traditional way of designing and building to the industrialized one. Enlightening in this regard are the words pronounced by J. Barets in his aforementioned speech at the *Società degli Ingegneri e degli Architetti* in Turin: «prefabrication (of the Barets system) consists of manufacturing on site all the elements that are part of the building under construction. For this reason, we have created an organization that requires relatively limited resources from each individual company, but that allows companies to have access to common technical services, which, by the simple fact that they intervene in a group, are competent, qualified, and effective to the extent of the importance of the group itself and in the function of the experience acquired, which is constantly enriched. Our organization is not a company; it is an organization that plans and gives the company the indispensable coordination so that, in the spirit of prefabrication, the construction is carried out in perfect and total cohesion». In this specific case, as well documented by the 1966 Gescal report on the construction of the lot, the general project had to respond to the requirements of simplicity and linearity to reduce the number of formworks used to create the prefabricated elements and, therefore, contain costs. It was up to the architectural project to try to obtain a compositional and plastic variety of the fronts within a system that was necessarily rigid and constrained by modular coordination needs. The difficulty of managing the compositional and architectural work, the distribution variants, the tight construction times, the intermittent financing, and the lack of experience in organizing the industrialized process is documented not only by the subsequent testimonies of the professionals commissioned by the Borini firm, Mario Roggero, Ugo Mesturino and Emilio Giay but can also be glimpsed between the lines of the Gescal publications and make evident the lack of experience and adequate knowledge of these systems among the players in the Italian building sector of those years. Despite this, almost sixty years after its construction, the result of this experience – unlike the subsequent construction episodes that completed the construction of the neighborhood (in particular, the eight Towers of Via Artom built between 1965-66 with the Tracoba system by Recchi), highly controversial for their poor construction and urban quality and which contributed to worsening the phenomena of marginalization and social degradation of Mirafiori Sud – has been a product of overall good construction quality. The choice of materials, the attention to design and composition, despite the obvious constraints imposed by the system, the origin of the workers and of the company itself from the good rules of the art of traditional construction, have created a complex that is appreciable from the formal and living point of view, without severe phenomena of deterioration and degradation of the materials and buildings. The main limitations of the intervention are to be found not so much in the construction aspects but rather in the rigid planimetric system and the urban and logistical choices underlying the neighborhood's location. Mirafiori Sud is still spatially distant from the city center, and the provision of social and commercial services has been delayed and implemented with difficulty. Furthermore, the proximity to the large automobile plant, which has been progressively decommissioned for some time, poses further problems for the urban redevelopment of the area and its environmental regeneration. Mirafiori Sud is currently the city district with the greatest problems of thermo-hygrometric comfort due to heat islands caused by the largely asphalted and waterproofed ground surfaces. From a construction point of view, the main problem today is the need to intervene to improve the energy performance of buildings built in years when the abundant availability of fossil fuels made the energy problem negligible. How to intervene to safeguard the peculiar characteristics of the complex and its undoubted value as a historical and technical testimony while improving its performance and comfort is a very current issue.

Fig. 9. *View of the buildings of the I core of Mirafiori Sud, Turin. Source: author's photo, 2024.*

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NURSERY SCHOOL BUILDINGS IN PREFABRICATION TECHNIQUES FROM THE EARLY 60S TO THE 80S IN ITALY. HISTORICAL, TECHNOLOGICAL, AND PEDAGOGICAL OVERVIEW

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Abstract

Prefabricated technologies have historically been associated with large-scale construction projects, particularly gaining momentum after the Second World War due to the demand for rapid and cost-effective building solutions. From the 1960s to the early 1980s, several innovative prefabricated systems were developed in Italy specifically for the construction of nursery schools. While prefabricated systems in compulsory school buildings have been extensively researched, innovative designs for nursery schools have largely been overlooked. The introduction of new cellular prefabricated systems has enabled a novel design approach, resulting in innovative school configurations that have significant implications for pedagogical practices. This paper provides a critical overview of the most widely used systems, transitioning from those based on the Camus model to those specifically designed to meet the needs of nursery school buildings. The novelty of this approach lies in the correlation between the new prefabrication systems and their associated pedagogical implications. It demonstrates how effective prefabricated technologies can address the educational requirements of increasingly flexible learning environments, accommodate potential spatial variations over time, and achieve a high level of environmental integration to optimize the efficient use of both indoor and outdoor spaces.

Keywords

Prefabrication, Nursery school building, Prefabricated system, Pedagogical needs.

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1. INTRODUCTION: PREFABRICATED BUILDINGS IN ITALY

Industrialized construction is a widely accepted concept, but prefabrication is often mistakenly associated with it. Prefabrication is a combination of traditional and industrial methods used in construction, reducing costs by requiring less time, labor, and materials. It has been used in various forms, such as drywall systems, wall panels, floor panels, roof trusses, room-sized components, and entire buildings. Despite its benefits, prefabrication does not meet the criteria for industrialization. Prefabrication can be defined as the assembly of buildings or their components at a location other than the building sites [1]. As Olivieri observed in his book [2], prefabrication is a form of pre-existing industrialization. It can be traced back through the centuries.

Prefabrication, a technique rooted in ancient industrialization, offers numerous benefits, including time and cost savings, predictability due to controlled environments, increased safety due to workers operating in a protected environment, and a significant reduction in the influence of the construction site on surrounding activities. It eliminates external factors like weather and site accessibility, ensuring a safe and efficient construction process [3].

Economic considerations related to reducing costs, relocating some manufacturing activities, and reducing labor costs on site, have driven the Italian building industry toward prefabrication since the economic boom, particularly in response to the urgent need to recover the public residential building heritage [4]. Historical studies on housing reconstruction in the 1960s revealed that a higher proportion of a country's annual housing production provided by the public sector correlates with a more significant role of industrialized prefabrication methods within the broader construction industry [5]. Regrettably, there was a widespread belief that prefabrication was associated with *an interim* and unqualified product. Since then, prejudices have persisted and multiplied, evoking associations with lower-quality and less durable goods. Many designers perceived prefabrication as a tactic that limited and constrained their freedom of expression and creativity. On the other hand, adopting new construction techniques is considered a reliable strategy to help alleviate the housing crisis [6].

Prefabrication, designed to reduce costs and delays, becomes unprofitable without large orders with a multi-year production horizon. Standardized systems can reduce construction expenses. Challenges arose in Italy due to the transformation of construction firms, affecting scale and time management [7]. Prefabrication faces psychological limitations due to traditionalist Italian building sector attitudes, leading to misconceptions about its true meaning and the need for significant scale and time management changes in construction firms [8]. Prefabrication was frequently mistaken for uniformity or disassembly [9] and believed to be detachable. Industrialized construction has been criticized for poor architectural quality and urban agglomeration all over Europe. Prefabricated systems were used to provide affordable, ready-to-use homes, but their effectiveness remains debated [10].

While the scientific literature has predominantly focused on the compositional, functional, and technological aspects of compulsory schooling buildings [11] constructed with prefabricated technologies, a significant gap in research regarding nursery schools is evident. The latter has not received the same level of attention as other prefabricated structures over the years [12]. Nursery schools have not undergone frequent seismic or energy adaptation and improvement interventions like different types of schools, leading to several persistent global deficiencies that continue to exist today.

The study critically examines the origin and development of prefabricated construction in nursery school buildings, highlighting limitations and constraints and providing a historical and pedagogical assessment of its benefits.

Toward this aim, the work is developed into the following parts:

1. A historical overview of the development of nursery school buildings using prefabricated systems;
2. A critical assessment of the pedagogical advancements related to the prefabricated systems in assembling nursery school buildings;
3. A technological appraisal of different patented prefabricated systems specifically designed for single-story schools.

1.1. THE DEVELOPMENT OF PREFABRICATED NURSERY SCHOOL BUILDINGS IN ITALY

In the 1950s and 60s, the post-World War II economic boom led to the rise of prefabrication techniques for shorter construction times. Initially used for industrial roofs, these methods faced limitations due to Italy's reliance on traditional methods and social and environmental barriers. Although building schools has always been a choice for municipalities and provinces, the government's decision to support prefabricated school buildings has led to the introduction of new regulations meant to stimulate research in this field.

Enzo Frateili [13] declared that «the school sector, alongside residential construction, has seen the most concentrated efforts to implement new construction processes in our country in recent years» ("Il settore della scuola è quello dove, parallelamente con l'edilizia residenziale, più si è concentrato in questi ultimi anni, nel nostro Paese, il tentativo di attuare i nuovi processi costruttivi").

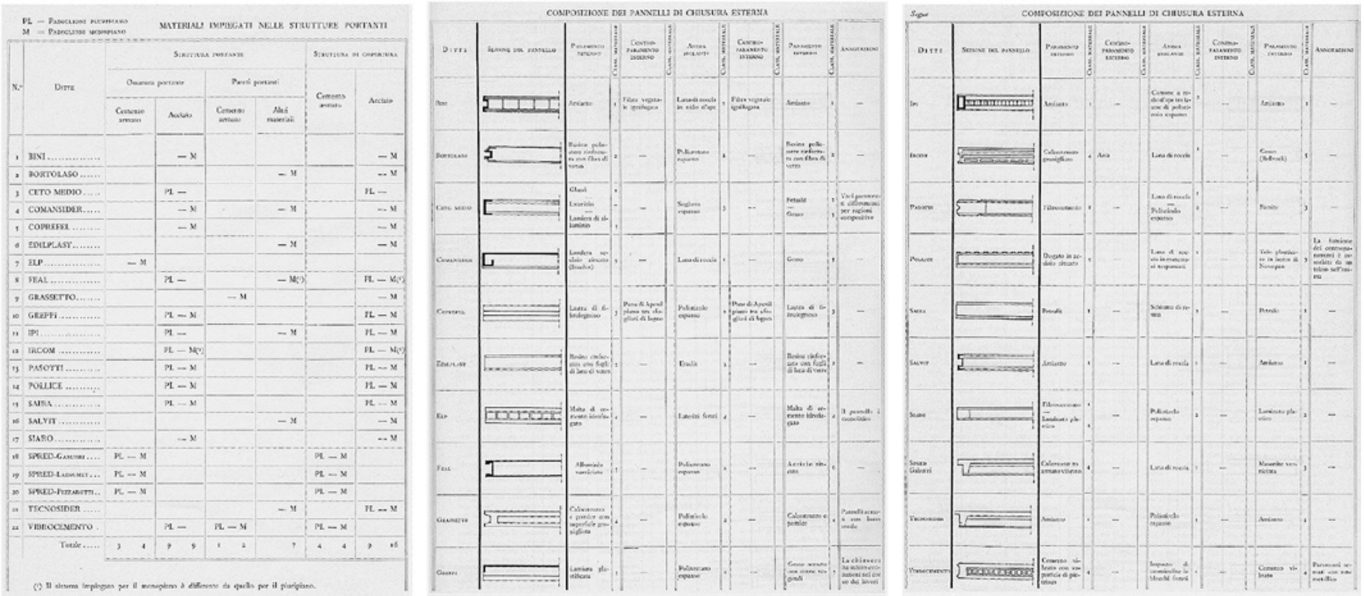
The following decades were marked by an increasing demand for educational facilities brought on by population growth and the implementation of mandatory education. Quantitative concerns, including low enrollment, took priority over building quality issues, exacerbating pre-existing flaws and undermining the entire educational system. Attempts by the government to set up new schools with both conventional and innovative curricula have never been able to solve the shortages effectively.

To meet the needs of modern educational institutions, including those catering to the youngest students, Italian Law No. 444 was enacted on March 18, 1968, to establish nursery schools. Before that, private institutions provided service-related funding. However, with the advancement of women's role in Italian society, mass education became a pressing need. As more women enter the workforce, nursery schools are expected to support families and prepare children for elementary school. While the increase in school attendance, even among 3-6-year-olds, led to a notable rise in the demand for new buildings, advancements in technology also motivated builders to develop new types of buildings.

The Italian school construction industry experienced a slowdown during the late 1970s energy crisis, leading to changes in building design. Many schools abandoned natural light and ventilation for artificial lighting and mechanical ventilation, resulting in poorly designed classrooms and overlooked indoor comfort. In order to address this issue, prefabrication techniques were used to create compact buildings with load-bearing elements. The design of classroom layouts and functional areas in educational buildings was facilitated by applying functional flexibility, leading to the creation of shared spaces for multiple classes.

The Italian Law of 1962 [14] allocated 1400 million *lire* for prefabricated school buildings, marking the beginning of this sector and further disposition focused on classrooms and optimal functional and construction needs. Law 5 August 1975 [15] promoted national studies and experimentation in school prefabricated building types, promoting industrialized construction systems

Fig. 1. *Two of the well-renewed Italian manuals for school building construction, front pages.*



a) b) c)

Fig. 2. *Materials chart (a) and external closing panels (b) (c) as described by the selected prefabrication companies after the 1962 competition. Source: Prefabrication in school buildings, Quaderni del centro studi per l'edilizia scolastica, n. 4-5, by the Italian Ministry of Education (1962).*

and flexibility, and guaranteed the full psycho-physical well-being of the occupants.

In accordance with the 1962 law, a national call for proposals was made to choose prefabrication companies. The agreement grants government control over contracts and their execution, with ISES (*Istituto per lo Sviluppo dell'Edilizia Sociale*) delegated for the technical inspections. The Center for Studies of School Buildings supervised operations and published several valuable manuals to support designers (Fig. 1). The contract competition involved selecting prefabrication companies and constructing the system using modular pieces. Of the 108 invited companies, 43 submitted applications, and 24 met the eligibility standards. By the end of 1965, 339 school buildings were built, featuring an overall capacity of 2767 classrooms.

The prefabricated solutions (Fig. 2) from the 21 selected companies demonstrated a lack of creativity, as their products frequently replicated conventional wall structures. The standard responses to modular systems and panels neglected fundamental principles of internal composition, leading to missed opportunities for benefits such as cost reduction.

Modularity systems and panels were replied in a very standard way, with scarce attention the internal composition principles that can positively affect the educational models. Due to these limitations, the expected benefits of prefabrication, which included a decrease in the expenses and time associated with cost production and utilization, were widely overlooked. Following the introduction of Italian regulations that encouraged innovation in prefabricated school buildings, several prefabricated systems were developed for schools afterwards.

1.2. PLAN FLEXIBILITY OPPORTUNITIES IN PREFABRICATED NURSERY SCHOOLS

The plan flexibility that the prefabricated systems offered in comparison to the traditional techniques (solid brick walls and concrete beams) allowed the designers to experiment with new plan dispositions. New spatial aggregation mechanisms, which are special to nursery schools, were used for both external walls and interior partitions. These mechanisms can be summed up in two main schemes (Fig. 3), based on parallelepiped-shaped cells that are assembled using prefabricated building components:

1. Planimetric proliferation of cells (dimensionally identical);
2. Organic planimetric expansion of homogeneous cells.

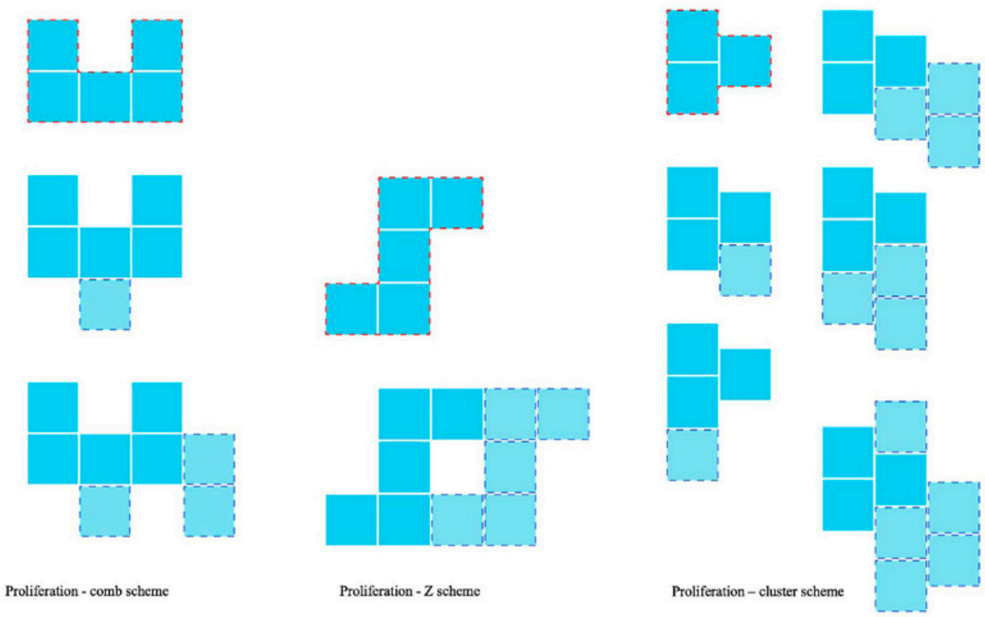


Fig. 3. *Proliferation schemes, according to three different mechanisms (elaboration by the authors).*

Three open and flexible aggregations arise from the two methods mentioned above [16]. With the benefits of mass production, a variety of architectural and spatial mechanisms can be developed from these three plans to best respond to varied pedagogical and environmental contexts:

a. Comb scheme (*schema a pettine*);
b. Z scheme (*schema a Z*);
c. Cluster scheme (*schema a grappolo*).

The comb scheme is a spatial organization based on repeating cells, alternating repetitions and flanking rectangles. Glass walls provide access to open spaces, with each unit having three open sides. Thus, each branch accommodates one nursery school section, which can be expanded and transitioned to multiple sections through proliferation. The Z scheme is a structural unit system consisting of five elements, with three linearly arranged and two at the top and bottom left, regulating the shared environment and allowing for expansion and doubled layouts (Fig. 3). The cluster scheme is a flexible scalar aggregative model consisting of three structural units, allowing for various internal and external organization and volume growth. It features a planar arrangement of two units and a staggered third unit.

1.3. SPATIAL CONSEQUENCES AND PEDAGOGICAL ASPECTS

The pedagogical unit (*sezione*) is a new mixed space designed for educational and holistic purposes, replacing the traditional classroom. It consists of interconnected spaces and subspaces that facilitate various teaching experiences, from routine tasks like, lunch and personal hygiene, to quieter activities, like desk work and active pursuits, like indoor and outdoor play. This concept replaces the traditional classroom with a more complex and varied area.

This setup allows for both whole-group and small-group activities, catering to the diverse needs of all the children in the section. According to the description of a school project [17] from the late 1970s in Carpi (Modena): «The articulated design of the classrooms, along with the inclusion of openings specifically tailored for children, ensures complete autonomy for each section concerning lunch, changing rooms, cleaning, and bathrooms. Additionally, the provision of porticoes and play areas in front of each classroom, as well as easily accessible outdoor spaces adjacent to the common room, enhances the overall environment. Finally, the visual and functional continuity between all these internal and external spaces is rooted in the belief that the environment as a whole can stimulate a child's interest in the various activities that

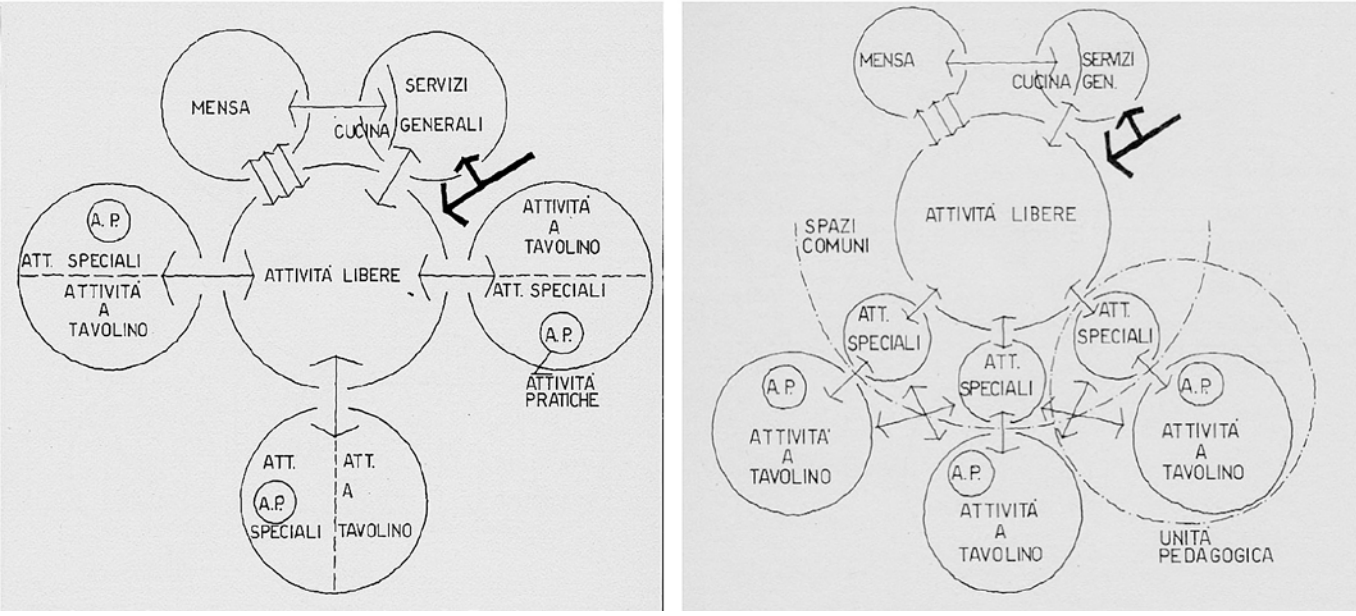


Fig. 4. *Nursery school distribution plan based on ministerial requirements (left) and internal distribution of nursery schools according to the new approach. Source: [13].*

take place there, mainly when there is a seamless transition between different moments of child engagement. This approach serves as a crucial foundation for the harmonious development of the child's personality».

The section is not intended to be a separate entity from the rest of the school [18]. Therefore, it should not act as a barrier to more specialized activities that cater to small groups of children from different sections. During that time, a method was investigated to enhance interaction among children from different groups, as opposed to the traditional approach, where such interaction only took place during lunchtime [19].

The traditional solution was challenged by the "open solution" [20], which achieved a high degree of flexibility by replacing all the internal walls with movable walls made of wood or plastic materials. On a pedagogical level, however, this technique encountered considerable pushback since the youngster felt lost and puzzled at not being able to locate something stable. It was determined that being too free-form is equally deleterious as being forced into strictly predetermined places, times, and activities.

Therefore, sections were created by dividing the spaces into closed, open, and intermediate areas shared by several sections. Areas were designed to accommodate flexible and spontaneous activity [16]. Spaces were integrated visually and functionally to facilitate a gradual transition from activities designed for small groups to those intended for larger groups and from section-based activities to mobile group activities across different sections.

The adoption of a prefabricated system could allow for a new vision of the nursery school [17]: «In our view, the school should be conceived as an association comprising no more than three sections organized around a central hub – a heart – effectively serving as the focal point of the entire school's community. This structure fosters operational interrelationships and enhances spatial connections among all educational areas».

The *atelier*, a space for group activities, underwent significant improvements to cater to various events and activities. Its dimensions, lighting, layout, and outdoor connection were carefully considered to support storytelling, impromptu performances, group creative work, and collaborative work.

2. PREFABRICATED SYSTEMS REVIEWS FOR NURSERY SCHOOL BUILDINGS IN ITALY

The French CAMUS system [21] was a sophisticated prefabricated system made of load-bearing reinforced concrete panels and one of the most diffuse systems in Europe. It was considered a pioneer in prefabrication for residential buildings and was then implemented in construction schools with some modifications, mainly adjusting the façade panels' openings and dimensions to meet non-residential needs.

The load-bearing internal transversal panels and exterior façade panels are crucial components of the building's structural system. The external walls are made of reinforced concrete panels with a load-bearing function and a thickness of 24 cm. Each panel consists of an outer layer of reinforced concrete, a layer of expanded polystyrene for insulation, and an inner layer of reinforced concrete with a welded metal mesh interlayer. External coverings can be added to the final layer of the panels. The flooring consists of 14 cm-thick concrete slabs with upper and lower-face electro-welded meshes.

In 1961, heavy prefabrication debuted in Italy, primarily applied to public housing and other large building complexes. This development was inspired by the increasing popularity of French prefabrication systems, particularly the well-known patents of Balency, Barets, CAMUS, and Coignet.

Besides the well-known CAMUS system, five additional prefabrication systems (Fig. 5), that resembled the French ones, were developed in Italy during that period [22]:

- *Girola* system, designed by Eng. Paolo Viola; owner company: Umberto Girola S.p.A., Milan;
- *Borini* system, design and company owner Eng. Franco Borini, figli & C., Turin;
- *Codelfa* s.p.a. system, design by Eng. Aldo Spirito & Franco Scarantino; owner company: Codelfa S.p.A. costruzione Del Favero, Milan;
- *Gerola - Co-Ge-Far* system, designed by Arch. Luciano Gerola; owner company: Co-Ge-Far, Milan;
- *Sacie-Koncz* system, designed by Eng. Tihamer Koncz; owner company: Sacie S.p.A., Milan.

Among the most profitable companies in prefabricated construction, Umberto Girola developed a patented structure with a steel profile framework, self-supporting brick floors, and concrete panels. These elements rest on the extrados of beams with an average thickness of 12 cm. The sandwich panels are composed of two layers of reinforced concrete (5.5 cm each) and a layer of expanded polystyrene (2.5 cm), resulting in a total thickness of 13.5 cm. Additionally, the partitions are made of honeycomb plaster panels and false ceilings with sound-absorbing plaster panels. The roofs are constructed from corrugated sheet metal and are insulated for both thermal and acoustic performance. The connections are made of a push connection system (Fig. 5).

Most of the school's prefabricated systems were constructed using flat load-bearing panels with a transverse structural system. Exceptions include the Borini and Codelfa systems, which incorporated both transverse and longitudinal structural systems. In most cases, the joining mechanisms rely on pins or joints, leading to significant variability in the width of thermal bridges. As illustrated in Figure 5, most of these systems were designed for factory production, except Borini's patent, which permitted staged production, and the Gerola [23] and Codelfa systems, which allowed for modifiable production methods.

Borini system offers exceptional flexibility and versatility for both small and large-scale construction projects. This prefabricated system consists of load-bearing panels assembled on-site to create a box-like structure. The primary components include sandwich façades, which feature a load-bearing concrete layer (14.5 cm thick), a layer of polystyrene, and an external protective layer made of cement conglomerate (5 cm thick). These layers are reinforced with electro-welded mesh and are interconnected by galvanized iron elements that pass through all three layers. Additionally, the system includes load-bearing walls made of solid concrete conglomerate, as well as non-load-bearing walls and floors constructed from reinforced concrete.

Gerola system relies on the use of three-dimensional elements, which are achieved by assembling three-dimensional boxes or half-boxes. These components can be coupled in three directions, enabling the creation of various buildings with one or more floors. The primary

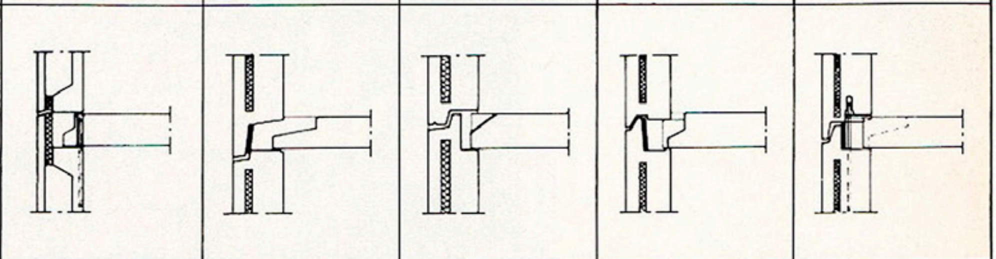
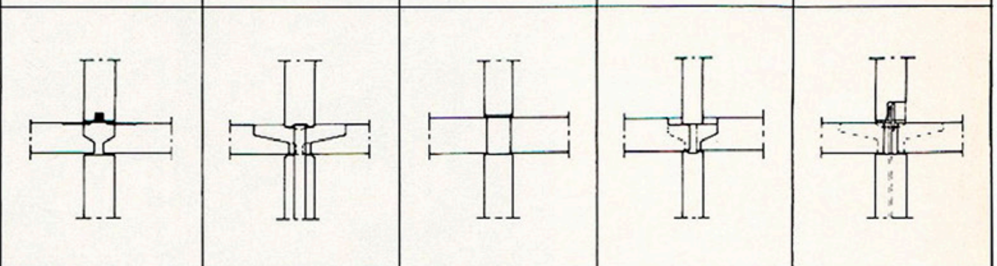
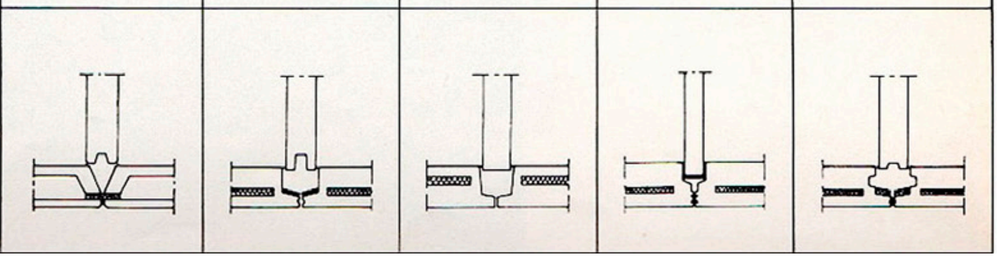
CARATTERISTICHE	SISTEMI				
	SACIE-KONCZ	GIROLA	BORINI	GEROLA	CODELFA
ELEMENTI	Pannelli portanti piani	Pannelli portanti piani	Pannelli portanti piani	Pannelli portanti piani	Pannelli portanti piani
SCHEMA STATICO	Trasversale	Trasversale	Trasv.-Longitud. incrociato	Trasversale	Trasv.-Longitud. incrociato
COLLEGAMENTO GIUNTI ORIZZONTALI	Saldatura e getto	Getto	Saldatura e getto	Saldatura e getto	Getto
COLLEGAMENTO GIUNTI VERTICALI	Getto	Getto	Saldatura e getto	A secco	Getto
GIUNZIONI PANNELLI COMPLANARI	Concentrate ai piani	Distribuite	Concentrate	Concentrate ai piani	Concentrate ai piani
CENTRAGGIO DEI PANNELLI	Piastre con spinotti	Spinotti		Incastri	Ganci di imbrago
N° OPERAZIONI GETTO E SIGILLATURA PER PIANO	3	2	3	1	2
SEZIONE DI GETTO NEL GIUNTO ORIZ. ESTERNO	120 cm²	255 cm²	135 cm²	243 cm²	270 cm²
SEZIONE DI GETTO NEL GIUNTO ORIZ. INTERNO	125 cm²	403 cm²	216 cm²	279 cm²	445 cm²
SEZIONE DI GETTO NEL GIUNTO VERT. ESTERNO	130 cm²	220 cm²	225 cm²	—	235 cm²
AMPIEZZA MASSIMA DEI PONTI TERMICI	—	7 cm	18 cm	6 cm	5 cm
IMPERMEABILIZZAZIONE GIUNTO VERTICALE	Impermeabilizzato	Posteriormente ventilato	Impermeabilizzato	Posteriormente ventilato	Posteriormente ventilato
IMPERMEABILIZZAZIONE GIUNTO ORIZZONTALE	Impermeabilizzato	Impermeabiliz. + sagoma a gradino	Impermeabiliz. + sagoma a gradino	Impermeabiliz. + sagoma a gradino	Impermeabiliz. + sagoma a gradino
PRODUZIONE	In stabilimento	In stabilimento	In stabilimento o a piè d'opera	Impianto mobile	Impianto mobile
GIUNTO ORIZZONTALE ESTERNO					
GIUNTO ORIZZONTALE INTERNO					
GIUNTO VERTICALE ESTERNO					

Fig. 5. *Comparative overview of the five prefabricated Italian systems derived from the CAMUS French system. Source: [2].*

element consists of three walls and two floors, constructed from monolithic cast concrete with an insulating layer of extruded polystyrene. These elements are fully manufactured in the factory. The Gerola system can utilize both joints and welding plates, which are employed to seal the various cells directly on-site.

Sacie S.p.A. patented the Sacie-Koncz panels, which are constructed from solid concrete and incorporate a layer that serves as thermal insulation. The load-bearing structure, also prefabricated, is already connected to the foundations on site. This system enables the development of a wide variety of combinations that can be completed in a short timeframe.

In Europe, many other systems were developed, such as the CLASP (Consortium of Local Authorities Special Programme) system [24], which was developed in England in 1957 to create a prefabricated school building program to be applied all over the country, as well its following patented systems, known as *SCOLA* and *MACE* [25].

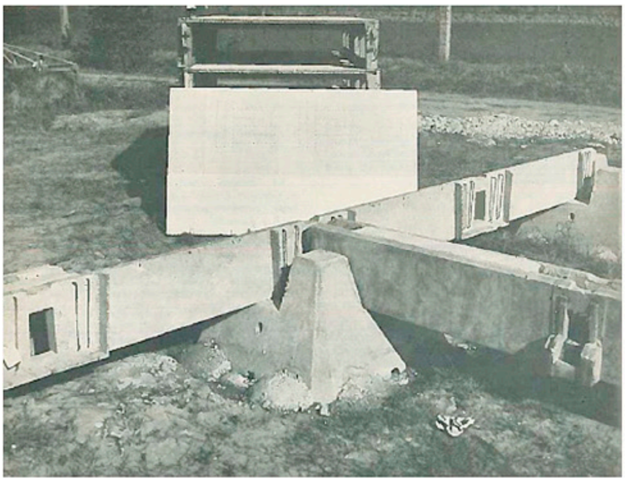
In Italy, the CLASP system was awarded by the Milan Triennale as the most outstanding school building system in 1960. Its use in Italy and other nations followed this success. This system has been gradually gaining momentum. Nonetheless, other national prefabricated and local and regional systems in Italy have found a more widespread diffusion [26].

Given the widespread adoption of various prefabricated systems in Italy and abroad, there has been a growing focus on specially patented prefabricated systems designed to meet the specific needs of educational buildings. The following paragraphs will provide an overview of the most prevalent Italian systems developed for constructing new school facilities.

2.1. THE STAGER SYSTEM

The engineers Nicola Germano and Massimo Starita invented the prefabrication system with modular pieces called Stager. Then, Vibrocement S.p.a. in Perugia acquired the patent. Stager is a reinforced concrete prefabrication method for coordinating components. It operates on a 10 cm scale and creates modular spaces in both directions, ranging from 9 to 34 vertical modules and 15 or 30 horizontal modules. There are four main parts: flooring, beams, panels, and pillars. The horizontal structure on the ground floor consists of elements that are prefabricated from brick and concrete, with finishing casting performed on-site. In contrast, the horizontal structure on the roof is partially composed of ribbed plates that rest on the perimeter beams.

The Stager system offers quick installation and flexibility in nursery school interiors, with three main areas: the section area, the common area, and additional areas like bathrooms and changing rooms. This innovative principle maximizes individual developmental stages by dividing the classroom into sections for similar children and a common room for social interaction [27]. The common room serves as a hub for social interaction and knowledge sharing, connecting with sections, the kitch-



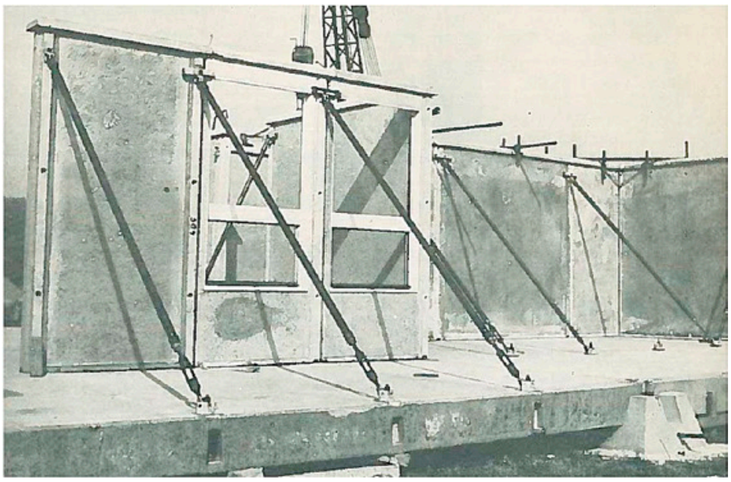


Fig. 6. *View of the construction site with the insertion of beams (on the left) and vertical panes. Source: Forlipedia, www.forlipedia.it.*

en, and the entrance. Prefabricated panels enable plan design and ongoing interaction.

2.2. THE STANDARD SCUOLE SYSTEM

The Consortium of Production Cooperatives and Work of the Province of Forlì developed the *Standard Scuole* prefabrication construction system, using reinforced concrete and expanded clay conglomerate panels. The system features a static structure with load-bearing frames, external infill panels, and floors that can span long distances (Fig. 7).

The floors can span great distances without the need for precompression: up to 9.50 m and up to 8.40 m on beams that are part of the floor's thickness. A grid with a mesh size of 120 cm x 120 cm enabled modular coordination among different parts of the building, allowing for several internal configurations in school buildings.

The system uses two load-bearing structures: a prefabricated reinforced concrete frame with ground-level plinths and stiffening beams and an external perimeter structure with panels. The horizontal slabs create ventilated spaces underneath each flooring structure. The panels of expanded clay, approximately 22 cm thick, form the opaque external enclosures.

The internal flat-section partitions comprise prefabricated, 50 cm x 70 cm identically sized blocks of silicalcite with a plaster outer surface. The flexibility provided by the width of the *Standard Scuole* system panels for horizontal and vertical closures makes the prefabricated system highly suitable for larger nursery schools, offering extensive possibilities for aggregation following the initial aggregation cells.

2.3. THE S3 SYSTEM

The so-called *S3* system was designed by the *Consorzio Provinciale delle Cooperative di Produzione Lavoro e Trasporti di Bologna* (C.P.C.P.L.T.). The *S3* system was designed for constructing school buildings [28]. Due to its high degree of adaptability, it could be tailored to the specific requirements of each municipality, making it suitable for a variety of projects. The system could be customized to meet diverse needs.

The *S3* system is a prefabricated, pre-stressed system for classrooms, utilizing linear reinforced concrete parts with a maximum weight limit of 4000 kg. The modular grid controls component sizes based on classroom layout dimensions and light requirements.

The system features pillars with a constant cross-section, double T-beams, and flooring made of longitudinal and transverse rib plates (Fig. 8). The initial beam solution was abandoned due to the high costs associated with overstocking. The construction process involved five structures: a pillar, a beam, two attic elements, and stairs. The system aims to provide a more efficient and light-efficient classroom environment.

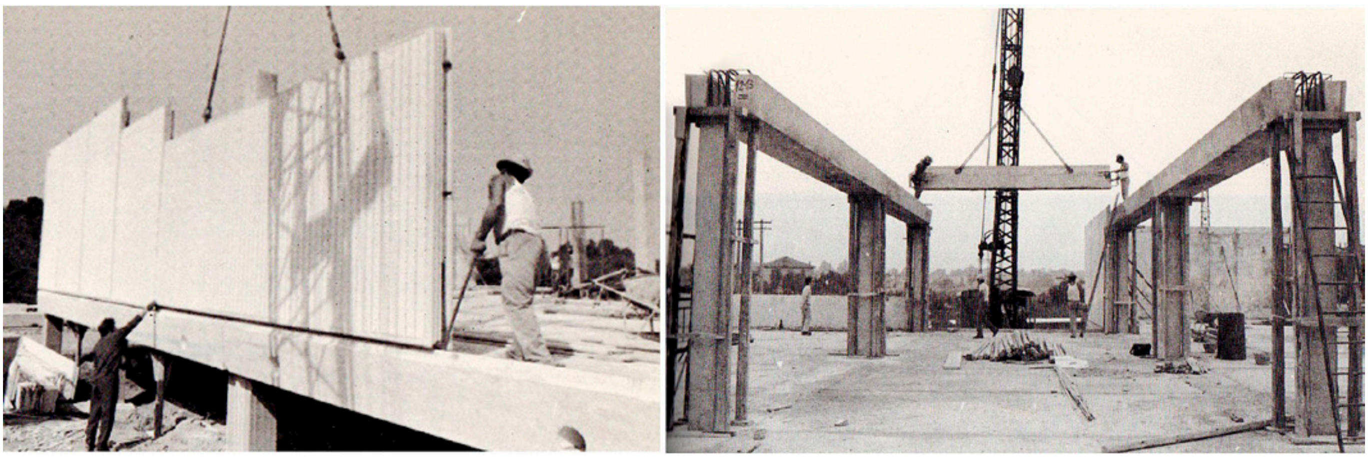


Fig. 7. *Historical pictures of the Standard Scuole system on construction sites. Source: Forlipedia, www.forlipedia.it.*

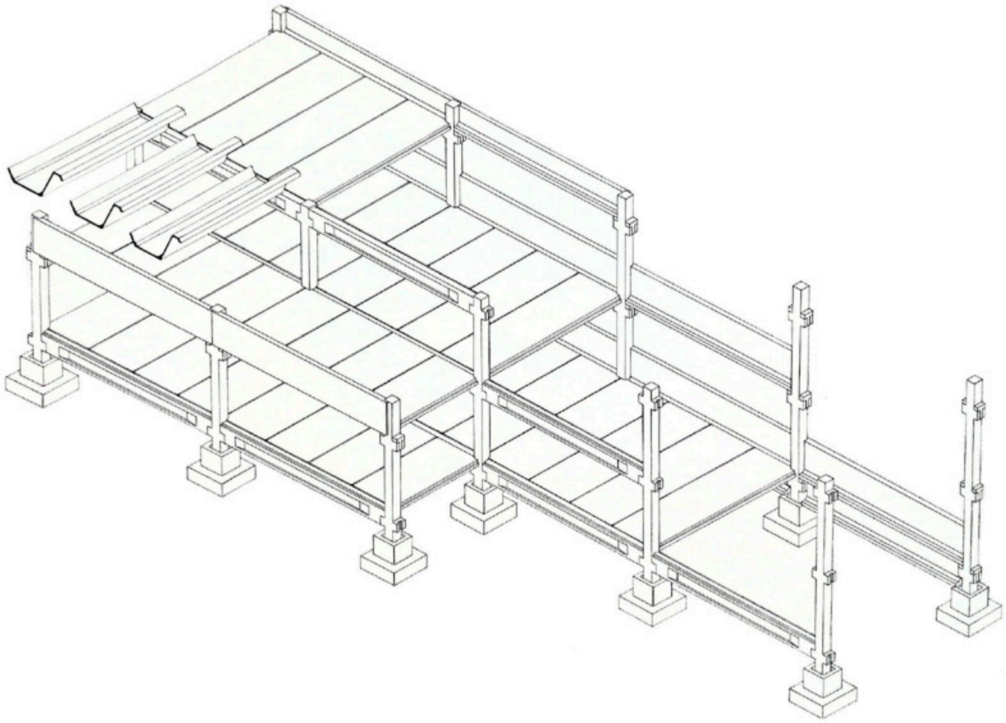


Fig. 8. *Axonometric scheme of the 3S System (1977). Source: Consorzio Provinciale delle Cooperative di Produzione Lavoro e Trasporti di Bologna.*

2.4. THE CMB SYSTEM

The *Cooperativa Braccianti* of Carpi, established on November 27, 1904, and the Bricklayers Cooperative Society, representing Carpi's cement workers and carpenters, merged to form the CMB. This company is still acknowledged today as one of the largest in the prefabrication industry in Italy. In 1977, their union gave rise to the CMB of Carpi (Modena).

A prefabricated brick-cement framework and finishing system for residential and educational buildings was patented in 1966 by the CMB in Carpi [29].

The core of the CMB prefabrication system included load-bearing panels that were not fully prefabricated, along with a variety of small and medium-sized element dimensions. The joints, completion of the structure, foundations, and some roof elements were assembled on site. The construction consisted of panels for the external and roofing walls; traditional materials were mainly used to create the vertical elements, while prefabricated horizontal structures were also incorporated [30]. Because prefabricated components were assembled independently, they were suitable for structures of any size, whether single or multiple stories. These features have led to the widespread adoption of the CMB system in the Emilia Romagna region for new nursery and school buildings.

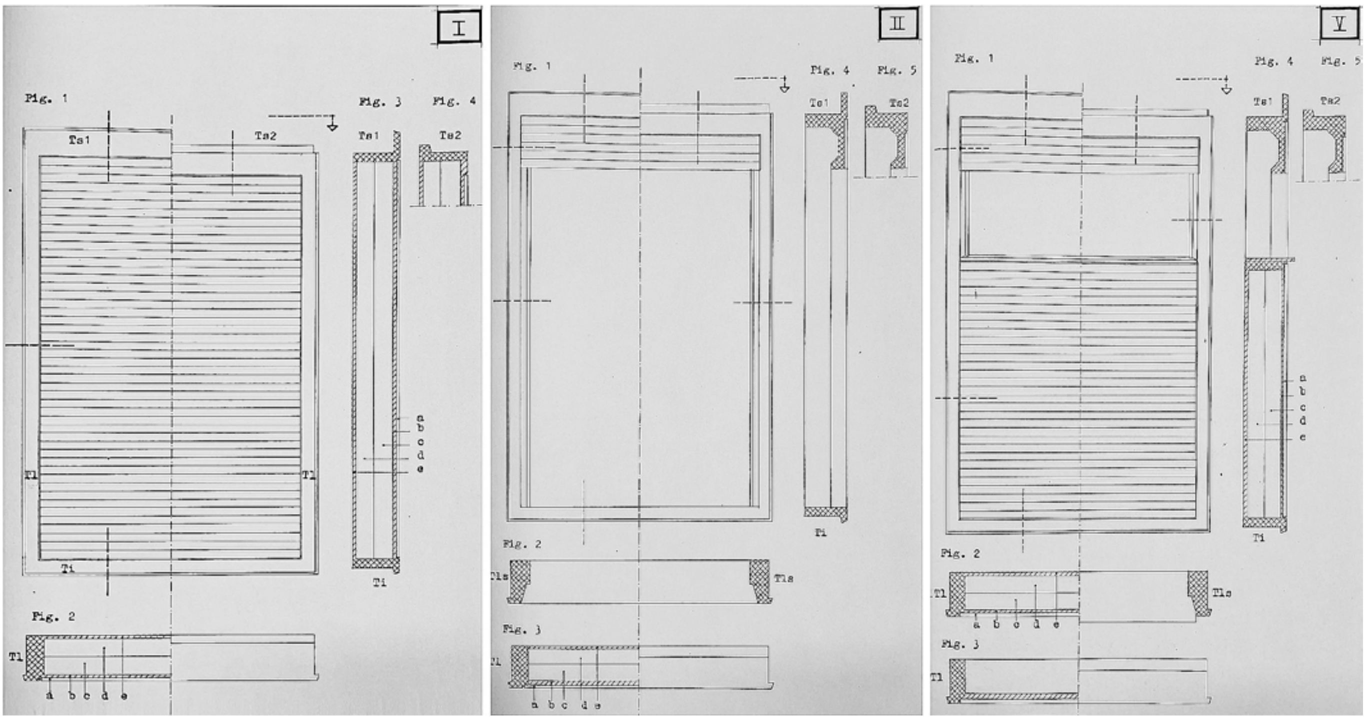
One of the most interesting innovations that distinguishes the CMB patent is the construction procedure that enables the production of elements with a modest weight, less than 3 kg/m^2.

The open-loop process allows for versatile design and typological choices, with a wide range of assemblies and production equipment features, enabling customization of internal and external finishing materials.

The CBM system was patented in 1966. The authors discovered all the technical details in the private archive of the *Cooperativa Muratori, Cementisti e Carpentieri di Carpi* (CMB) in the manual entitled *Prefabricated structural and finishing brick-cement construction elements for school and residential buildings* (*Elementi costruttivi latero-cementizi prefabbricati di struttura e di finitura per edilizia scolastica e abitativa*) (Fig. 9).

The prefabricated exterior panels are installed at intervals of two meters and have a thickness of 32 cm. Each panel consists of a central mixed section placed within a perimeter frame made of T-armed concrete. The panels are used to construct exterior walls. They are joined to one another by an on-site cast joint.

Fig. 9. *External view of Gianni Rodari primary school in Carpi and the central common room with lowered ceiling beams. Source: https://www.cmbcarpi.com/storia.*



a) b) c)

Fig. 10. *Standard CBM panel types: (a) blind panel; (b) with external door; (c) with small window opening. Source: CBM historical archives.*

The panel's outer frame is made of reinforced concrete, which supports its weight. The frame's exterior edges feature specific designs that facilitate installation, enable connections to other prefabricated components, and allow for the placement of casting to complete the load-bearing structure. The standard panel has the following structure (Fig. 10):

a) external cladding made of coloured marble chips that have been scraped and cleaned – 1.5 cm;
b) fine-grained, thin concrete slab reinforced with thick metallic frame – 5 cm;
c) a layer of perforated brick elements – 12 cm;
d) a layer of perforated brick elements with staggered joint – 15 cm;
e) plaster interior finishing with thick cement and bastard mortar lime – 1 cm.

The standard panel can differ in layer (d), which can also be realized in concrete and expanded clay conglomerates.

2.5. LIMITATIONS, POTENTIALS AND PERFORMANCE OF MODULAR PREFABRICATED NURSERY BUILDINGS

Modular prefabricated construction serves as the foundation for new school buildings in Italy. The construction elements have been developed using various patented systems, each featuring slight variations in their structural frames, construction components, and panel joint methods.

The potential inherent in cellular and prefabricated models effectively addresses the educational needs of nursery schools. The new distribution model significantly benefits from the flexible management of spaces and the modular reusability of sections and other secondary areas. The compositional freedom offered by various systems has supported the construction of schools of different sizes for decades, allowing for increasingly complex spatial aggregations that promote more flexible and adaptable management of both indoor and outdoor spaces to accommodate classes of varying ages. Today, despite the well-recognized advantages of prefabricated school systems, many of these buildings are undergoing significant retrofitting to comply with recent seismic regulations, energy efficiency standards, and environmental requirements. Acknowledging the most prevalent deficiencies, which primarily relate to their overall energy performance, the greater potential of these prefabricated panels and other slabs lies in their stratigraphic and modular features. Currently, various commissioning actions can be easily implemented by removing and replacing existing air conditioning ducts and electrical systems, upgrading lighting fixtures, or adding thermal or soundproof insulation within the already installed false walls or ceilings. Ultimately, these actions do not require alterations to the modularity and repetitiveness of the originally defined system dimensions or the initial composition schemes.

3. CONCLUSIONS

After the Second World War, Italian companies shifted their perspective on prefabrication, adopting new technical standards for new school buildings. The new standards, adopted in December 1975, led to the creation of a single-building organism facilitated by standardized prefabricated panels. This allowed for flexibility and changeability over time for internal spaces and allowed for school grouping complexes with shared services and equipment. The new systems also recognized the importance of technological aspects in plant engineering systems. The classroom unit was recognized as complementary to the overall teaching space but still considered an essential element.

Understanding each system’s patents and historical evolution is crucial for designing, retrofitting, and enhancing existing schools today. As demonstrated by the historical overview, while commonly shared among most patents for prefabricated panels, the construction methods shared unique features and distinctive elements that must be carefully considered to implement optimized energy and environmental requalification interventions. The typological and technological analyses of the primary types of technological elements used in modern prefabricated kindergartens should serve in developing interventions aimed at improving energy efficiency, seismic resilience, and environmental rehabilitation tailored to various school buildings.

Furthermore, capitalizing on the repetitive nature of modular elements and recognizing the replicable characteristics of specific components that constitute the building envelope and structure can be an effective strategy for managing the costs of a retrofit project, while minimizing future maintenance expenses. Further considerations should address seismic and energy issues, as these topics, which were secondary during the construction phase, are now of primary importance in the context of retrofit strategies. This focus is essential to ensure a more sustainable environment that meets educational needs.

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Authors contribution

Conceptualization, formal analysis, methodology, and writing, B.G.; data curation and resources, F.M.

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THE MODULAR AND FUNCTIONAL DESIGN OF THE PREFABRICATED BUILDING ORGANISM.
THE EMBLEMATIC CASE OF THE "BLOCK-VOLUME" SYSTEM

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Abstract

The contribution addresses modular and functional design within the building organism. Specifically, it relates to prefabrication processes. The topic of modularity and modular coordination has been the focus of numerous research studies from the early 20th century to the present. This begins with a preliminary analysis of the state of the art concerning studies and publications focused on modular coordination and prefabrication, which established the scientific prerequisites for the first implementations. In fact, using modular coordination is a key process tool for industrialisation in construction. The research analysed various applications of prefabricated systems in northeast Italy, particularly in the Friuli Venezia Giulia Region. The representative case of the company *Ursella di Buja* in Udine shows a synthesis between the evolution of prefabricated systems through the realisation of numerous buildings and, most importantly, the creation of new construction solutions. The paper highlights the innovation of prefabricated systems, transitioning from the production of two-dimensional panels to the "Block-Volume" system. This represented an innovative response to the urgent demand for new housing following the tragic earthquake that devastated the Friuli Venezia Giulia region in 1976.

Keywords

Prefabrication, Friuli Venezia Giulia, Ursella, Modularity, Block-Volume.

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1. INTRODUCTION

In the immediate post-World War II period, the theme of modular coordination and prefabrication was the subject of numerous studies and reflections in relation to the intense building activity resulting in the vast building heritage characterising the Italian territory today. Module and modularity concepts are transversal topics to design and construction disciplines as they refer to theories, methods, and standards interacting in all phases of the building process and with all aspects of the architectural organism.

Modularity has always played an essential role in building procedures based on prefabrication. It is worth mentioning that the process of prefabrication and the industrialisation of construction deeply differ, even if they are often improperly used as synonyms. When we refer to prefabrication, we intend that the construction elements, in this case, called components, are manufactured not on site or near the building site but in specific factories or workshops. On the other side, building industrialisation is defined as construction based on processes in which industrial logic intervenes using advanced mechanisation and/or a planned, programmed organisation. Additionally, the application of modular systems in prefabrication also allowed the use of dimension standardisation tools and, consequently, the implementation of a "univocal language" between different professionals and operators: designers, suppliers, programmers, performers, etc. In the historical period after the Second World War, modularity was considered through the conceptual and operational tools of "dimensional coordination" as the main means of achieving an "open system" [1] in the prefabrication of building components. It was therefore foreseen that the building could be realised through the open composition of various manufacturers' components due to their wide possibility of correlation. The hypothesis of such prefabrication based on a unifying and simplifying regulatory system was to guarantee a free market for multi-purpose and usable components through simple assembly operations in all building projects. The alternative was the so-called "closed system" [2] prefabrication in which each manufacturer made a series of components that could only be combined with each other. This system, which eventually became prevalent, allows for realising large-scale building programmes, usually promoted by public authorities through competitions or tenders. In these cases, the modulation principles formed the basis of the design and "meta-project" phase. It was precisely in these experiments that the building organism was dimensionally coordinated. Precisely, modular coordination consists of: «a modular system of lengths; a reference system; a system of coordination dimensions; a coupling system» [3].

The research intended to examine a part of the vast repertoire of research and publications on the subject of modular coordination aimed at prefabrication and to critically analyse a prefabricated construction system defined as "Block-Volume", developed in the mid-1970s by the Friuli company *Ursella di Buja*.

2. PREFABRICATION AND MODULAR COORDINATION: A REVIEW OF THE STATE OF THE ART

Summarising the theme to outline the state of the art is difficult, given the density and abundance of studies on the subject. Then, the aim is to delineate a brief "common thread" connecting these studies to the experimentation and prototyping as leading elements of broader research, which will be partly described later. Already during the 19th century, the first prefabrication systems were introduced, mainly related to metal structures, whose technology was rapidly developing. The drawings by Baltard and Callet for *Les Halles* in Paris (Fig. 1, top) testify to the first implementation of these technologies. Even if they were included in industrial productions, they showed a taste and a refinement not found subsequently in prefabrication. Similarly, the famous *Crystal Palace* (Fig. 1, bottom) appears as a concentration of innovative technical solutions in the structure incorporating the water system, the ventilation, the corrugated roof – already experimented by Paxton in the Chatsworth greenhouse – and the modular design based on standard measurements of the largest available glass slabs. The *Crystal Palace* has been recognised from its construction as a manifesto of «an entirely new order of architecture», as reported by a Times journalist at the time. According to Benevolo, its importance «lies not in the resolution of significant static problems, nor in the novelty of prefabrication processes and technical devices, but in the new relationship established between technical means and the representative and expressive purposes of the building» [4]. However, the path outlined was not fully explored, and this certainly deserves specific investigation from subsequent industrial construction to the mid-twentieth century. Perhaps issues related to the static resistance of multi-story buildings, fire safety requirements, the need for thermal-acoustic insulation, or possibly economic motivations hindered the widespread adoption of prefabricated metal buildings, even though they had emerged in the context of commercial and utilitarian architecture. However, the expressive and social dimensions may also have influenced the development of prefabrication [4]. The concept of the module and its application as a tool for dimensional composition and coordination in architectural works can be traced back to classical Greek and Roman architecture. In modern architecture, the history of modular coordination begins just before the Second World War, when Albert Farwell Bemis, in 1936, proposed a module for industrialised buildings measuring 4 inches. It was in the years of World War II that proposals regarding the value of the module as the basis for coordination emerged: «Ernst

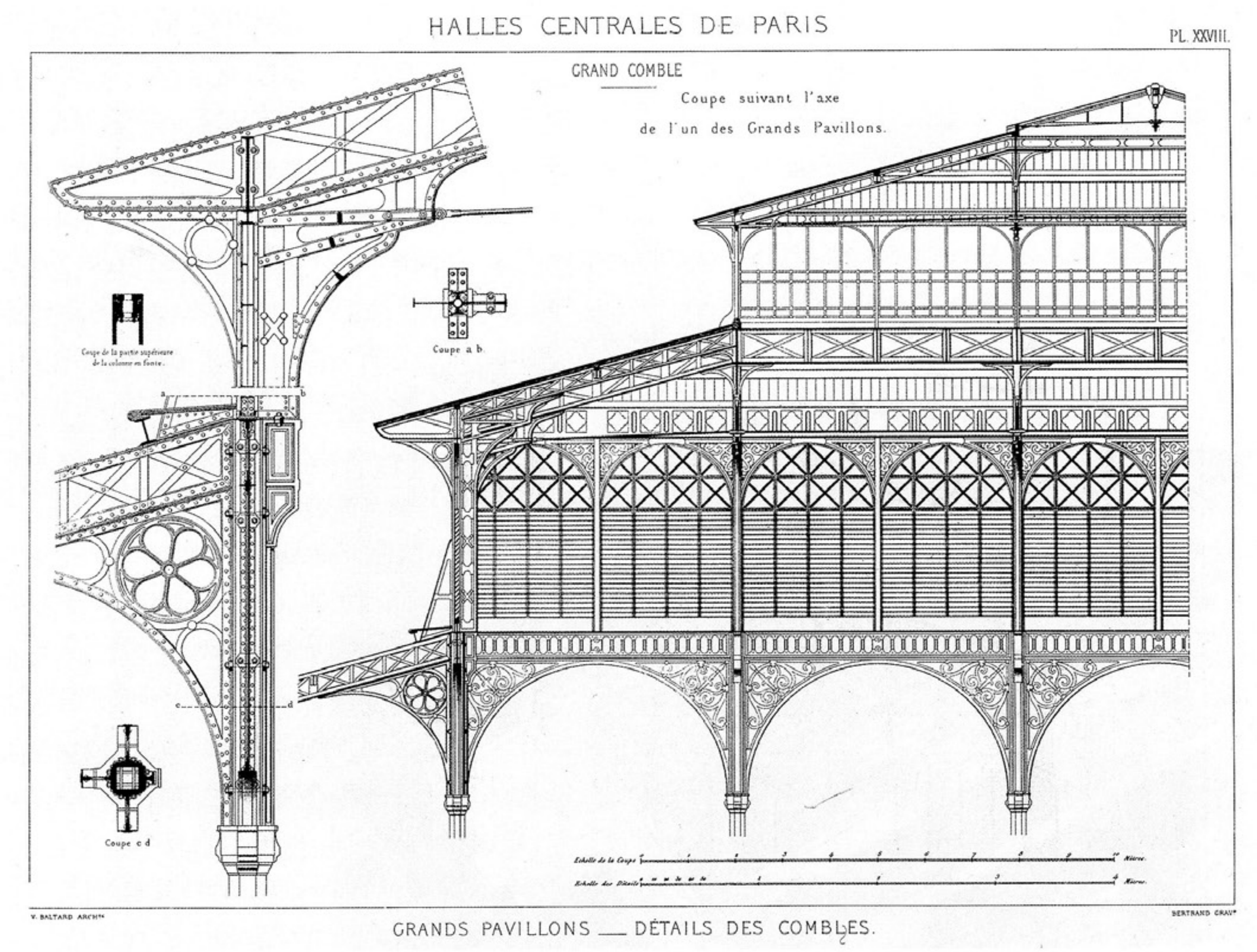

Fig. 1. *Top: boards designed by Baltard and Callet for* Les Halles *in Paris. Bottom:* Crystal Palace.

Neufert in Germany proposes the module of 1/8 m = 12.5 cm giving rise to the so-called *sistema ottametrico*; Jean Pierre Paquet in France proposes the module of 10 cm, which approximates, by defect, the value of 4 inches proposed by Bemis; Lennart Bergwall in Sweden arrives at the same proposal as Paquet» [3].

To reinforce the importance of experimentation and prototyping carried out in those years, it is worth mentioning the *16 Patents of Le Corbusier 1918-1961*, which Charles-Édouard Jeanneret filed during the Second World War and the subsequent reconstruction. A notable example is the *Modulor*, a practical translation of a theoretical principle. With its system of design coordination and dimensional unification, the *Modulor* sought to establish harmony in the chaos of post-war global production [5].

The module is, therefore, a crucial tool to pursue the goal of so-called "dimensional coordination" – the preplanned agreement, in terms of dimensions involved, between the design and construction phases of the building. The module, excluded as a factor of proportioning, returns as a tool for dimensional discipline in the often complex and articulated process of industrialised building production.

From the 1960s onward, in many implementations and most practical cases, the reference system used for the module is a flat, orthogonal Cartesian coordinate system and a base grid with a pitch of 1M, according to the internationally adopted standards. This module was adopted by nations adhering to the OEEC (Organization for European Economic Cooperation) and by others outside the organisation after the research conducted in 1953 and following the Monaco Agreement of 1955 and the normative principles outlined in the "Deuxieme Rapport - Project AEP 174", 1961, *la coordination modulaire*. On this grid, choices are made for preferred parameters, multiples of the base module: these choices can be "simple", that means based on a single multi-module for the linear case, or a single grid in the plane and space, or "composite", originating combinations of several simple grids, resulting in "Scottish" grids [6].

The importance of issues related to modularity in connection with prefabrication is exemplified by the attention it received in the literature of the time. Enrico Mandolesi dedicates a significant portion of the first volume dedicated to the "Building Organism" in his encyclopaedic work *Edilizia*.

Here, he highlights that «the international base module corresponds to a whole number to have a simple relationship with the decimal metric system to which it refers, avoiding fractional parts in the modular dimensions of the component. Finally, with the 1M module, small modular entities normally present in building works, such as the thickness of partitions and the layers of vertical and horizontal closures, are not overlooked. So, a correlation is established between the modular dimensions that the industrialised component must possess and the reference parameters to be adopted while designing the organism» [6].

Mandolesi again emphasises the importance of using so-called "Scottish" grids. In the first instance, we can assume a 10 cm x 10 cm (1M x 1M) grid, which is called a "basic grid" (Fig. 2).

However, other grids defined by multiples of the basic module or its submultiples can also be used. All the grids can be superimposed on each other, and their summation will produce a grid called "Scottish", as it clearly recalls the characteristic fabrics of that country. Each of the grids can be used separately for a specific type of design (for example, for the structural grid, for partitions,

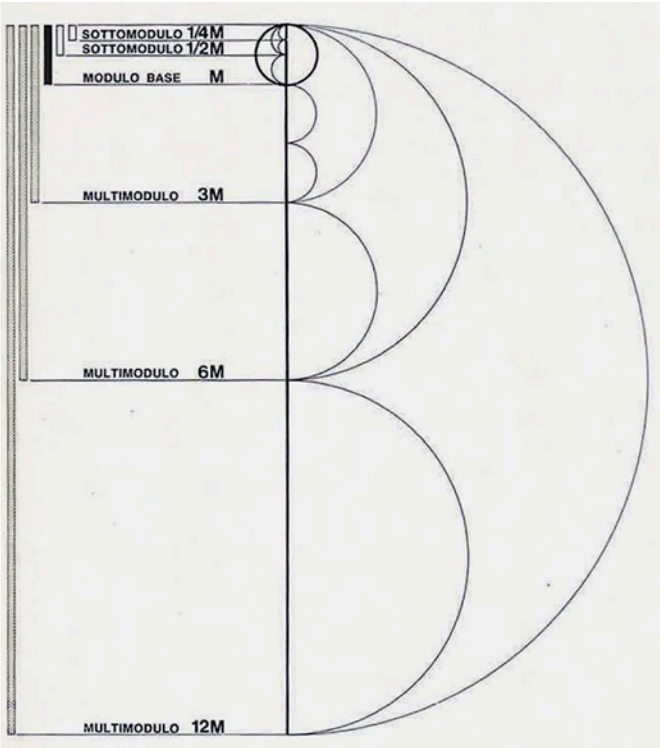

Fig. 2. *Modular Coordination Length System. Source: [9].*

for flooring or ceiling elements, etc.). Still, their perfect overlapping ensures functional and formal integration between the various subsystems (Fig. 3). This principle remains valid today because it is congruent with the "layer" logic characterising automated drawing programmes.

In the Italian national scenario, the first research developed on the topic of modular coordination can be attributed to Giuseppe Ciribini [7, 8] in the years following the end of the Second World War. From 1955, the *Centro per la Ricerca Applicata ai Problemi dell'Edilizia Residenziale* (CRAPER) in Milan continued on this theme. A series of research projects followed until the late 1960s and early 1970s. From 1968 to 1971, the *Consiglio Nazionale delle Ricerche* (CNR) developed a specific *Special Programme on the Industrialisation of Construction* [9].

Among the numerous experiments in the field of numerical series useful for modular coordination, in addition to the already mentioned *Modulor* by Le Corbusier and the A.E.P. project of the German Standards Association, the Renard number series and the MACC system are of particular interest. The Renard series takes its name from the French aeronautics colonel Renard, who initiated a study to fix cable dimensions for aerostats in 1880. Later, however, some limitations of this numerical series were highlighted with regard to its use in building dimensional coordination, and it was therefore abandoned [10].

The MAAC method, on the other hand, was devised in 1970 by G. Cislaghi, A. Monticelli, N. Sinopoli, and G. Turchini and was based on «the graphic representation of dimensions and combinations along a half-line on which are represented all the integers that correspond to possible dimensions to be realised». «On such a ray, all points corresponding to the dimensions of the starting components and all their possible combinations are shown» [11].

The MAAC system represents an interesting exemplification of using numerical series as a valuable and necessary tool to solve a range of coordination problems and help designers and manufacturers standardise construction elements. In fact, it is a system that has not found easy application due to its complexity concerning the context of the prefabricated construction world. An interesting example of its application can be found in the Italsider-CECA research concerning the design of a pedagogical unit of the compulsory school, with three classes

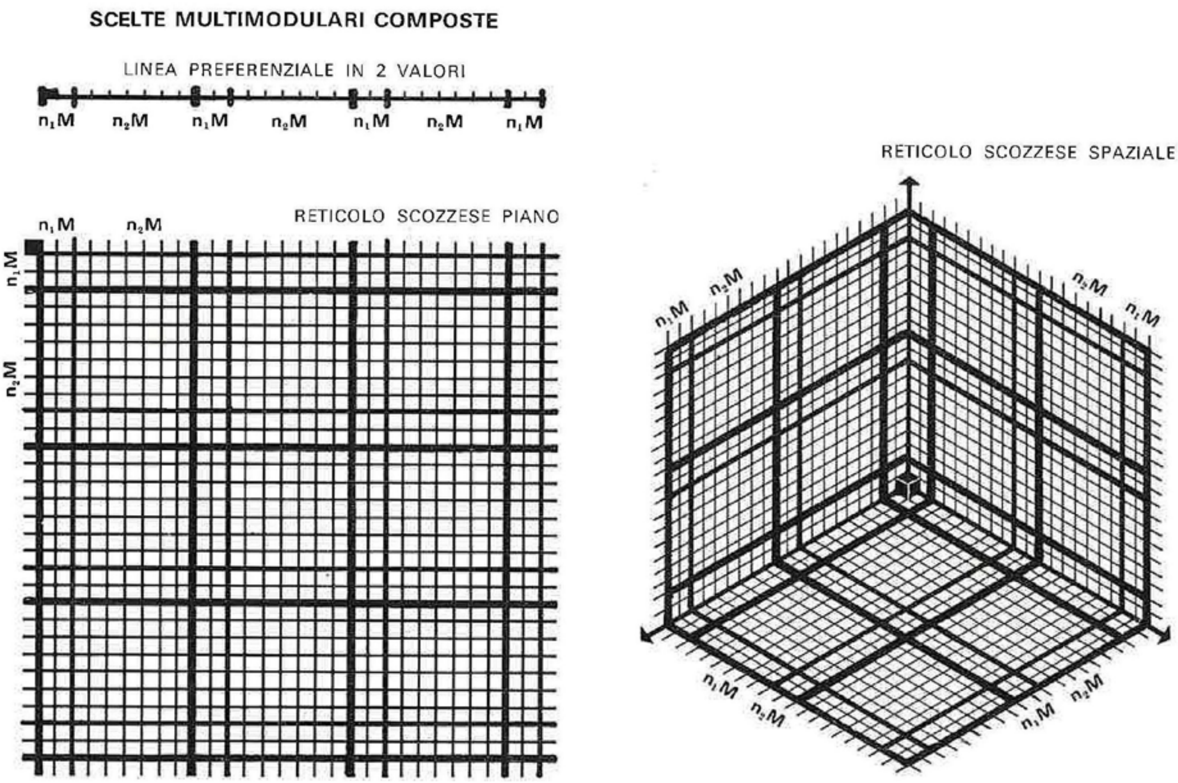

Fig. 3. *Scheme of composite multi-modular choices «Compound multi-modular choices can result in the combination of several fixed grids, thus the Scottish grid applied in the design of the building organism, or the reference line or variable grids, applying the system known as the "number pair" (combination of geometric progressions with a Fibonacci series)». Source: [6].*

of 30 schoolchildren, activity spaces, services, and changing rooms. In this case, the MACC system is decisive in solving the problem of choosing the components of the internal partition subsystem in relation to the specific dimensional requirements. The results of this study are reported in detail in the research "Modular Coordination Procedures for Building Design" conducted by G. Turchini, M. Simonazzi, N. Sinopoli, and E. Zambelli [11].

Even though it is not exhaustive of the large number of research carried out over time in this field, it is considered that what has been outlined above constitutes a useful basis for understanding the developments of industrialised production and experiments developed by the *Ursella* company in the Friuli Region.

3. THE URSELLA COMPANY AND PREFABRICATION

As introduced, the topic of prefabrication is closely connected to building industrialisation processes, both in terms of the integral execution of a building (heavy prefabrication) and in terms of completion structures (light prefabrication).

The professional and entrepreneurial adventure of the Ursella family began in the mid-nineteenth century with the founder Giuseppe Ursella, who initially worked in a brick kiln near Munich.

Ultimately, the brick can be considered a first example of a prefabricated element and an "object module", given that an entire building can be obtained from juxtaposing such elementary elements. The knowledge gained in the production of bricks was handed down to his son Ermenegildo, who, at the end of the First World War, started a production of economical kitchens and a department to produce prefabricated elements linked to the construction company activity in the areas near Buja (Udine). The shortage of materials during the Second World War forced Ermenegildo to stop the production of kitchens (based on metal profiles) and concentrate on the construction activity [12].

Among the first prefabricated components made, the "L" shaped elements used to replace the typical stone framing of the windows are worth remembering. Also, within the scope of the evolution of the Ursella family's know-how is the experience of Ermenegildo's son, Gino, who gained important knowledge as a Work Supervisor of a company that operated in Venezuela, creating buildings in reinforced concrete.

A substantial step in the company's evolution in the world of concrete construction was the projects developed in collaboration with the architect Marcello D'Olivo. In particular, those relating to the *Villaggio del Fanciullo* in Opicina (Trieste) should be mentioned with the decisive collaboration with the engineer Silvano Zorzi from Treviso for the calculation of the pre-stressed roof beams of the printing plant. Another important project was the *Fabbricato Negozi* in Lignano Pineta (Udine), where the "design hand" of Marcello D'Olivo (Fig. 4)

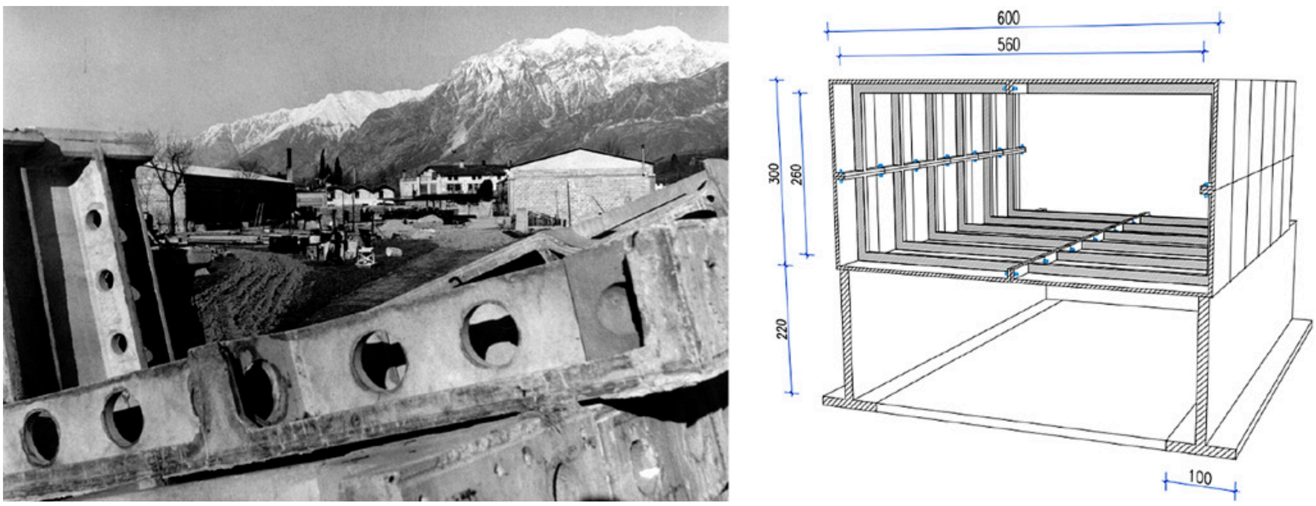

Fig. 4. *Left: prefabricated elements realised according to architect D'Olivo's design in the first attempt at the prefabricated tubular house in 1960. Source: © E.M.E. Ursella Srl, 2024. Right: three-dimensional reconstruction of the architect D'Olivo for the study and experimentation of the first prefabricated house. Source: [12].*

Fig. 5. Torre di Zainer *in Lignano Sabbiadoro. Left: the site assembly phase. Middle: the final realisation. Source: © E.M.E. Ursella Srl, 2024. Right: detail of the lower groove of the slab, with particular reference to the lower and upper splines and the "male-female" joint in the cross-section. Source: [12].*

traced the foundations of a new field of experimentation in the use of reinforced concrete with innovative shapes in the prefabricated solutions applied in construction [13].

Summarising the experience of Ursella Company, from its founding to the present, is no easy task. However, it is possible to outline some construction episodes representing crucial moments in the development of production and construction techniques.

A turning point was the construction of the *Torre di Zainer* (Fig. 5) in Lignano Sabbiadoro (Udine) on the Trieste seafront, designed by the architect Aldo Bernardis, towards the end of the 1950s. The 13-storey tower, over 40 meters high, was contracted in November 1958 to be delivered in June of the following year. At the time, it was the tallest tower in Friuli Venezia Giulia, and it was one of the first and most important experiments in the area that used prefabricated buildings. The plan consisted of three rectangular elements identical to each other, with a short side adhering to a central sector consisting of an equilateral triangle where the stairs, elevators, and access spaces to 3 apartments per floor were located. The detailed studies, in particular, were concentrated on the façade cladding. Silvino Ursella explained how the idea was inspired by the installation system of shutters and roller shutters, which were lowered from above across two lanes.

In fact, the solution implemented for the perimeter closure of the building was utterly innovative as well as quick and economical, considering that, without the use of external scaffolding, the newly assembled panel also acted as protection for the floor. The structure well represented in the production information was designed to be fixed with a particular "male-female" solution, which allowed rapid installation (Fig. 5). The tower had 36 apartments as well as services and concierge offices, and it was an innovation for that period, especially in terms of planning and execution times; this also considering that in the Buja factory, more than 3500 m^2 of reinforced concrete panels, 90 m of parapet elements, 1100 m of attic ends, 24 flights of finished stairs, 12 landings, 12 shelves, and 39 tubular elements were created.

Since 29 July 1959, with the birth of the S.I.C.E. S.p.A. (*Società Industrializzazione Costruzioni Edili*) managed by Gino Ursella together with Silvino Ursella, has begun a long period of experiments resulting in the construction of various industrial warehouses and, above all, *Lignano City* (Fig. 6), a settlement complex made up of homes, shops, restaurants, squares, etc. This phase essentially ended in 1971 in correspondence with a general crisis and a marked slowdown in the production and construction of prefabricated buildings.

Fig. 6. *Top:* Lignano City *with* Palazzo Celeste *and* Palazzo Rosato. *Bottom: site phases of the assembly of the perimeter closure panels of* Palazzo Celeste *in* Lignano City. *Source © E.M.E. Ursella Srl, 2024.*

4. THE PREFABRICATED HOUSE: FROM "SEMI-BLOCK" TO "BLOCK-VOLUME"

4.1. THE "SEMI-BLOCK"

The infill panels of the *Torre di Zanier*, the "C"-shaped elements of the Pittini (UD) and Snaidero (UD) factories, the ribbed roofs and the general-purpose concrete formwork, even the "Semi-Block" elements represented a new stage in the development of Ursella prefabrication in determining a new concept of building construction and assembly.

Compared to the "Block", the "Semi-Block" is not a product to be used independently to provide a turnkey house as it is an industrial product [12] (Fig. 7).

The construction procedure can be summarised in the following steps. As a first step, a metal frame is constructed with lattice-work profiles covered with electro-welded mesh on both sides, as in formwork walls. In the vertical element, the load-bearing metal reinforcement is represented by two supporting trusses positioned at the sides. Spacer or distribution trusses are placed crosswise, and the electro-welded iron mesh is welded onto them. Cement coating uses the immersion technique in the vibrated concrete mix, first on one side and then, after tilting, on the other. The special aspect of these elements is that the load-bearing vertical profiles are not entirely covered by the concrete mix, but remain uncovered along their entire length so that, when the elements are laid, the point of contact between one element and the next is the iron profile, which allows them to be joined by electro-welding. Door and window openings can be positioned as desired. The modular width measurement of the element is 2.40 m, while the height is dependent on the expected room height. The thickness is determined according to structural and insulation requirements. The integration of the profile section supports any higher loads for multi-storey constructions without having to change the production scheme or the construction of the individual components. During installation, the elements are joined by welding at the edge trusses, which, when joined, will form closed-section load-bearing pillars. The sandwich composition of the elements forms a cavity suitable for the housing of the systems and determines the space required for the insulation of the building. The horizontal element has a metal reinforcement made on the same principle as the vertical walls but of greater consistency since it is subject to overload stress with much more distant supports. The manufactured plan width corresponds to the width of the perimeter walls so that a tubular element like that of the "Block-Volume" is formed when the work is completed [13].

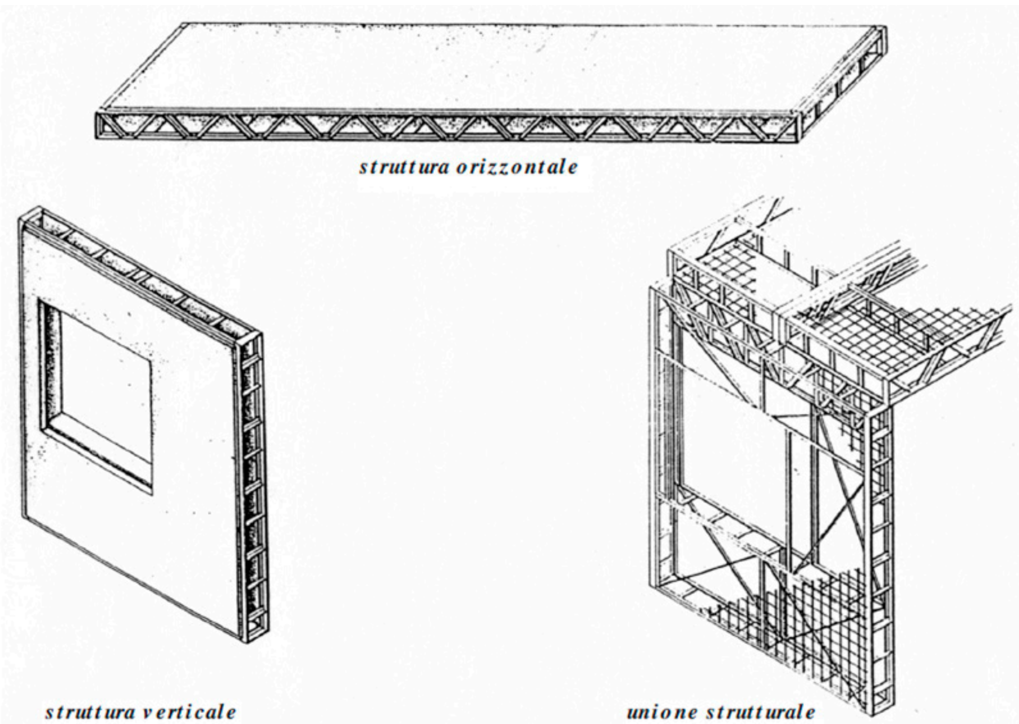

Fig. 7. *The "Semi-Block": axonometry of the vertical and horizontal element as well as the structural union. Source: © E.M.E. Ursella Srl, 2024.*

4.2. THE “BLOCK-VOLUME”

The system called “Block-Volume” is characterised by its considerable weight; in fact, it is designed by employing the material statically reasoned, using it in the compressed areas and removing it from the tensioned areas (Fig. 8). The methods of realisation are taken and reported in this paragraph, thanks to the oral and written testimonies of Silvino Ursella [13, 14]. It was thus possible to reduce the weights of the artefact and the thickness of the floors, bringing the height of the rib beams to only 25 cm. This reduction, increased by an additional 10 cm for the incorporation of the floor and ceiling slabs within the thickness of the ribs, made it possible to solve the problem of the maximum height of the elements for transport (4.10 m from the ground). This was also made possible using a tubular with a monolithic structure that allowed interlocking bonding instead of simple support. This required a metal mould to be made with frames corresponding to the thicknesses of the walls and floors to be placed in adherence to the metal structure of the “Block-Volume”. These frames were then joined with rigid internal lattice-work, spaced, and connected by bolts. In essence, mould and framework carpentry formed a single entity until the castings of all four sides were completed, an operation that took four days, or one per façade (Fig. 9, bottom).

It was then easy to solve the problem by lifting the “Block-Volume” altogether and simultaneously with the overhead crane hoist, employing two pulleys hooked to the end of a solid sling bar by ropes held at the necessary distance to allow tipping. The most delicate part of the manoeuvre consisted of the moment when the weight exceeded the balance position, so it was necessary to make the manoeuvre as smooth as possible by operating the overhead crane translation simultaneously with the downward movement of the hoist. On the day following the casting of the fourth façade, dismantling was done by removing the bolts joining the spacers to a side frame, which was placed temporarily toward the wall, while all the rest of the mould was slipped off the “Block-Volume” through the use of the overhead crane. After cleaning and oiling, the mould could be repositioned and secured in its previous location. Concreting was carried out once the end-head frame was positioned and restarted, and the metalwork of a new “Block-Volume” was threaded into place. The first realisation of a “Block-Volume” form was in August 1985. Therefore, a solution was tested involving the construction of three reinforced concrete walls of the height of the basement floor, which would then be joined together in the shape of an “H” with the two side bearing walls and a connecting and joining wall on the centerline in the transverse direction. Coverage of the basement would occur automatically with the placement of the “Block-Volume”. Two “C”-shaped elements, placed above the “Block-Volume” in the longitudinal direction, would delimit the upper floor and, at the same time, serve as support and backing for the roofing elements. The latter was built double-sloped, the same width as the “Block-Volume”, and with tubular tie-rods at half-height to facilitate the use of that floor.

Only two houses were built with this system, which was later abandoned. In fact, the construction of the basement floor was simplified by incorporating the plinth into the wall, thus achieving greater economies. Concerning the upper floor, from an economic point of view, it was found that the higher cost involved in the finishing did not justify the addition of a second habitable floor. Still to transport over great distances and ensure possible new compositional solutions, the 10 m “Block-Volume” was put into production at the end of 1992, and in 1996, the 12 m “Block-Volume” was scheduled to be built to obtain, with only two joints, a 90 m^2 house, in addition to the basement and habitable attic floor. This possibility of working with factory-cemented “Block-Volume” has opened up new technical and market prospects in the development of Ursella’s civil prefabrication. It can be said that the “Block-Volume” can represent the “engine” of the house since everything needed to make it work is included; the other parts can be considered side works. The new technical possibilities include bringing “Block-Volume” to a stage of almost complete house finishing already in the factory. As Ursella wrote, the possibilities for marketing the product are greatly expanded. In fact, travel expenses are reduced in relation to the reduction in assembly time. In practice, small modular houses of a size and weight within the normal transportation range are made, which allow assembly with standard crane trucks and can be sourced on-site. Such three-dimen-

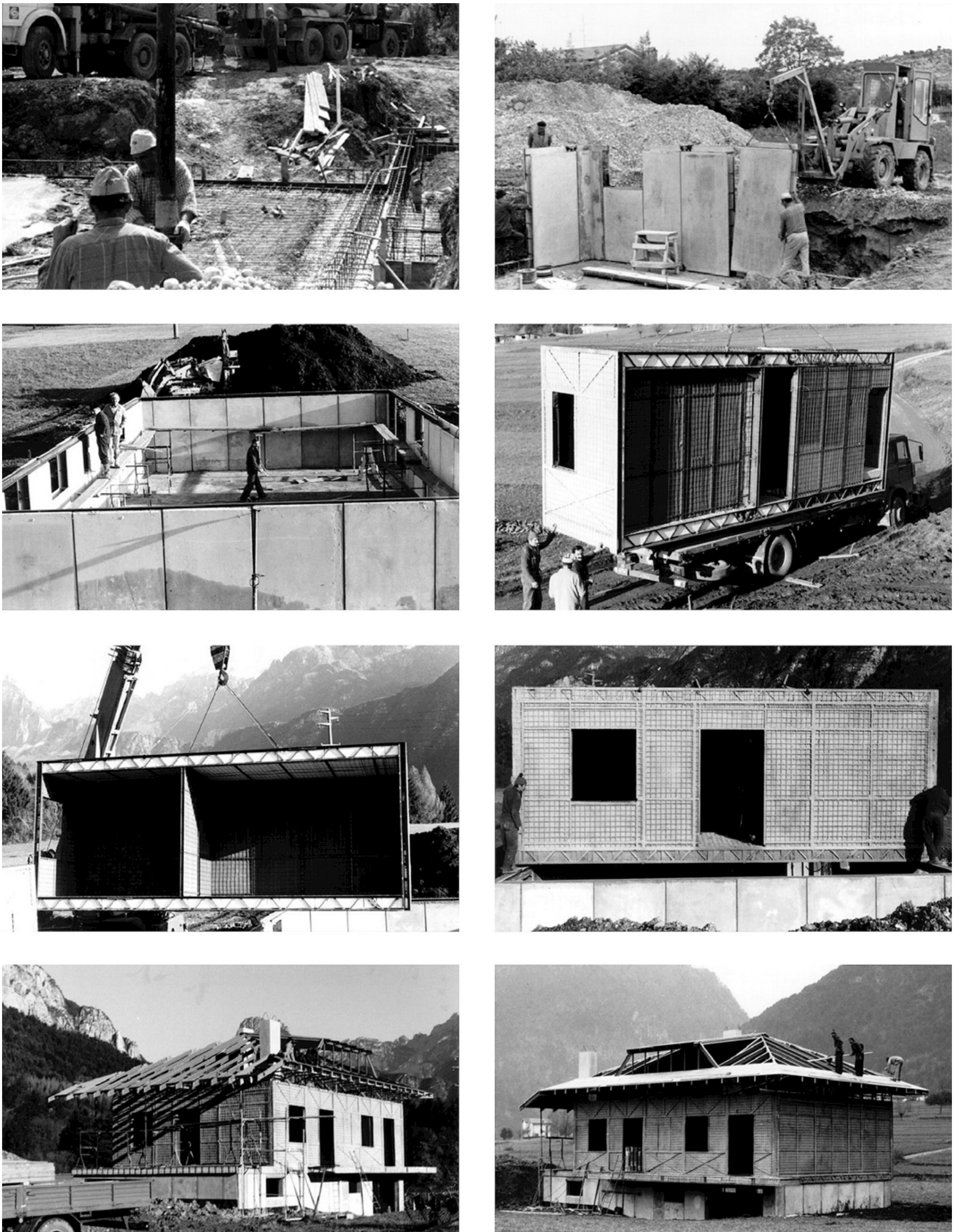

Fig. 8. *From the top, the assembly of a house with "Block-Volume" produced in the factory and plastered on site in the first years after the 1976 earthquake. Source: © E.M.E. Ursella Srl, 2024.*

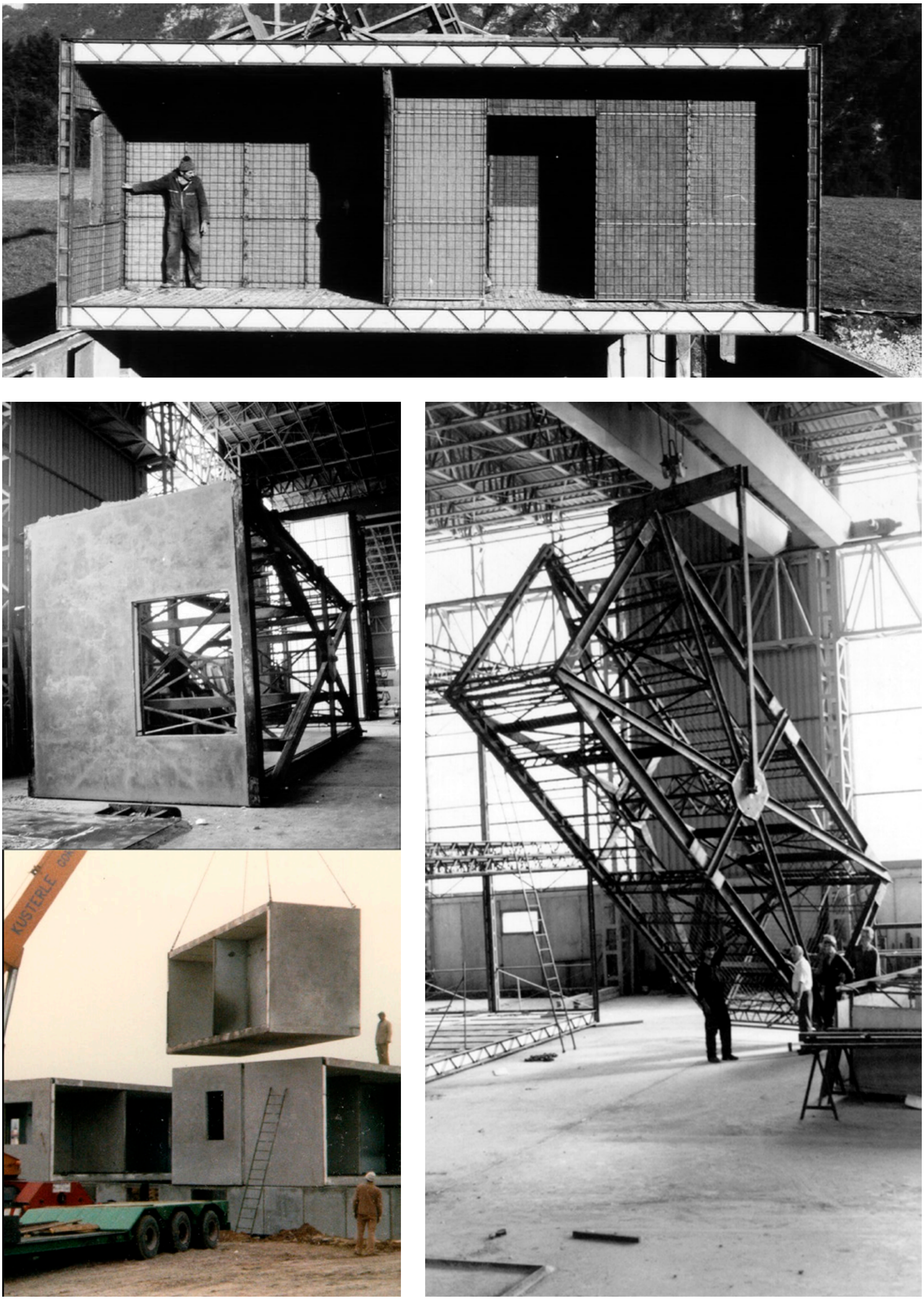

Fig. 9. *Top: "Block-Volume" laid on formwork panels forming the basement floor. Bottom left: production and assembly of a "Block-Volume" element forming part of the villas plastered in the factory in the post-1985 period. Bottom right: tipping of the "Block-Volume" using an overhead crane (the solution used). Source: © E.M.E. Ursella Srl, 2024.*

sional elements form the final building, placed side by side according to the design scheme. The constraints imposed are very limited, and the advantages, in addition to the convenience of industrial cost and speed of erection, are many. By integrating the works forming part of the "Block-Volume" into the factory, the headers were added in the head blocks, i.e., the outward closing panels in the long part of the rib. In each "Block-Volume", the partitions of respective pertinence are placed, and conduits are prepared on the walls and floors to pass the electrical system and heating system piping. The water system and drains for the bathroom and kitchen are then prepared.

Some improvements were then made by replacing a part of the inert material in the concrete with expanded clay to lighten the weight, improve thermal and acoustic insulation, and add the percentage of cement on the interior surfaces. In this way, weight was reduced so that larger elements could be used; insulation was improved, and nailable surfaces were achieved on all interior surfaces. Artificial stone windows and doors were drilled at the factory, which could also be fixed on-site. For the internal partitions, in which the sheaths for the vertical installations are laid, after various experiments, we believe that we have arrived at an optimal solution with the monolithic Leca-cement casting reinforced with electro-welded mesh bordered by "C"-shaped metal profiles with the possibility of joining by electric welding. In order to optimise transport, the "Block-Volume" were increased from 2.40 m to 2.50 m. However, the walls defining the basement floor must be mentioned (Fig. 9, top).

These are the Sandwich Walls where the lower sloping shell delimits the foundation plinth; thus, plinth and elevation walls are obtained in a single casting. The "Block-Volume" will then be placed on this base, the base floor of which will serve as the roof on the basement floor, and the ceiling will serve as the floor above.

Assembly work phases		
1		Excavation and earthworks up to a height of 30 cm from the finished basement floor
2		Anchoring with concrete plinths of the metal profiles positioned at level, at the rate of two or three per formwork wall
3		Levelling of the ground surfaces between the anchors with concrete screed or simply with compacted gravel
4		Laying of basement formwork walls, including:
	4.1	Finished plinths, complete with windows and rubber recovery joints on the inside of the plinth at the height of the floor casting
	4.2	Laying of floor drainage pipes, foundation stones, plastic sheeting for vapour barrier, electro-welded mesh anchored to the round profiles projecting from the perimeter plinth
	4.3	Concrete slab with a net thickness of 10 cm. All this until slabs with polished surface are prefabricated in order to give the customer a finished floor
	4.4	Drainage pipe around the entire outer perimeter and bituminisation of the wall up to the ground surface after completion. Concrete filling of the formwork walls for the entire height
5		Transport and installation of block-forming houses, including:
	5.1	Reinforced monolithic internal partitions made of Leca© and cement mix
	5.2	Water system and drains for bathroom and kitchen
	5.3	Pipes or conduits for heating system piping and template for fixing heating boiler
	5.4	Artificial stones for door and window frames
	5.5	Chimney flues for the kitchen and boiler and for the fireplace, where required
	5.6	All walls, ceilings, and partitions are to be considered finished, as well as floor screeds with levelling compound
	5.7	These works may also include completion of the electrical system with wires and inserts; and semi-completion of the heating system
6		Transport and installation of loose elements for the ferro-cement roofing, with finished linda overhangs. The roofing is now supplied in wood for less weight on the structures
7		Transport and installation of any porch, access steps, ramp boundary walls, and terraces
8		The completion works after assembly are therefore a:
	8.1	Joining elements with electric welding, sealing joints with cement mix
	8.2	Installation of tinwork and roof covering
	8.3	External scratching or staining
	8.4	Installation of interior fittings and sanitary fixtures
	8.5	Staining and flooring

Tab. 1. *Summary table of on-site assembly steps of the "Block-Volume" system. The "Block-Volume" arrive on site complete, with almost no need for masonry work. This is made possible because the houses are built with three-dimensional elements, which allows the house to be assembled in one working week and completed in the next month, depending on the number of finishing works to be carried out.*

The roofing slab will be replaced by a thin reinforced concrete slab on an iron lattice structure for the part up to the eaves line; the projecting part and the porch part, on the other hand, must also be finished with polystyrene (as single-use formwork) at the bottom. The dimensions used in the roofing elements usually are 2.50 m in width and length up to the perimeter limit of the "Block-Volume", while the protruding eaves is made in the longitudinal direction to reduce joints. So from the S.I.C.E. Ursella Spa houses of the 1960s, built with panels and loose floor slabs, we moved on to the guardhouses on the Tagliamento embankment, built in 1970 as an attempt to create "Block-Volume" by connecting the floor plate with the ceiling plate, using four pillars at the corners. In October 1976, the new company E.M.E. Ursella Srl set up the new construction system, which bore the initials "GUS-System" (Gino Ursella Silvino), whose purpose was to build three-dimensional module housing units in iron and insulating material in the factory, to be completed with mixture after assembly. In October 1984, after the static part had been verified, it was possible to construct these "Block-Volume", complete with concreting using different mixes according to the covered surfaces to improve insulation and reduce weight (Fig. 9, left). The *Ursella company*, therefore, continually sought the possibility of delivering an assembled and finished house within a short timeframe precisely because prefabrication had changed from two-dimensional to three-dimensional.

5. CONCLUSIONS AND FUTURE DEVELOPMENTS

In conclusion, the article presents a sample of the results of broader research in the field of the analysis of construction techniques applied to building prefabrication. The study shows a close relationship between modular coordination and the production of finished elements to optimise prefabricated constructions.

Prefabrication is still a topical issue that demonstrates a continuous evolution of techniques with the transition from two-dimensional to three-dimensional prefabrication. However, the introduction of the *Casa a Nastro* construction solution in the 2000s testifies to continued research and development in the sector that continues to improve products with the use of high-performance insulating materials and improved integration with the plant engineering part. This type of prefabricated solution has always shown a certain architectural rigidity as it only allows a small number of customisations, but, citing Silvino Ursella, only «with the repeatability of the elements can something be achieved at a low price». Consequently, the solutions under consideration are still valid systems for responding to the need to reduce costs and build housing modules quickly, such as those required by emergencies (earthquakes, floods, etc.). The research provides for further in-depth studies of the technical solutions implemented in those years, also in order to identify useful tools for the building restoration of these types of artefacts. The research also intends to develop analyses to evaluate the energy improvement and reuse of modular housing solutions in relation to the design of near-zero energy buildings.

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POST-WORLD WAR II PREFABRICATION AND INDUSTRY IN CENTRAL-SOUTHERN ITALY: TWO CASE STUDIES, IN CAMPANIA AND LAZIO

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Abstract

The paper presents two emblematic examples located at the extremes of the most significant phases of building industrialization in Italy. The first example, in Campania, is the *Pozzi Ginori* complex in Sparanise (1960-1963) by Luigi Figini and Gino Pollini; the second, in Lazio, is the *IBM Italia* factory in Santa Palomba (1979-1984) by Marco Zanuso. These industrial complexes both belonged to a program for the industrial development of the most disadvantaged socio-economic areas in Italy. These two industrial plants, resulting from studies by well-known designers, represent the transition from formal and technological experimentation to an adaptation to standard production. They involve the whole project and the construction site and are characterized by the concentration of various innovative aspects, such as the treatment of finishing materials and a sophisticated relationship between building typology and landscape context.

Keywords

Industrialization, Figini and Pollini, Marco Zanuso, Italy, Factories.

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1. INTRODUCTION

These two case studies mark the extremes of the most relevant phases of building industrialization in Italy. They summarize the developments of this theme in the field of factory buildings, represented on different scales, from design and construction experimentations to innovation in the treatment of finishing materials, and the exploration of the relationship between the production site and the landscape in transformation.

The *Pozzi Ginori* complex in Sparanise (1960-63) took shape in the early Sixties, within a framework characterized by the use of components inaugurating the development of prefabrication in the industrial sector after the spread of French systems in the residential field. On the one hand, the mature phase of the Seventies and Eighties marked the profile of the *IBM Italia* factory in Santa Palomba (1979-1984), where relationships replaced the minute scale of construction detail with the surrounding landscape. On the other hand, the settlement scenario was common in Central and Southern Italy, where the process of industrialization was slower than in other areas, and the distance from the poles of Northern Italy was more marked. The *Pozzi Ginori* complex in Sparanise was, in fact, part of the industrialization program developed by the *Cassa per il Mezzogiorno* for the socio-economic and industrial growth of the regions of Southern Italy, such as Abruzzo, Molise, and some areas of Lazio and Marche, through the establishment of public and private industries. The district of Sparanise, in the countryside of Caserta, was one of the active hubs in Campania and hosted some episodes of significant construction interest [1]. It is worth mentioning, as contemporary experiences of the *Pozzi Ginori* production site – all based on the use of reinforced concrete and with a widespread presence of prestressed solutions – the *Siemens* factory in Santa Maria Capua a Vetere (1961-62) by Antonio Antonelli and Manfredi Greco, with the structural consultancy of Elio Giangreco and Giuseppe Giordano, the SIAG (*Società italiana per la produzione di agglomerati di sostanze vegetali o minerali*) plant with housing and social services (1962) by Angelo Mangiarotti and Aldo Favini in Marcianise, up to the subsequent cases of the *Olivetti* factory of Edoardo Vittoria and Marco Zanuso (1968-70), also in Marcianise, and the *Kodak* factory in Caserta (1976) by Gigi Ghò and Favini. These works «constitute the tangible testimony of the unexpected confrontation of the most cultured Milanese circles, with the inviolate territories of the *ager campanus* ("costituiscono la testimonianza tangibile dell'inatteso confronto, tra gli ambienti nilanesi più colti, con i territori inviolati dell'ager campanus")» [2].

On the other hand, the architectural project designed by Zanuso for *IBM* belongs to the *ager romanus*, which was part of the process of constant and often disorderly growth that, since the Sixties, has involved the suburban areas of the capital. Some rare autonomous demonstrations of architecture for the industry stood out in an area populated by an anonymous building fabric. For example, the *Reliability and Qualification* building of the large *Enea Research Center* at Casaccia, by Gregotti Associati (1985-88), belonged to this category. It was the only other space for work in those years in the Roman area that critics recognized. The building was qualified by the elegant simplicity of the solution that resolved the theme of the amorphous, full-height container typical of laboratories. This was also the context of the Santa Palomba complex, located in a south-eastern area of the Roman countryside, which housed an industrial sector of about 100 hectares, thanks to the good connections and opportunities offered by the capital's market.

In addition, an element that united the two factories was the Milanese cultural matrix of the designers. Their influence extended throughout the country, intervening to varying degrees in the Italian debate on the industrialization of construction and marking the two settlements with the stylistic features of the different cultural seasons to which they belonged.

The first, by Figini and Pollini, coincided with the founding phase of rationalism and modern construction in Italy, whose influences supported developments in the post-war period; the second, by Zanuso, corresponded to the later debate and the mature formation of the scenarios of the second half of the twentieth century, connotated by the theme of industrialization.

The consultation of bibliographic sources, investigation in public archives, and the archives of designers and companies, which preserve the original materials of the projects and the site documentation, allow for reconstructing some currently unpublished aspects relating, in particular, to the technical and construction peculiarities of the works.

Finally, both cases show the relationship between the designers and the industrial sector. The designers are attentive to the market's needs and are often directly involved in the study and production phase of the industrialized component. Also, they are interested in experimenting with the possibility of renewing the architectural language through the adoption of new ways of building and adherence to the updating of production processes. Companies are oriented toward confirming the validity of construction systems by reducing time and costs and showing sensitivity to the renewal of the image.

The study is part of a project funded by the European Union – Next Generation EU – PRIN 2022 "Light prefabrication: knowledge, monitoring, and redevelopment of the architectural heritage of the second half of the twentieth century in the regions of Calabria and Lazio".

2. THE *POZZI GINORI* COMPLEX IN SPARANISE (1960-1963)

In the Italian architectural and construction experimentation conducted in the Fifties and Sixties, modular roofs with standard spans between 15 and 20 meters assumed importance in the industrial building sector. They distinguished those situations where the processes of structural conception and morphogenesis of space were combined in a synthesis in which «the structure results as a form of expression» [3]. In these cases, the designers translated the structural theme into a construction matter affecting the functional flexibility and the adaptability of the planimetric layouts, as well as the environmental factors (lighting and internal ventilation). The technique of prestressed reinforced concrete supported this research and suggested solutions for larger spans, finding, from the mid-1950s, applications in cast on site and prefabricated roofs using thin vaults, sheds, and domes schemes [4].

The *Ceramica Pozzi* complex (1960-63) in Sparanise, near Caserta, belonged to this background. It occupied an area of about 850,000 m^2 and was realized according to an urban architectural plan to ensure the conservation of large pre-existing green areas. The creation – with the material from excavations – of an artificial hill, and the composition – through recurring techniques and materials – of the buildings were comprised in a master plan aspiring to invest «the land with itself» and to give «a new face to the landscape of Caserta» [5] (Fig. 1).

The master plan and the architectural project were developed by Luigi Figini and Gino Pollini, who here expanded their architectural research on the industrial spaces outside the *Olivetti* microcosm of Ivrea, where they had worked since the 1930s. Silvano Zorzi and Gianluca Papini developed the structural design, while technicians of the engineering society *Tekne*, headed by Carlo Rusconi Clerici, took care of executive planning and supervision of the works. The complex was built by the company *Sogene*. Gianluca Papini was the pivotal figure of the group, which interacted in that period both with Figini and Pollini and *Sogene* itself for collaborations, including the *Avon* factory in Olgiate Comasco.

The Sparanise complex consisted of four industrial groups, briefly called “Vernici”, “Laminati”, “Calandrati” and “Ceramica”, which were flanked by the buildings of the common services (central offices, workshop, and entrance). Each building was planned on the basis of functional requirements with specific technical-construction schemes and details without losing the system-

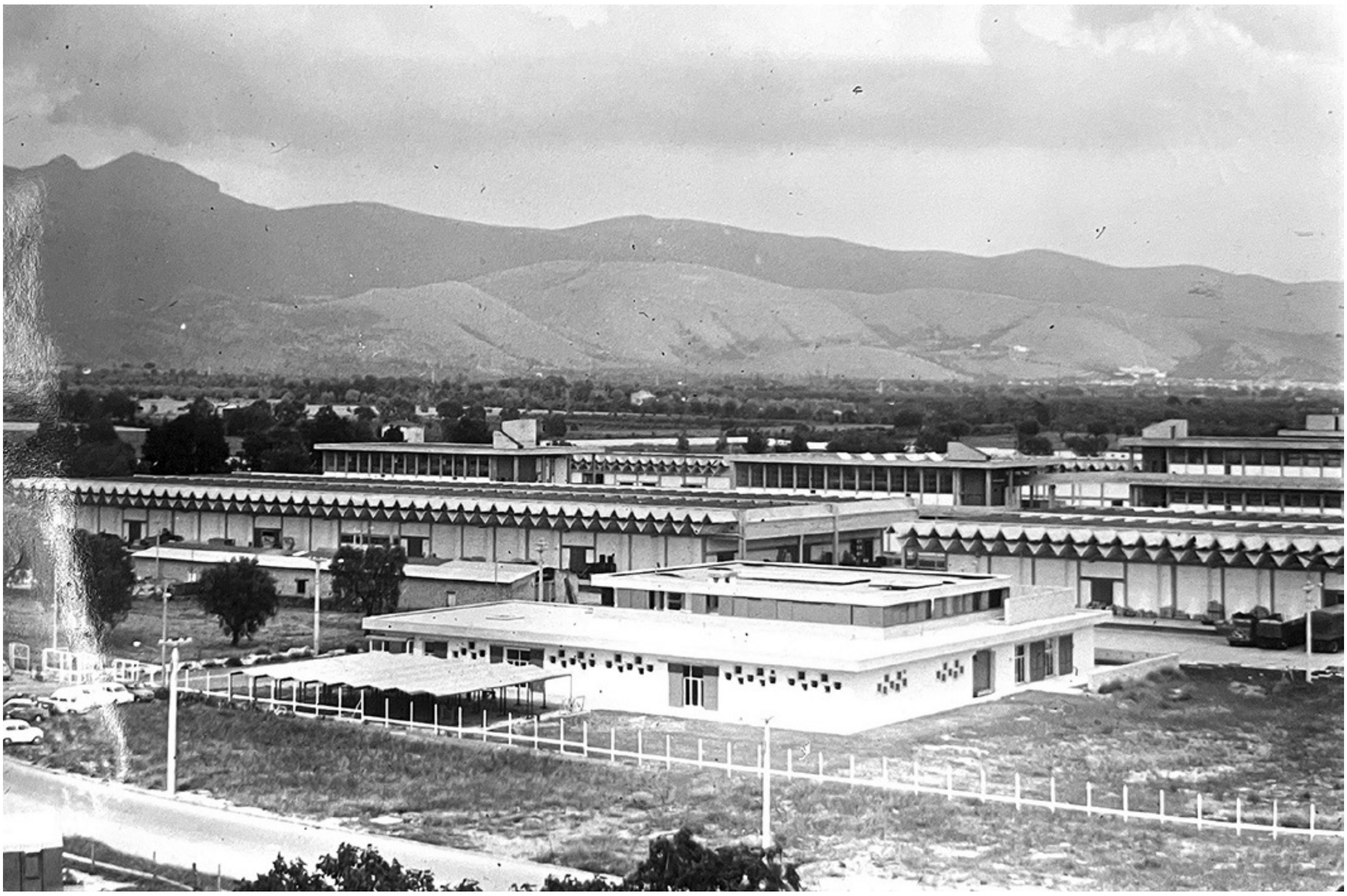

Fig. 1. Pozzi Ginori *complex in Sparanise, view of the industrial plant. Source: courtesy of Ministero della Cultura-Archivio Centrale dello Stato, SGI-Sogene collection (subsequent citations ACS-SGI, authorization for use n. 2877/2024), folder 4091-266.*

atic vision of the complex, underlined by the materials and techniques selected: exposed concrete contrasted with traditional and prefabricated external walls. The examination of some of the buildings of the complex clarifies the analysis and indicates the relationships between structure, construction and space in the composition of the industrial volumes. The "Vernici" group was the first to be built and covers an area of approximately 27,000 m^2, distributed in four multi-story buildings, one two-story office building and services volume, and six single-story industrial buildings. The multi-story buildings have exposed the cast on site reinforced concrete structure, external walls made of concrete blocks, flat slab floors, and roofs solved with hollow tile floors.

The "Laminati" and "Calandrati" units occupied a total area of 21,000 m^2. The construction and aesthetical system arranged by the designers was based on the cast on site reinforced concrete structure organized on the standard span of 20 m, on which the roof was placed (Fig. 2). Its structure consisted of prefabricated prestressed reinforced concrete beams (B.B.R.V. system), with a T-shaped section, 90 cm high at the supports and 1 m high in the centreline, arranged with a center distance of 2.50 m [6] (Fig. 3). The "Ceramica" group occupied an area of 38,000 m^2, divided into four buildings, of which the two largest had a structure of cast on site pillars and omega section beams placed on a square grid (10 m x 10 m), on which the roof was arranged. The complex, which is still in use, although not in its entirety, is no longer managed by *Pozzi Ginori*. In 2008, it was declared a work of significant interest by the Italian Ministry of Culture and subject to protection restrictions.

The one-story buildings of the "Vernici" group are distinguished for their construction interest in the roof and are capable of generating a relationship between the construction scheme, functional needs, and definition of the industrial space. In fact, although two of the buildings were storage spaces, the solution adopted stood out for the elegant composition of the prefabricated components and the full compliance with the microclimatic conditions required inside. The warehouses were intended for the storage of paint packs that were of considerable volume and low weight. To maximize storage capacity, no windows were planned on the perimeter walls to increase the stacking height of the packages, and given the high flammability of the products, to avoid the incidence of direct light inside whilst ensuring good thermal insulation. The most common option, the shed roof, would have required the adoption of sunshades to screen the windows and the insulation of opaque and transparent surfaces. Therefore, designers chose to use prefabricated components, reducing the execution time and becoming the hallmark of the project. The Sparanise complex is, in fact, emblematically identifiable with the iconic series of prefabricated prestressed reinforced concrete large tiles with a V-shaped section used for the roof structure. The large tiles were placed, on the standard span of 20 m, on perimeter beams set on the pillars arranged at a distance of 5 m or, in the case of buildings with greater depth, on intermediate supports, also organized on a modular layout of 5 m. The V-shaped components had asymmetrical arms with a thickness of 6 cm for the long arm and 8 cm for the short one. They were arranged in two orders: the lower one formed by V with the vertex placed at the bottom and the upper one composed of rows of upside-down elements (Fig. 4). Skylights that diffused the light inside were positioned between the two layers.

To facilitate the connection between tiles and beams, the section of each element was equipped with a 20 cm thick concrete raised part. The connection was completed by means of two bars protruding from the beam that crossed the tile for the entire height. Once the components had been assembled, the connection was completed with cement mortar poured to join the large tiles to the metal bars [7]. The prefabricated components, which had an overhang between 1.5 and 5 m, were finished on the head with a dripstone, cast on site using formworks supported by the same tiles.

The roof construction system also affected the composition of the façade. The rhythm of the prefabricated elements was underlined by the play of lights and shadows, marking the succession of large tiles, and corresponds with the rhythm of the external walls, arranged between exposed concrete pillars and advanced compared to the walls to define a thin shadow [5]. Downpipes make a third and thinner pattern. In this composition of lines and planes, it is possible to read the essential design of the façade, all based on the figurative use of the elementary

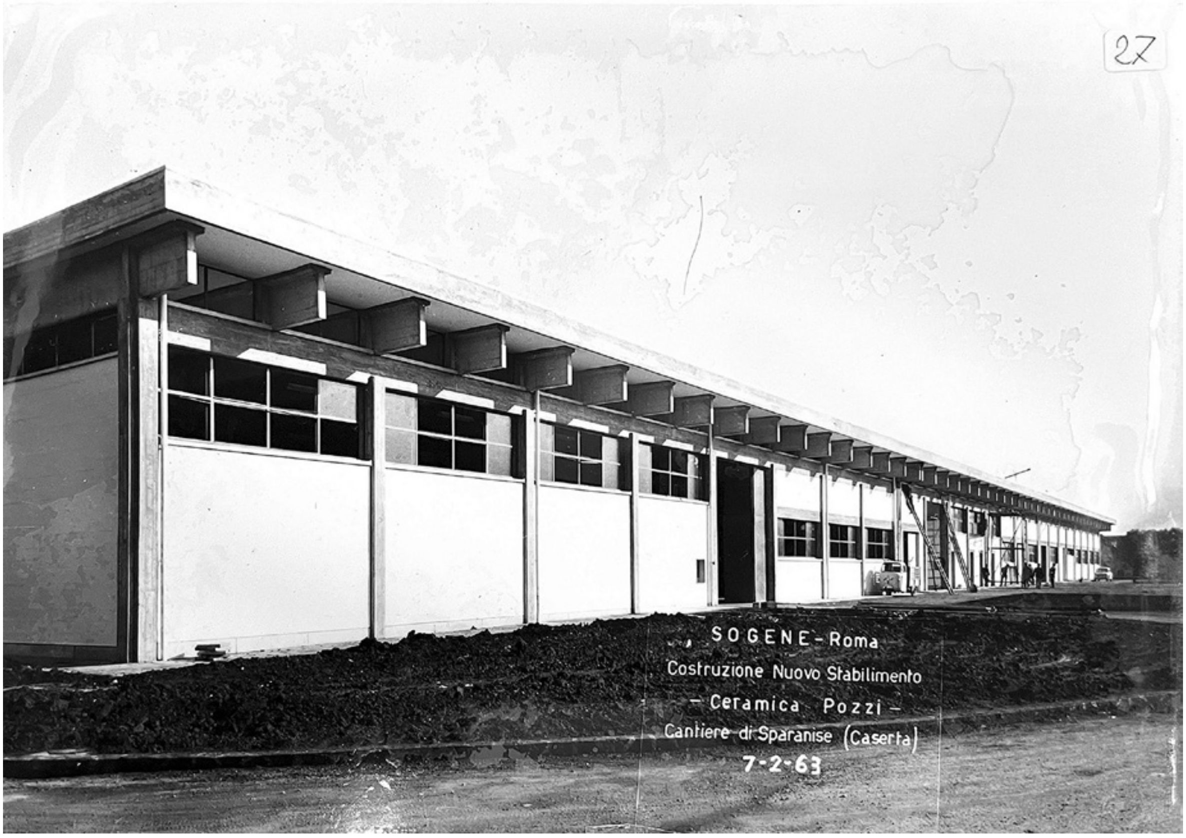

Fig. 2. Pozzi Ginori *complex in Sparanise, view of the "Laminati" building. Source: ACS-SGI, authorization for use n. 2877/2024, folder 4091-72.*

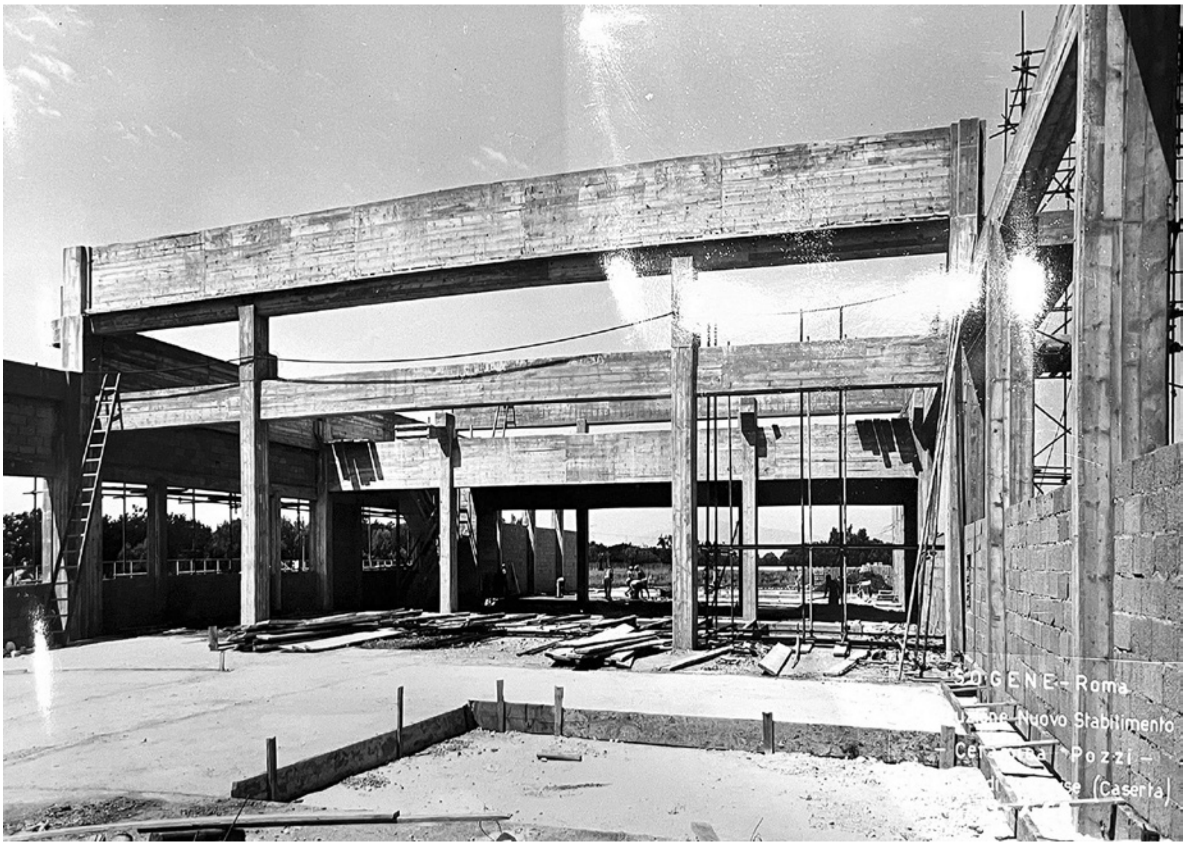

Fig. 3. Pozzi Ginori *complex in Sparanise, view of the "Calandrati" building site during assembly of the T-shaped roof beams. Source: ACS-SGI, authorization for use n. 2877/2024, folder 4091-71.*

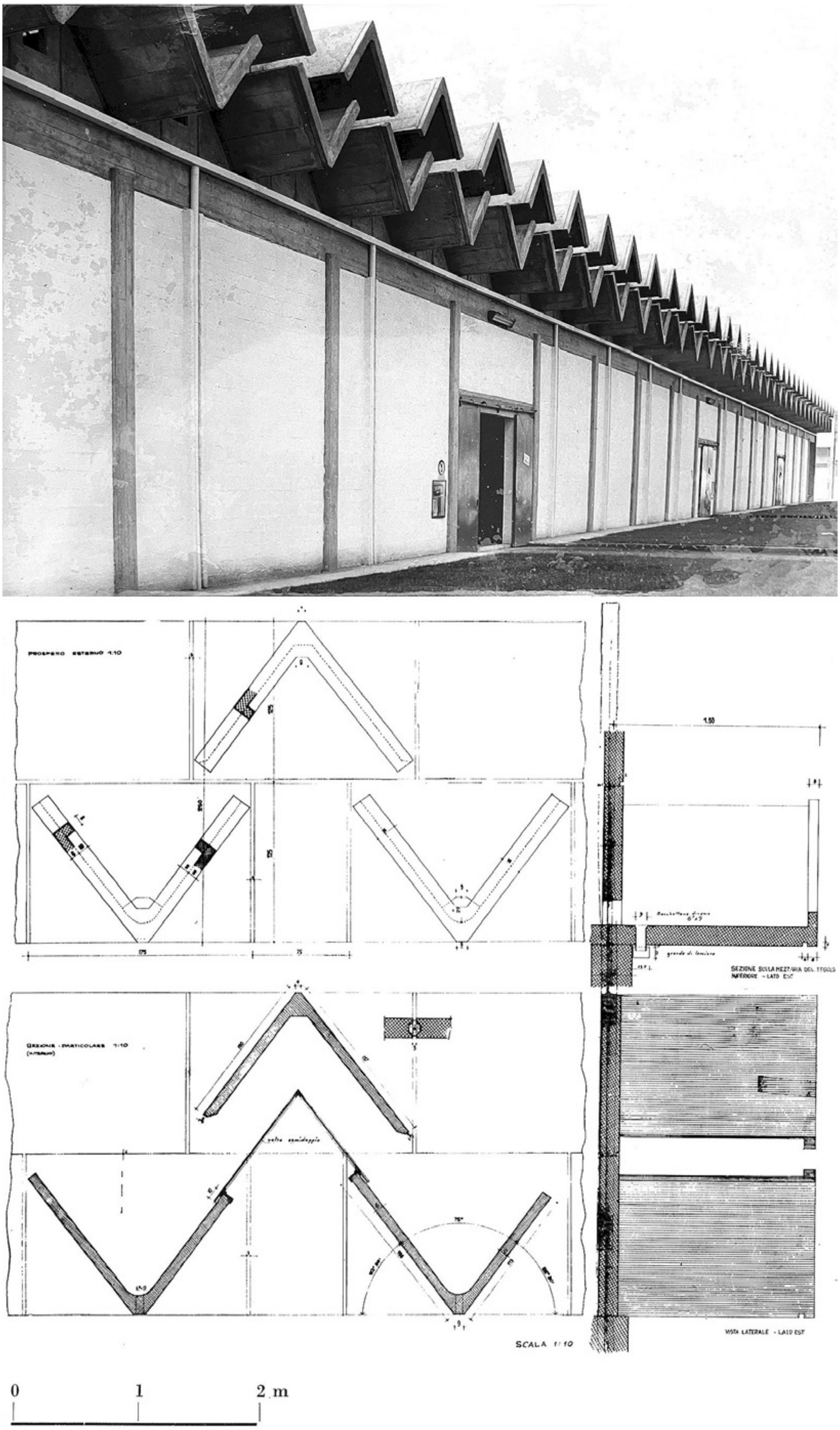

Fig. 4. Pozzi Ginori *complex in Sparanise. Top: view of the "Vernici" building. Source: ACS-SGI, authorization for use n. 2877/2024, folder 4091-72). Bottom: details of the V-shaped roof tiles. Source: [5].*

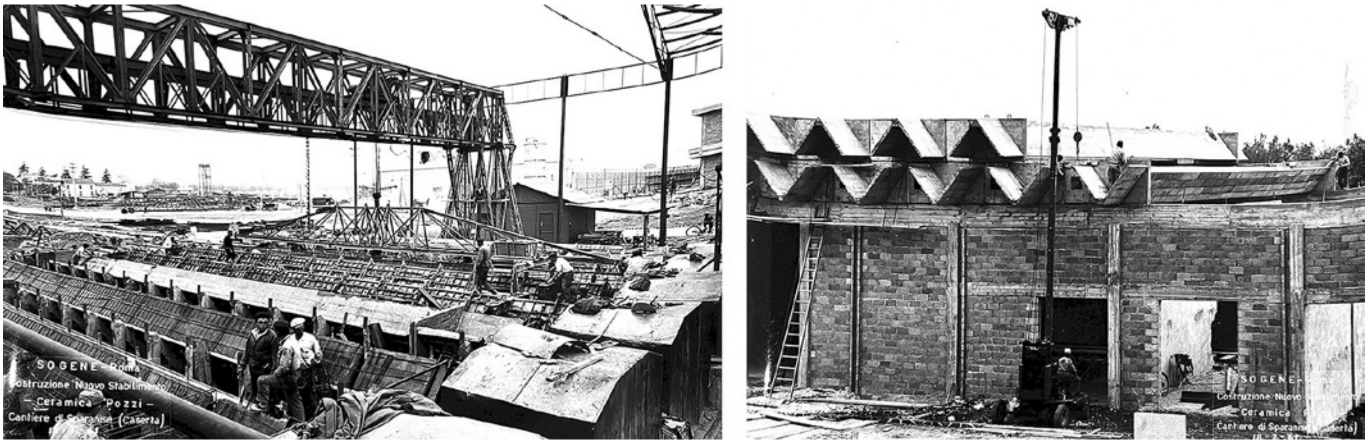

Fig. 5. Pozzi Ginori *complex in Sparanise, "Vernici" building. Left: view of the V-shaped roof tiles prefabrication site. Right: assembly of the V-shaped roof beams. Source: ACS-SGI, authorization for use n. 2877/2024, folder 4091-71.*

construction parts: large tiles, pillars, walls, and downpipes. The key element is the large tile, an expression of the design of the prefabricated component that marked the development of industrial buildings in the 1960s, tracing one of the evolutionary lines of prefabrication in Italy. Thanks to the elegance of the component resulting from the design awareness of Figini and Pollini and the mastery of Zorzi, the buildings of the "Vernici" group of the Sparanise complex participated in this experience, testifying to an evolutionary phase of Italian prefabrication that preserved the construction site as the main context for the production and assembly process of components.

The large tiles were produced in a prefabrication area inside the construction site, where three to four components were produced daily (Fig. 5). The prefabrication machine set up in Sparanise contained in *nuce* the features of building components' industrial production that Zorzi, considering the buildings of the "Vernici" group, indicated as the following: reuse of molds (those for the tiles were metal elements), the use of vibrators applied to the formworks and the concrete vacuum technique (introduced in the complex to reduce execution times and allow the contemporary construction of the different groups of the *Pozzi Ginori* factory), the pre-stressing of the elements with adherent wires (for each tile there were twenty strands with seven steel wires with a diameter of 3.15 mm). In brief, the system of techniques and tools distinguishing the industrial production of building components was anticipated in Sparanise, indicating the evolutionary phase of the traditional building site that enriched its layout and organization in this period [8]. In Sparanise, the devices for handling the components and the internal service paths related to the two poles of the building site (the production area and the construction one): each large tile, once taken from the storage area, was transported by truck (each tile weighing, in reason of its length, between 12.8 and 14.5 tons) to the construction area, where it was lifted by cranes for assembly.

3. THE *IBM ITALIA* FACTORY IN SANTA PALOMBA (1979-1984)

Ten years after the project for the IBM offices in Segrate (Milan, 1968-1976), the prestigious multinational corporation commissioned *Studio Associato Marco Zanuso e Pietro Crescini* to design a new plant in Italy intended to produce computer equipment. The theme of the industrial building has been recurring in the repertoire of Zanuso's works since 1951, with the design and construction of the warehouses and offices of the SIMA company in Jesi (Ancona). In Italy and abroad, with important commissions, the architect's thirty-year commitment alternated the study of the factory with industrial design, whose reflections also flowed into the technological declination of architectural projects. His interest in the workplace developed through his prolific journalistic production and his academic commitment at the Faculty of Architecture of *Politecnico di Milano*, where, since 1961, Zanuso had been teaching courses dedicated to construction materials and design for industry. The results of this incessant work, confirmed by continuous awards [9], testified to Zanuso's interest in a building typology in which he

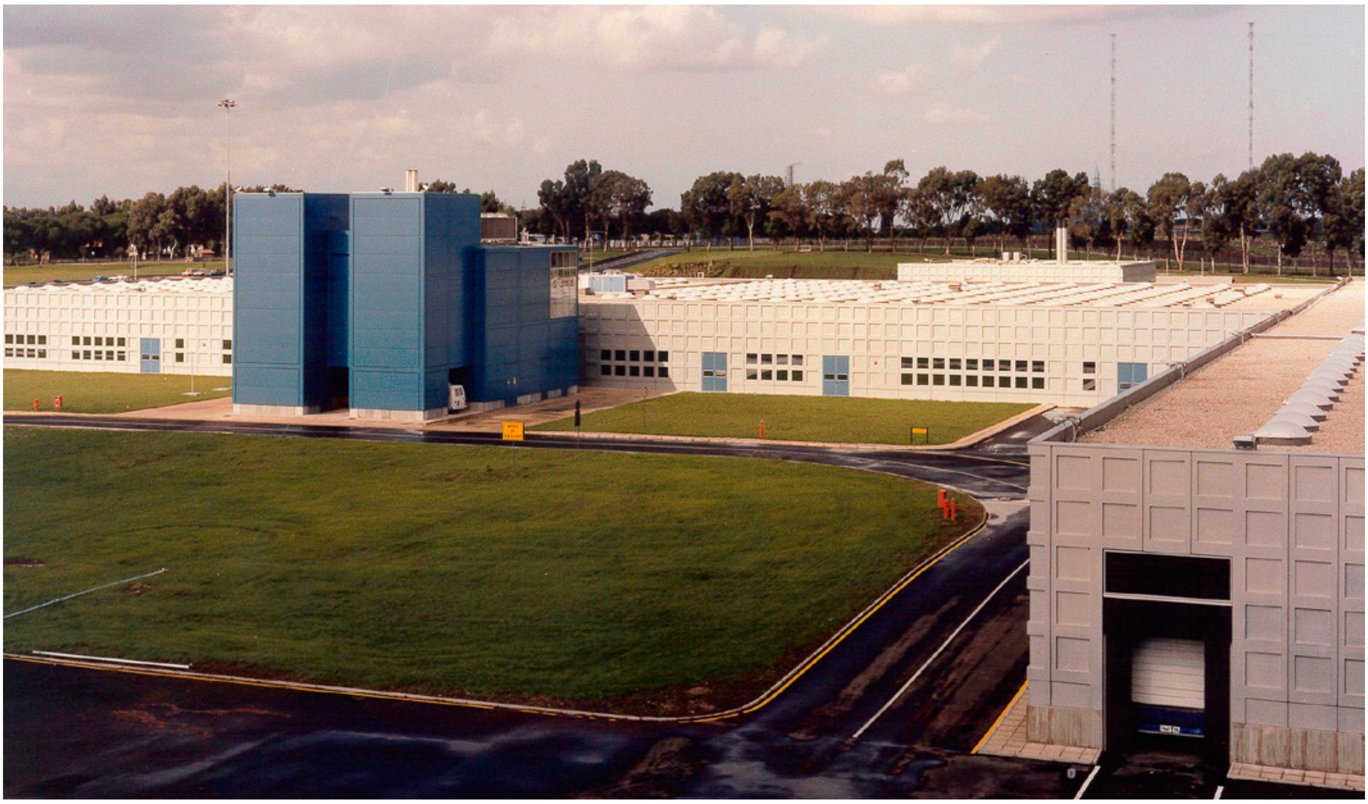

Fig. 6 – IBM Italia *factory in Santa Palomba, view of the industrial plant. Source: courtesy of ICRAS S.R.L., http://www.icras.it.*

could experiment with technological updating. This topic has been investigated for a long time, referring to the theme of modernity in the industrial age.

Also, in this new role, the client shared a meta-design program with the designer, which the company organization strictly conditioned. The Santa Palomba headquarters was inaugurated in 1983 and confirms the premises that had marked the Segrate complex (Fig. 6) and were dictated by the American multinational corporation. On that occasion, Zanuso affirmed that IBM was an entity consisting of «open systems of superior complexity, characterized by strong flexibility in the coordination of roles and significant dynamism in transformation and development for adaptation to accelerated technological innovations ("sistemi aperti di complessità superiore, caratterizzati da forte duttilità nel coordinamento dei ruoli e di rilevante dinamicità nella trasformazione e nello sviluppo per l'adeguamento alle accelerate innovazioni tecnologiche")» [10].

The concept was also validated for the Santa Palomba program, which had a development forecast up to 2000. The subsequent project refinements determined the final layout: the industrial complex had to include a plurality of functions (areas for production operations of automation systems for companies, administrative workspaces, general services, and warehouses) and ensure maximum flexibility and versatility of the workspaces. The use of a wide structural mesh and building components that could be delivered quickly to the construction site was necessary to meet the company's requests to respect the 18-month construction timeframe and construction and affordability needs [11].

The design perspective required by IBM was therefore perfectly aligned with the architect's thinking, who never failed to support the need «to intuit, in an appropriately short time, any changes that may occur, both in terms of production and research» and consequently «it is necessary to have a design system and a provision of design standards that allow us to intervene, in a short time, and with maximum efficiency» [12]. In addition, the natural integrity of the site, its «wide undulations», and «the ancient plastic of the Lazio countryside» engaged Zanuso in a «program of spatial organization ("programma di organizzazione spaziale")» that had to include such suggestions and establish a relationship between architecture and nature [13].

With the request to open the industrial complex to subsequent expansions, Zanuso set the structural scheme on an ordinary module of 14.14 m x 14.40 m, which is considered suitable for integrating and accommodating the space to produce computer equipment and administrative work. The iteration of the module determined the size of the buildings: seven parallelepipeds with a square base of 57.60 m on each side for an area of 3,300 m^2, developed on a single floor (the original program provided 17 for a total area of 200,000 m^2 [14]). In addition to the buildings, arranged side by side or staggered, there were four other pure volumes: the technical towers, 13 m high, which host the refined distribution scheme of the fire-fighting systems, the connection with the database, and differentiated conditions of comfort in all functional areas. Three towers each served two parallelepipeds, while the last served one. The connection with the towers was entrusted to ducts, passages, and walkways that freely crossed the open space. Supporting the concept of plant decentralization that would have allowed more manageable growth of the industrial settlement, the association of two low parallelepipeds and a tower was configured as a macro-module, an "organic and autonomous unit" destined for serial repetition.

The essentiality of the spatial and functional organization corresponds to the ordinariness of the prefabricated reinforced concrete structure, deduced from current production. Produced by *Vibrocemento* from Perugia [15] (now *Generale Prefabbricati S.p.A.*, https://www.generaleprefabbricatispa.com), the frame was formed by pillars with a square section of 60x60 cm, supported by pocket foundation cast in place (Fig. 7). The infill

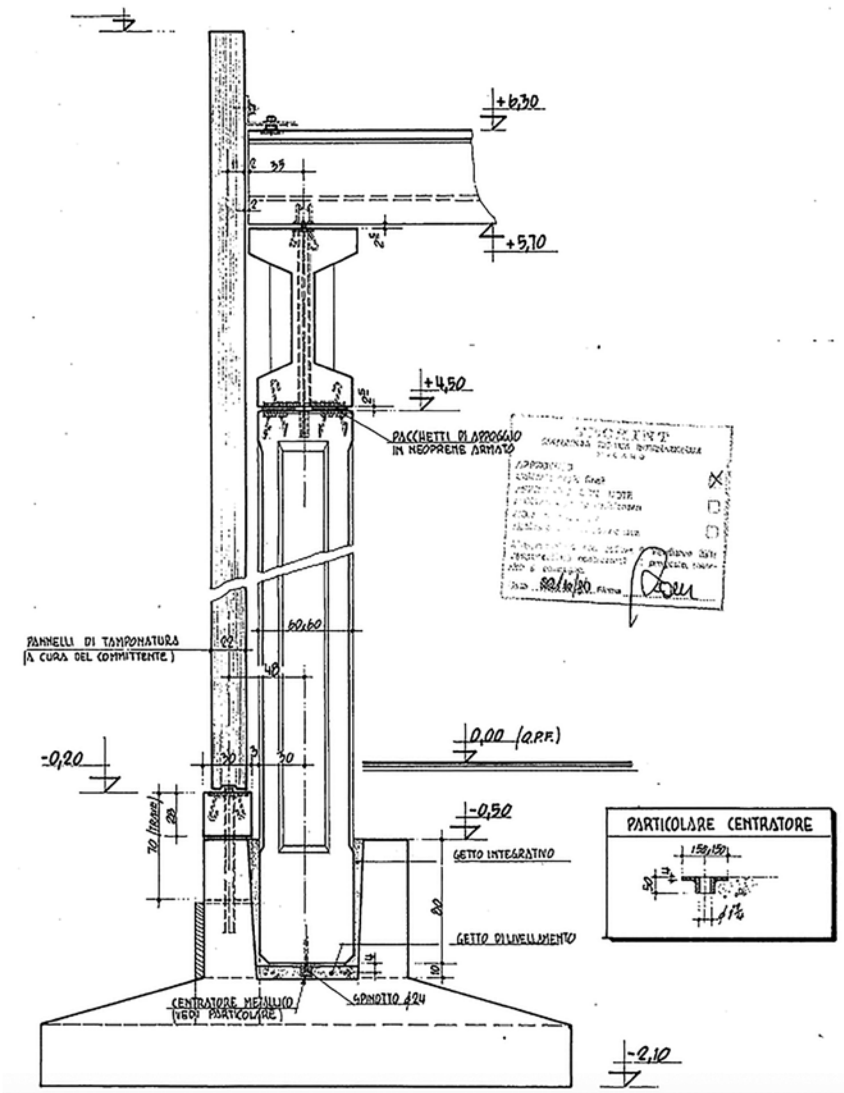

Fig. 7. IBM Italia *factory, a section of the structure: details. Source: courtesy Generale Prefabbricati S.p.A.*

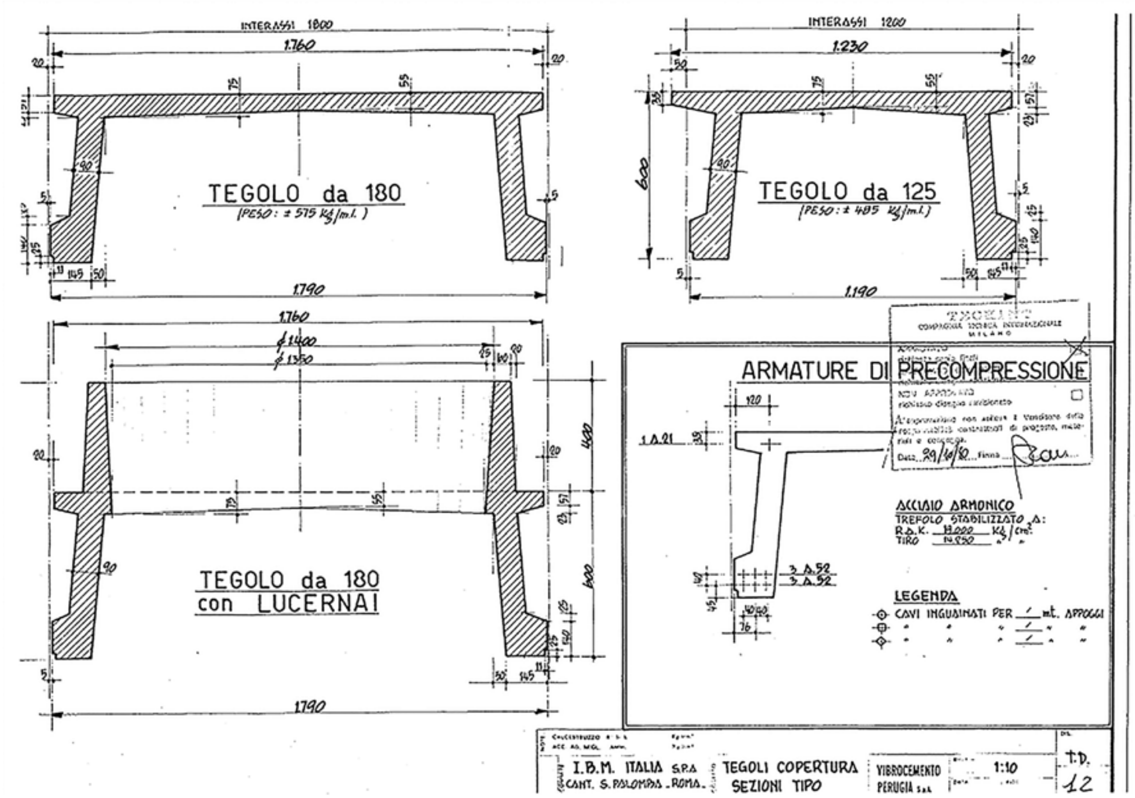

Fig. 8. IBM Italia *factory, a typical section of the roofing tiles. Source: courtesy Generale Prefabbricati S.p.A.*

panels laid on base beams made of vibrated reinforced concrete, while the roof beams had a double-T geometry and were made of prestressed reinforced concrete. The roof tiles, always in prestressed reinforced concrete, had a U-shaped geometry and were equipped with metal plates to create sliding supports (Fig. 8). The structural expansion joint is arranged on the side of two buildings. The only modification to the industrial production line concerned the tiles, some punctuated by a regular series of holes, closed by transparent resin domes with a double cavity (Fig. 9). The zenith rays of light accentuating the frame direction and the systems' texture became the only plastic elements of the interior spaces, which were left open and delimited by the walls.

Unlike Zanuso's previous experiences, where the integration between the structural part and plants' ducts emerged with an eloquent language expressing the architectural image [16], in the *IBM Italia* factory, the architect proposed not to exalt the technology [17]. Following the themes of flexibility, large planimetric extension and future expansion, he concealed static devices within pure stereometries, relegating the load-bearing elements to choice in the catalog (Fig. 10).

Fig. 9. IBM Italia *factory, view of the building site during assembly of the U-shaped roof tiles. Source: Archivio del Moderno, Fondo Marco Zanuso, Balerna.*

Fig. 10. IBM Italia *factory, the bearing structure during construction. Source: Archivio del Moderno, Fondo Marco Zanuso, Balerna.*

Moreover, this solution made it possible to speed up the administrative procedures, start the contract for the execution of the load-bearing structure during the design phase, and, consequently, commence the execution in parallel with the development of the executive design and the definition of the other main contracts [18].

The attention paid to the buildings' envelopes was different. Their prefabrication process was contaminated by targeted interventions decorating the components and redeeming the standardization of the catalog, providing an identity image.

Therefore, the perimeter closure of the net prisms for production was made with prefabricated modular concrete panels, thermally insulated with extruded polyurethane. 2.40 m wide and 6.90 m high, they were defined by a regular square grid of opaque and transparent parts; the latter was arranged by considering the activities executed inside. The reduced durability of concrete, which «does not resist over time, having a surface that degrades quickly and does not allow maintenance» [19], had recommended the use of polyurethane paints integrated with very light aluminum pigments, obtaining a mixture like that of paints generally used for cars [20]. The treatment gave the façades a silvery white color that enhanced the effect of the reflection of natural light, which varies at different times of the day in relation to the angle of incidence on the surfaces.

Today, unfortunately, with the transfer of ownership to another company, the buildings have been standardized with an anonymous grey color. The towers, true hinges of the composition and prevalent from an architectural and chromatic point of view, technologically characterized the entire complex. Unlike the low volumes, the towers had a reinforced concrete structure cast in place. The cladding was made of modular multilayer aluminum panels with horizontal development, framed within a large weave of uprights and beams, anchored to a galvanized steel substructure that guaranteed the movements necessary to absorb the expansion. Produced by *ICRAS S.R.L.* of Rovereto, the panels were dark blue with a semi-glossy effect and consisted of two sheets coupled to a central core in thermoplastic resin with mineral padding. The panels were subjected to milling and subsequent bending techniques to obtain large backgrounds in absolute flatness. The abstract character of the cladding was enhanced by the hidden fasteners, made possible by the particular flap of the side edges that emphasized the sharp edges and the Cartesian matrix of the joints, ranging from 7 mm to 30 mm [21].

4. CONCLUSIONS

Among the different types of buildings, the industrial building is perhaps the one most constrained by both the complexity of the production and organizational processes and the associated services. Nevertheless, many authorial examples and authentic monuments of modernity can interact with and contribute to their development on the territory. The two complexes presented here are exemplary cases of industrial architecture in Italy, not only because they have polarized the attention of critics and outlined new research paths but because they represent the cultural and professional phases accompanying the theme of prefabricated buildings in our country. In the Sixties, prefabricated building systems were essential for optimizing construction processes and economic requirements, particularly in production buildings.

The Sparanise factory seemed to attest to the most enthusiastic technological and formal experimentation expressions. The prefabricated component of prestressed concrete – anomalous compared to the production of Figini and Pollini – was exhibited to obtain an architectural value. On the other hand, at the end of the following decade, Zanuso testified, through the revision of the language, to the downsizing of expectations, moving towards an approach less contaminated by trends and confronted himself with a simple, almost anonymous construction scheme, with ordinary structural spans, reserving the completion and finishing parts for experimentation.

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Authors contribution

Conceptualization, methodology, validation, S.M, L.G.; writing, review & editing, S.M, L.G.; resources and data curation, F.S; editing, F.S.

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THE ITALIAN EXPERIENCE IN PRECAST CONSTRUCTION IN THE SECOND HALF OF THE 20TH CENTURY: SYSTEMS FOR INDUSTRIAL BUILDINGS

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Abstract

The developments in concrete prefabrication techniques from the second half of the 20th century, particularly in Italy, have established these methods as a dominant force in the construction of industrial buildings. This period offers a valuable opportunity to explore the industrialisation of the construction sector. The roots of this transformation can be traced back to the 1920s, when a highly rational approach to building design and production processes began to take hold in industrial construction. This rationality persisted into the post-World War II era, where technological advancements in materials enabled the creation of innovative and daring structures for industrial purposes. The industrial boom further fueled the demand for new buildings to be constructed rapidly, ensuring swift production capabilities. This article aims to provide an overview of the key precast reinforced concrete construction systems that formed the backbone of industrial construction in the post-war period. During this time, industrial construction fostered experimentation and the development of cutting-edge techniques, achieving significant results across various fields of application. The article offers a taxonomy of the main systems used during the period under review, with a particular focus on structural systems, ranging from those partially cast in situ to fully industrialised systems, as well as on building envelope elements. The goal is to provide a comprehensive understanding of the critical role of precast systems in Italy's industrialisation.

Keywords

Architectural engineering, Italian precast construction, industrial buildings, History of 20th-century construction, Reinforced concrete buildings.

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1. INTRODUCTION

The ontological singularity of industrial construction is its relatively short history, which detaches it from the value and semantic categories proper to residence. On the other hand, the matured environmental sensitivity is relevant regarding land consumption and its high impact on the quality of anthropised space [1]. Beginning with the building types generated by the Second Industrial Revolution and the striking examples that characterised the phenomenon of Universal Expositions, industrial construction also found its modernity in the period between the two world wars, especially in the 1930s immediately following the development of the 1929 economic crisis [2].

The fact that the functional characteristics of the industrial building require internal clear spans of 10-15 m makes the roof the technically and formally characterising element of the specific typology [3]. Here too, reinforced concrete, which has been proposed by Hennebique as early as 1894 in the sheds of the Saint-Ouen refineries and "poetised" by Maillart at the beginning of the 20th century, tends to replace the classic metal solutions of the tie rod and rafter (Polonceau and triangular trusses), the three-hinged arch and portal frame that characterised industrial construction in the second half of the 19th century, projecting on this typological category design features of absolute methodological clarity [4].

In the 1940s and 1950s, new solutions were inspired by what was developed in the 1920s and 1930s about thin curved slabs and, more generally, double-curved surfaces. The general analytical treatment for the membrane analysis of rotating and translating surfaces is due, between 1928 and 1933, to Dischinger and Finsterwalder, who propose some covers that have become paradigmatic. Furthermore, in 1933, the magazine *Construction et Travaux Publics* published an article by Freyssinet dedicated to prestressed reinforced concrete. Synthesising all this wealth of ideas was Edoardo Torroja Miret, who, by expressing a design that legitimised technology as a source of inspiration, gave rise to a veritable School to which numerous structural engineers would refer, the most famous of whom were Ildefonso Sánchez del Río Pisón, Lucio Costa, Félix Candela, Eladio Dieste and, already mentioned, the Italian Pier Luigi Nervi. The latter also tackled industrialising the construction process, as it was evident that these structures' limitations resulted from the considerable cost of building on-site using essentially traditional construction techniques [5].

The return to Italy of Franco Levi, an expatriate following the promulgation of the 1938 racial laws and already Colonnetti's assistant, gave new impetus in Italy in the 1950s to studying prestressed structures [6]. The degree of maturity achieved in this field can be seen in the linear beams used for the monorail operating in the *Italia '61* event in Turin (Figs. 1a and 1b). The first precast roof element in the shape of a hyperbolic paraboloid, intended for spans of 18-20 m, is another example of the degree of maturity; it had been developed in the late 1940s, patented in Germany in the early 1950s by Wilhelm Silberkuhl and is still in production today (Figs. 1c and 1d) [7].

In Italy, however, the precasting of industrial roofing in the 1950s was heavily influenced by models developed in the pre-war period, as demonstrated by the activities of Rizzi, Donelli, and Breviglieri (R.D.B.). The R.D.B. company, which has been producing bricks since 1908, had already proposed early forms of precasting in the 1930s, such as reinforced beams made from hollow blocks, as well as SAP (*Solaio ad Alta Portata* – High Capacity Floor) and STIMIP (*Solaio in Travetti in Materiale Isolante e Pignatte* – Precast Hollow Core Slab with Insulating Material) slabs. It is no coincidence that the products currently on the market for industrial roofing utilise structural brick technology, in which the company has significant expertise. R.D.B. products, supported by the magazine *Il Laterizio* and technical manuals published by the company, became a general reference model for new producers of precast elements [8].

Similar to what happened in Italy, the situation throughout Europe is a result of the new social order complicated by the substantial blockage of activities due to the war events; in this shared context, construction responds with major public interventions characterised by formal simplification, unification of building types, compaction of housing blocks, and the meeting of art and industry. Interest in and attention to the issues of seismic safety and building energy behaviour will only arise from the 1970s onward. Since the Second World War, reinforced concrete has become the construction technique of reference for social housing and is no longer the object of patents and company specialisations.

The focus of research on building industrialisation often overlooks the use of precast reinforced concrete solutions, particularly in non-residential sectors such as industrial construction. This paper addresses this gap by highlighting the key precast building systems employed in industrial construction. Specifically, the study aims to emphasise the role of the precast industry in Italy, particularly in the construction of production facilities, whose development has frequently mirrored the country's economic growth phases. This paper provides an overview of the principal systems utilised in industrial construction during the 20th century, offering a technical perspective. Through an analysis of bibliographic sources, including contemporary volumes on the subject and

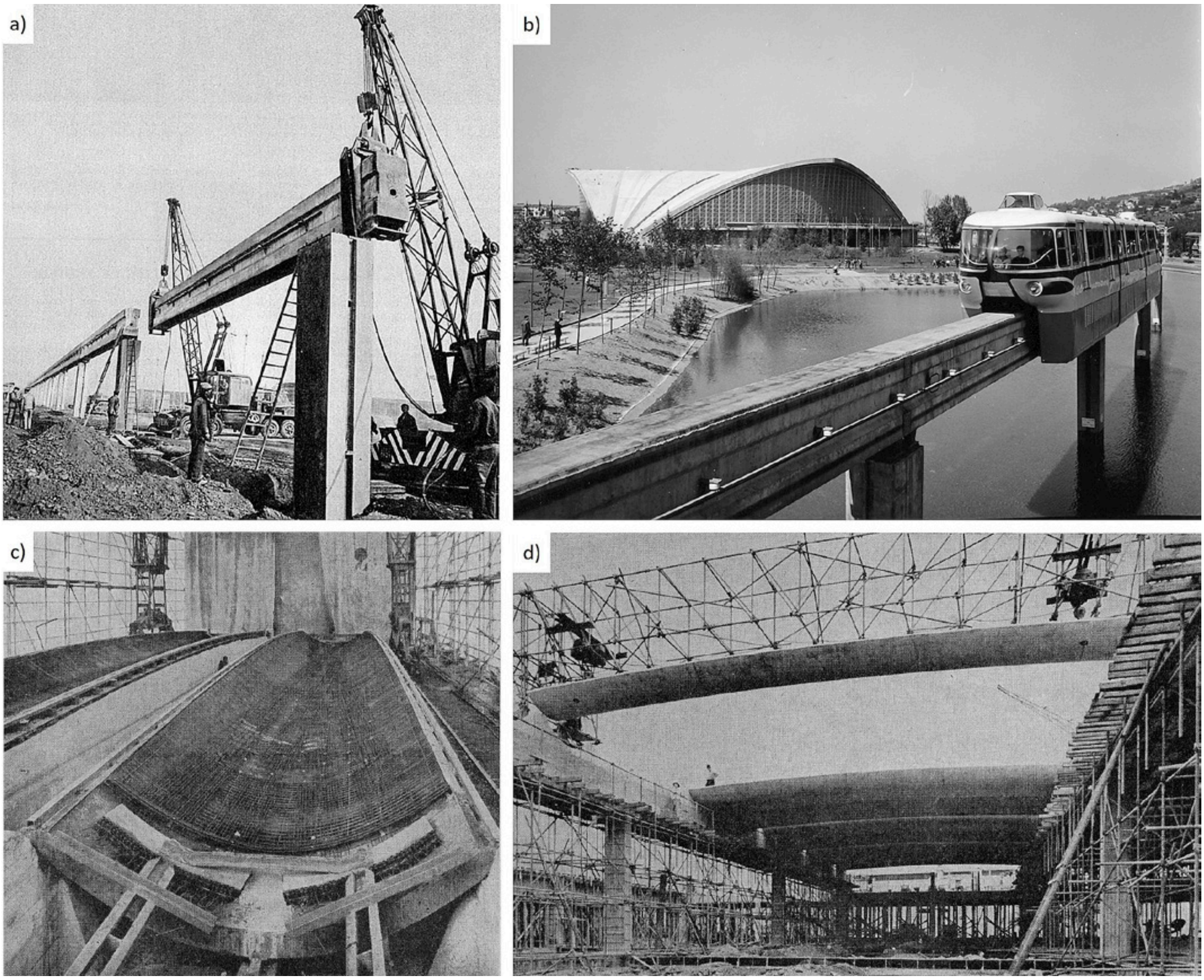

Fig. 1. *(a) Advances in precast reinforced concrete technology: assembly of the beam for the monorail built for the International Labour Exhibition, Turin 1961. Source: www.italia61.org; (b) the system in operation with the Palavela in the background. Source: Wikimedia Commons; (c) Silberkuhl production with special slab reinforcement. Source: [7]; (d) assembly of the Silberkuhl shell elements. Source: [7].*

period-specific catalogues, the paper presents the main solutions developed in Italy between 1950 and 2000. The evolution of each system is traced, showcasing the predominant types that became widespread from the mid-20th century onwards and establishing an evolutionary path among different types. In particular, the analysis focuses on structural systems, demonstrating how roof system design led to fully precast structures. The paper also outlines the significant developments in building envelopes, illustrating how the initial emphasis on lightness and installation speed has gradually shifted towards energy efficiency, reflecting the adoption of sustainable construction practices. The presented overview aims to serve as a tool for fully understanding the main technologies employed in industrial construction during the post-war period, with a view towards their future conversion and valorisation.

2. STRUCTURAL SYSTEMS

This chapter outlines the main precast structural systems, beginning with the earliest precast construction methods, where only roofing elements were precast while structural components such as beams and columns were cast in situ. These systems include no-thrust systems (older systems) and shell structures. The former comprises trusses and barrel vaults with metal tie rods, tensioners, and conoids; the latter includes ribbed and hyperbolic paraboloid vaults. Domes, the only non-precast structures, are not utilised in industrial buildings. The inclination of the components and the specialisation of the vertical supporting structures with sawtooth shapes introduces the shed variant, a concept originating in the 19th century when natural solid lighting was required. The chapter then details how the evolution of roofing systems has led to the development of lightweight precast roofs and slabs. Finally, it concludes with a description of fully precast structural systems and specialised roofing elements developed at the end of the 20th century.

2.1. ELIMINATED THRUST SYSTEMS

Eliminated thrust systems include truss variants (Fig. 2), with continuous pitches on ridge support and barrel vaults (Fig. 3). Both systems utilise off-site precast components [8]. These systems require edge beams cast in place and oriented according to the roofing direction. A more straightforward precast method is seen in the SAP© trusses (Fig. 2a), which consist of inclined SAP© slabs formed from precast beams placed side by side, with additional reinforcement extending into the sealing ribs, which are then saturated with concrete castings [8]. Another system is the BISAP© trusses (Fig. 2b), comprising precast panel elements 0.80 m wide, with additional reinforcement for negative bending moments at the supports and roof ridge, incorporated into the sealing ribs and saturated with concrete castings. Finally, the CELERSAP© trusses (Fig. 2c) represent a system with the lowest level of precasting. These trusses are composed of prestressed concrete joists and intermediate brick blocks bonded with concrete casting, with additional reinforcement for negative bending moments. These solutions can span from 7 m to 14 m, with thicknesses ranging from 0.08 m to 0.20 m.

Additional systems include barrel vaults. The SAP© vault (Fig. 3a) consists of reinforced brick beams (approximately 5.00 m long) that form the elements of individual arches, placed side by side and bonded with concrete casting. The heads are constrained by longitudinal reinforced concrete ribs (0.30 m to 0.50 m wide). With circular shapes ranging from 0.08 m to 0.20 m thick, these vaults can cover 8 m to 30 m [9]. Subsequent productivity demands led to the development of the BISAP© vault (Fig. 3b), a system consisting of BISAP© panels (0.80 m or 1.20 m wide) shaped with a curved profile to form the vault segments. In-situ casting is limited to the sealing ribs between the panels, which are reinforced along with the spring connections. With thicknesses between 0.12 m and 0.24 m, these vaults can span between 8 m and 30 m and achieve a productivity rate of 1000 m²/day per crane.

Further advancements in precast are represented by the PANSAP© vault (Fig. 3c), which consists of 1.20 m wide BISAP© panels spanning the entire width. These vaults are finished with plaster on the intrados and range in thickness from 0.13 m to 0.25 m, covering spans from 8 m to 30 m. The ST'AR© vault (Fig. 3d) completes the range of roof structural systems, characterised by a system not based on precast elements but rather on the industrialisation of the mobile ribbing system. The essential components include special hollow bricks joined together at the top and supported by joists at the bottom. This system is designed for day-to-day work, allowing for the stripping and sliding of the rib. An interesting variant, the "conoid", creates a surface formed from a straight line with a slope of no more than 35%, moving along parallel arcs with different arrows. The scaffolding for this variant consists of fixed ribs with varying curvatures, spaced 2.00 m apart and connected with wooden joists spaced approximately 1.00 m apart. This variant, with north-facing skylights, achieves unilateral and dif-

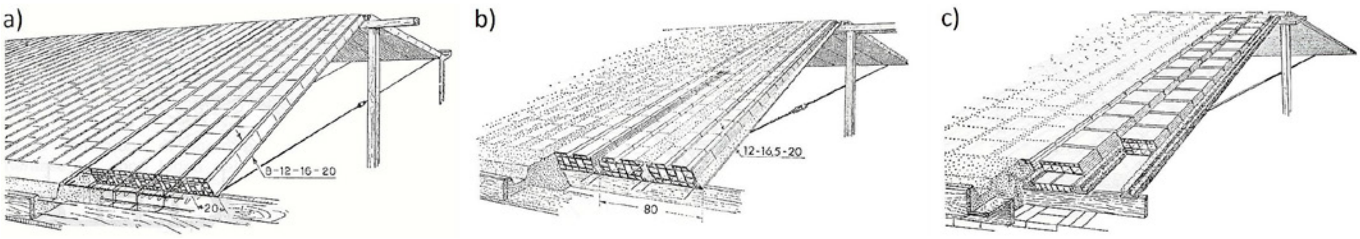

Fig. 2. *Eliminated thrust truss system: (a) SAP© trusses; (b) BISAP© trusses and (c) CELERSAP© trusses. Source: [8].*

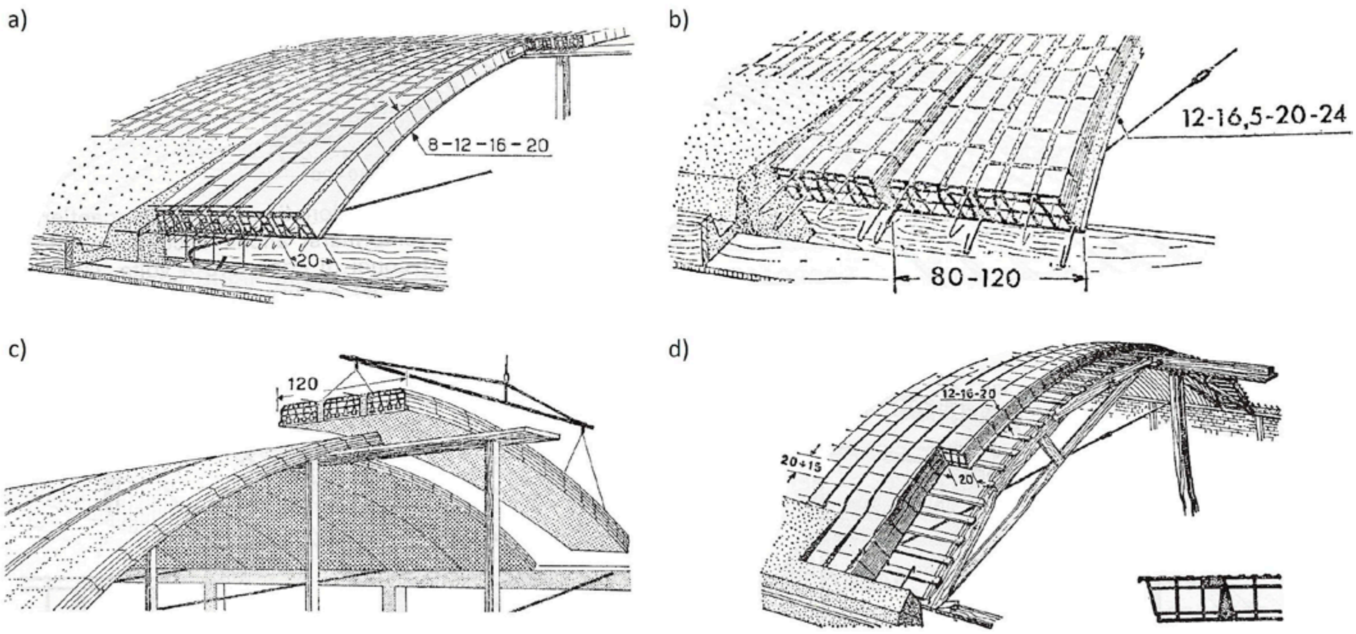

Fig. 3. *Barrel vault systems: (a) SAP© vault; (b) BISAP© vault; (c) PANSAP© vaults and (d) ST'AR© vault. Source: [8].*

fuse lighting. The ST'AR© vaults have thicknesses ranging from 0.12 m to 0.20 m and can span 8 to 26 m, while the conoid version covers spans from 8 to 20 m with similar thicknesses.

Membrane vaults represent a more complex category of structural elements in concrete. This category includes thin structures that lack flexural rigidity, do not resist shear forces perpendicular to the tangent plane, and remain undeformable under compressive and tensile stresses. It also includes hyperbolic paraboloid shells, corrugated vaults, double-curvature vaults, and beam vaults.

Hyperbolic paraboloids (Fig. 4a) are elements where the pitch is generated by the translation of a straight line that rests on two slanting directrices located in two parallel vertical planes. The generators are formed with precast reinforced brick joists spaced 0.20 m apart or with precast brick panels spaced 0.40 m to 0.80 m apart, featuring a slightly rotated straight axis. A collaborating slab, 0.03-0.04 m thick, is always provided. There are at least three construction solutions, depending on the configuration of the uprights. These structures have thicknesses ranging from 0.08 m to 0.16 m (excluding the slab) and a rectangular shape with maximum sides of 10 m to 40 m.

Another type is represented by corrugated vaults (Fig. 4b), constructed with precast joists or brick panels. The cross-section of these structural elements resembles a split unified by the reinforced upper collaborating slab. The long side of the vault varies from 30 m to 50 m with thicknesses of 0.12 m to 0.20 m, while the short side ranges from 2.50 m to 3.50 m. The main static behaviour is equivalent to a two-hinged arch with eliminated thrust.

The category of membrane vaults also includes double-curvature vaults (Fig. 4c). Geometrically, these are generated by an arc of a circle on a vertical plane that translates along another arc of a circle in a plane normal to the first. For aesthetic reasons and static simplification, the arrow of the long arch is set at 1/10 of the span, while the arrows of the side arches are equal. From a structural point of view, ST'AR© blocks on movable ribs or BISAP© panels are used. Perimeter Vierendeel arches replace the metal joints, with the lower flap acting as a tie rod, allowing support only on four pillars. Spans range from 10 m to 50 m with 0.12 to 0.16 m thicknesses.

A final type of membrane vault is represented by beam-vaults (Fig. 4d). These cylindrical vaults do not use continuous support along the spring generators but rely on terminal and, if necessary, intermediate lines. Geometrically, the most commonly used type has a ratio between longitudinal and transverse dimensions greater than 1.5. The cross-section can take on different shapes, with loads transmitted to the edge beams by gables or rigid arches shaped according to the cross-section.

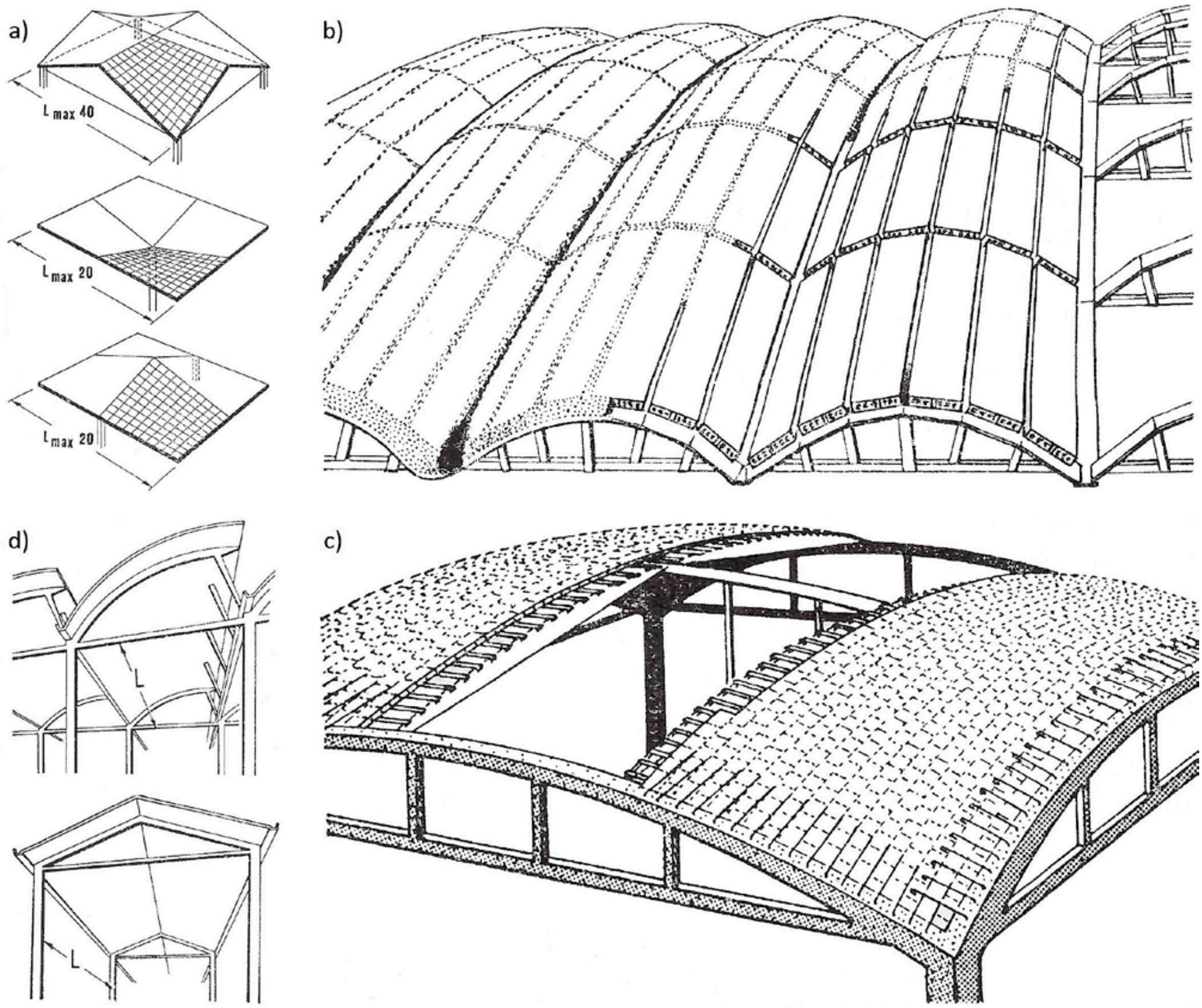

Fig. 4. *Curved surface shells: (a) hyperbolic paraboloids; (b) corrugated vaults; (c) double-curvature vaults; (d) beam-vaults. Source: [8].*

The previous systems were gradually abandoned starting in the early 1960s, as prestressed concrete technology reached a high reliability standard. Double-slope beams (usually with a 10-12% slope, also known as variable-height or delta beams) and double-T were produced based on existing German models [10].

The spread of precast construction during these years was also favoured by the significant development of the highway system, which substantially increased the production of factories located near major highways. The typical span of these beam systems ranged from 12 m to 24 m, with special series capable of spanning up to 30 m. The pitch of the beams was determined by the size of the roofing elements, which initially consisted of hollow brick slabs with spans between 6 m and 9 m or innovative prestressed components with an omega cross-section or pi-shaped profile. These double-ribbed panels, with widths of 1.20 m and 2.40 m, were optimised for road transport within the 2.40 m limit gauge. The structural grid dimensions were greatly expanded with these components, allowing spans from 12 m to 16 m. Omega slabs had a distinctive feature: they included reinforcement and supplementary castings, enabling them to be constrained in continuity with rectilinear beams, resulting in flat roofs where the slope (1-2%) was achieved by inclining the main beams. In contrast, the two-rib elements (Pi-shaped beams) were designed to form channels for collecting rainwater. These components were alternated with hollow areas covered with skylights to achieve natural zenithal lighting. These beams have a closed section, so they were secured with simple constraints, relying on weight and friction to resist horizontal forces [11].

2.2. SHED

Another solution commonly used in industrial construction was based on shed roofing systems. This approach was implemented in four configurations: macrosheds, simple sheds, double sheds, and Z-shaped roofs.

Macrosheds (Fig. 5a) consisted of rectilinear Prestressed Reinforced Concrete (P.R.C.) beams placed at an incline on pillars with double support seats. These systems typically spanned 10 m to 16 m, with inclined elements made from hollow brick slabs, which limited the spacing of the portals to 6 m to 10 m.

Another category was the simple shed (Fig. 5b), characterised by 7.5 m spaced piers with forked heads supporting prestressed concrete beams. These beams had pockets spaced 4 m apart to receive knee-high reinforced concrete beams. The structural grid in these systems typically had dimensions of 7.50 m by multiples of 4 (typically 12 m).

An evolution of this configuration is the double shed (Fig. 5c), where the primary difference is an increased distance of 12 m between the main elements. The prestressed concrete beams in this system support trusses that create the double shed configuration.

The final category is represented by Z-shaped roofs (Fig. 5d). This system's pillars are spaced 6 m to 7 m apart and support rectilinear beams spanning 20 m. At 4 m intervals, these beams carry double-knee secondary beams on both the lower and upper wings. In all configurations, the pitches are constructed using hollow brick slabs with a 4 m span.

2.3. COMPLETE PRECAST SYSTEMS

The previous systems persisted throughout the 1970s until improvements in basic materials – primarily concrete and admixtures – refined industrial manufacturing processes, and the emergence of computer tools for calculation and design impeded new construction solutions.

By the late 1980s, the market had expanded significantly, with over 250 companies registered under Assobeton in the precast structures category, specialising solely in industrial buildings. These companies were primarily located in central and northern Italy, particularly in Lombardy, Emilia-Romagna, and Veneto – the regions with the highest levels of industrialisation. Production was typically organised into complete systems that included foundation elements, columns, beams, floors, and specialised roofing components [12].

What characterises production in the late 1980s and early 1990s is the emergence of specialised roofing components, such as winged slabs inspired by the original Silberkuhl and microsheds, which are noted for their reduced thicknesses, a return to partial membrane behaviour, and increased formal variety. This production was made possible by the high standards achieved in ordinary concretes, the development of self-compacting concretes that eliminate the need for vibration, and the use of superplasticizing additives and fibres – first metallic and later synthetic [7].

Self-supporting formwork increased the speed of production related to the curing of the mix, eliminating the need for rigid prestressing tracks and heating them with

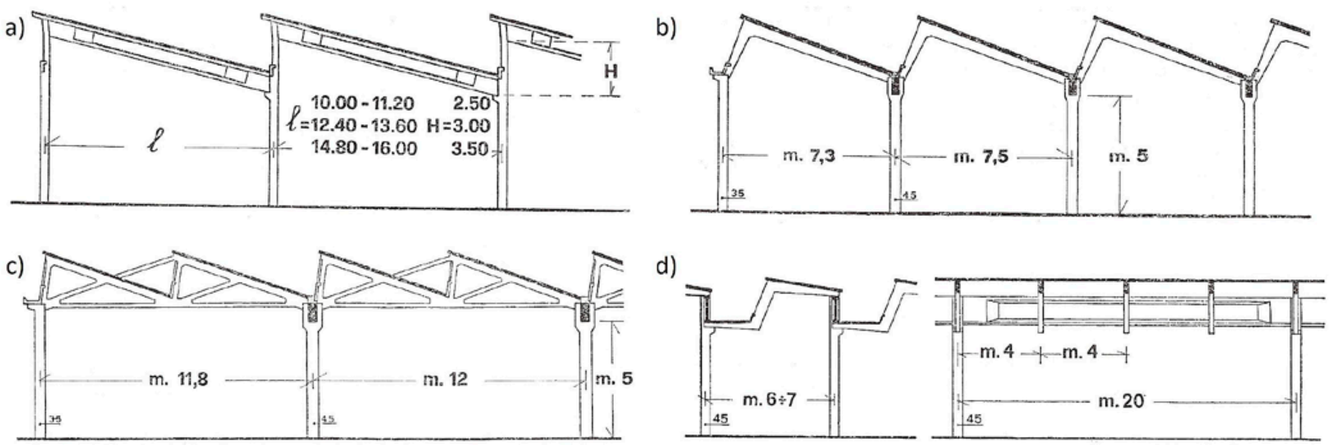

Fig. 5. *Shed system: (a) macroshed; (b) simple shed; (c) double shed; (d) zeta roofs. Source: [8].*

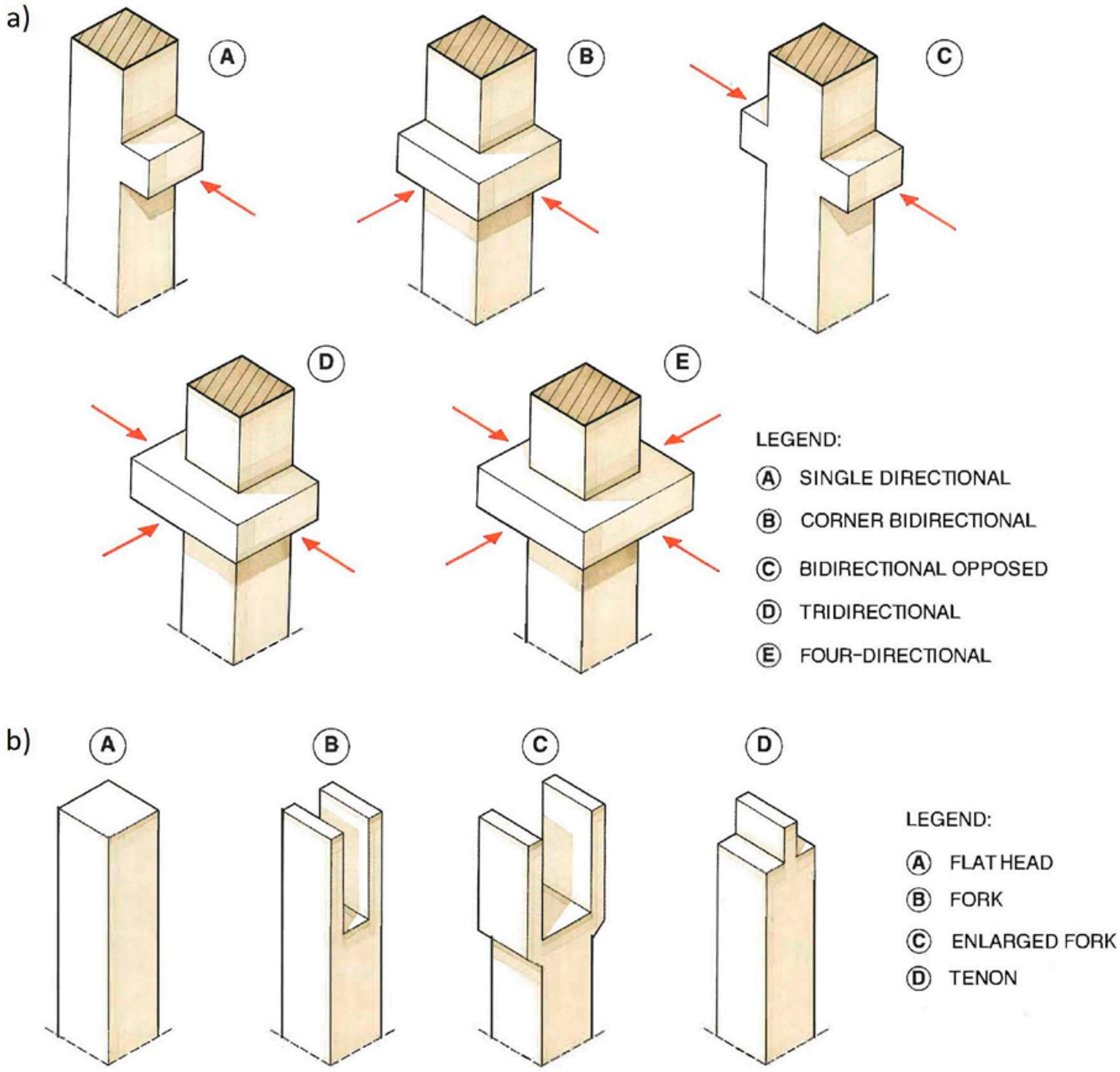

Fig. 6. *Morphology of (a) brackets and capitals, and (b) pillar heads. Source: [23].*

steam input [13]. Additionally, the finishing and accessorising of products at the plant were improved, effectively turning the construction site into a dry-assembly-only operation, significantly benefiting the overall construction process [10]. Seismic concerns were addressed by partially moving away from the trilithic system, using metal retaining inserts for horizontal components [14].

The foundation plinth receives the abutment in a socket, and subsequent grouting creates the only joint in the construction that can be likened, at least partially, to an interlock. The socket can be ribbed to counteract strong moments at the footing. If the sole size exceeds transport limits or to counteract excessive punching of the abutment, the sole socket may be precast and connected to a cast-in-place slab before casting [14].

Abutments, whose standard sections have minimum sides of 0.30 m with increments of 0.05 m, are not typologically classifiable but are designed according to the specific application. The typical pillar sections are square, while the H-section is used only when horizontal infill panels are planned to be inserted into the recess. This solution was widely practised until the 1970s but was gradually abandoned as the negative effects of thermal bridging caused by through-columns became apparent. At the intersection with horizontal structures, including bridge carriages, the abutment may have tapering, brackets, or capitals to allow for one to four beam connections (Fig. 6a). A notable feature is the head of the abutment, which may be flat, forked, or tenon-shaped to provide support and stability for the uppermost beams (Fig. 6b).

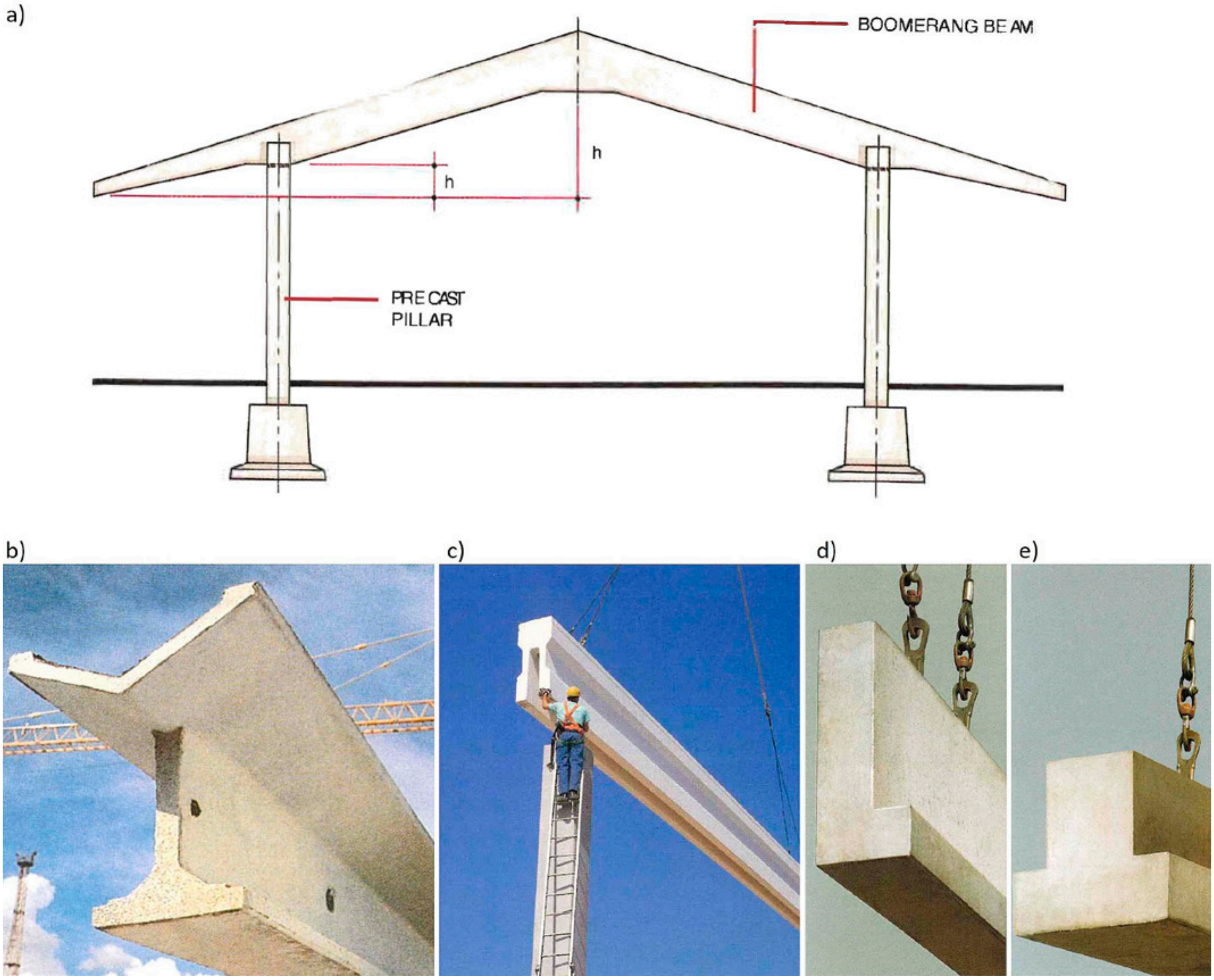

Fig. 7. *Types of beams: (a) boomerang beam; (b) Y beam; (c) H beam; (d) L beam, and (e) inverted T beam. Source: [23].*

Unlike plinths and piers, beams are not used indiscriminately; different types are employed to address specific structural requirements in conjunction with appropriate deck or roofing components. The production of double-sloped beams continues, including variants with lower slabs, although their usage has been gradually declining in favour of more versatile straight beams. In both double-slope and parallel flange variants, lattice girders have limited application due to the imperfect compatibility between the concrete material and the tensioned members, which sometimes necessitates prestressing [15].

An example of beam evolution is the "boomerang-shaped" beam utilised for open sheds (Fig. 7a). Other forms include Y beams and H-beams (Figs. 7b and 7c), prefinished with waterproofing layers and commonly referred to as channel beams due to their ability to collect and channel water to designated drainage lines or disposal points. Y-beams can be installed either side by side or spaced apart using thin curved slabs, while H-beams support winged slabs, whose mass production began in the late 1980s and continues to this day.

L and T beams are employed for intermediate flat floors or flat roofs (Figs. 7d and 7e). The L-shaped section addresses asymmetrical edge conditions, whereas the T-shaped section is designed for central bays supporting two adjoining floors of different thicknesses or at varying levels. Achieving continuous ceilings with increased usable height during operation is possible by partially precasting the beams or incorporating a dense metal bracket protruding from the top flange [16].

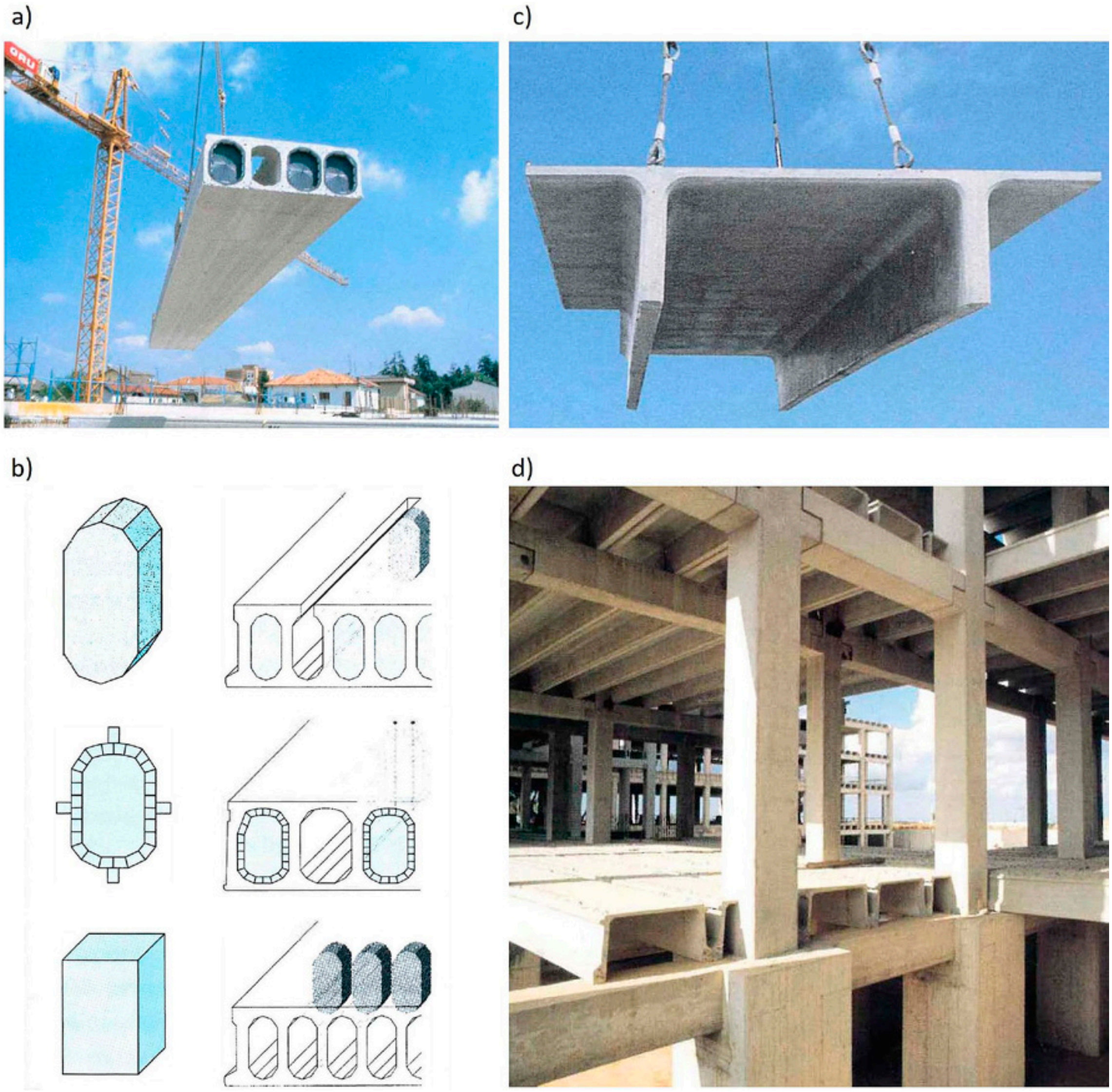

Fig. 8. *(a) Hollow core slabs and (b) diagram of the construction of horizontal lightening voids; (c) Pi and (d) Omega elements. Source: [23].*

Regarding horizontal structures, production categorises products into slabs and decks. A constant thickness characterises slabs, while decks are ribbed solutions that exhibit mixed slab-beam behaviour. In industrial construction, where reducing on-site castings is crucial, mixed panel solutions, as previously mentioned, and hollow core panels are predominantly used for flooring (Figs. 8a and 8b) [17]. The differences between these two products are significant, particularly in load-bearing capacity and design spans, which are limited to 8 m for the former and extend to 15-20 m for the latter.

The use of mixed panels has declined since the 1990s and is now confined mainly to double-pitch roofs on single-aisle buildings. Hollow core slabs, prestressed with pre-tensioned adhered reinforcement, derive their mechanical properties from gradually improving concretes dosed with very low water-cement ratios to ensure immediate shape stability. The ribbed slab family is highly versatile, with design spans ranging from 10 m to 30 m. This category primarily includes Pi and Omega slabs (Figs. 8c and 8d). These are prestressed elements featuring a minimum slab thickness, which has been increased since the 1990s to 0.05 m, with ribs recalculated to form a specific section. A collaborating top slab is used to enhance their load-bearing capacity, and for Omega-slabs, the filling between two consecutive ribs further increases strength. These components' large lateral surface area makes them particularly vulnerable to fire, leading to a significant increase in rib thicknesses following the introduction of UNI 9502:2001 [18].

2.4. SPECIAL ROOF ELEMENTS

In the late 1980s, specialised roof elements emerged on the market, with the aforementioned Silberkuhl serving as a key inspiration [7]. These structural components were designed specifically for terminal solutions of large spans, ideally ranging between 15 m and 30 m. Beyond their functional roles – such as providing lighting, thermal insulation, and water drainage – these elements also represent a shift toward finding formal solutions that give industrial buildings more identity, moving beyond mere functional containers.

This period marked significant advancements in industrial precasting, with all major companies striving for product customisation and offering at least one type of *roof slab*. By the late 1980s, nearly a hundred different types were available. The term *wing element*, derived from the distinctive shape of various cross-sections, aptly describes this category of roof slabs. These elements refine the aesthetics of support and intersection details with other structural components and optimise internal volume by reducing parasitic volumes and enhancing structural performance, as evidenced by the ratio of self-weight to load-bearing capacity.

Generally, wing elements consist of a central longitudinal prestressed core and two raised wings, which are not necessarily symmetrically reinforced and have a limited thickness of 0.05-0.08 m. The use of special formwork, self-compacting concrete, and, later, introducing fibres into the mix for the wings were crucial in maintaining these reduced thicknesses while eliminating complex secondary reinforcement, thereby allowing for greater formal flexibility. Shaped support saddles on the end beams enable different solutions based on the varying rotations of the component's vertical axis.

From a construction efficiency standpoint, the width of the roof slab is standardised at 2.50 m to take advantage of road transport limitations. It is worth noting that each transport load can supply approximately 150 m^2 of fully prefinished roofing, including the subframes of any window assemblies, with a potential installation rate of around 600 m^2 per day, assuming a 3-hour radius from the factory. Production in the 1980s and 1990s can be classified into wing elements, composite sheds, and microsheds [19].

Generally recognised by their V-shape, wing elements are characterised by the close relationship between design shape and static behaviour. The prolific production of these components can be statically classified according to their flexural behaviour along the longitudinal axis and the combined torsional actions due to the wings. The following types can be identified (Fig. 9a): a) single-rib elements with a solid core or closed box-type configuration, where tangential stress flow develops torsional resistance; b) two-rib elements, where torsional actions are resolved into two opposing flexural actions applied to the longitudinal ribs; c) box systems of three or more non-converging slabs, where torsional actions are decomposed into a complex combination of bending in the individual slabs; d) star systems of slabs with V or Y profiles, or similar, converging at a single axis, where torsional action is decomposed into torsional moments within the individual slabs; e) specially shaped elements, including unique solutions such as thin vaults and hyperbolic paraboloids [20].

Another classification of winged slabs can be made based on their arrangement in the composition of the roof. Winged slabs can be arranged as follows (Fig. 9b): a) juxtaposed for blind roofs; b) alternated with lightweight single- or double-walled translucent slab elements to form zenithal skylights; c) alternated with thin curved concrete or micro ribbed sheet metal slabs; d) spaced with the insertion of plates or connecting concrete slabs to achieve a shed configuration, resulting in so-called composite sheds [20].

As previously mentioned, microshed types can be obtained by rotating the winged slab, installing shaped support saddles, or using specific elements designed with asymmetrical wing sections (Fig. 9c). The production of microshed components has led to a market upswing for this type of roofing, offering remarkable improvements in the natural lighting of production spaces. These systems provide diffuse lighting modulated over a 2.50 m span, which performs much better than traditional shed solutions that require glazed surfaces to be positioned on the pitch of the vertical structures, necessitating the production of beams with complex geometries [20].

Initially, skylights were limited to widths of about 0.40 m, but they now reach widths of 2.00 m to 2.50 m

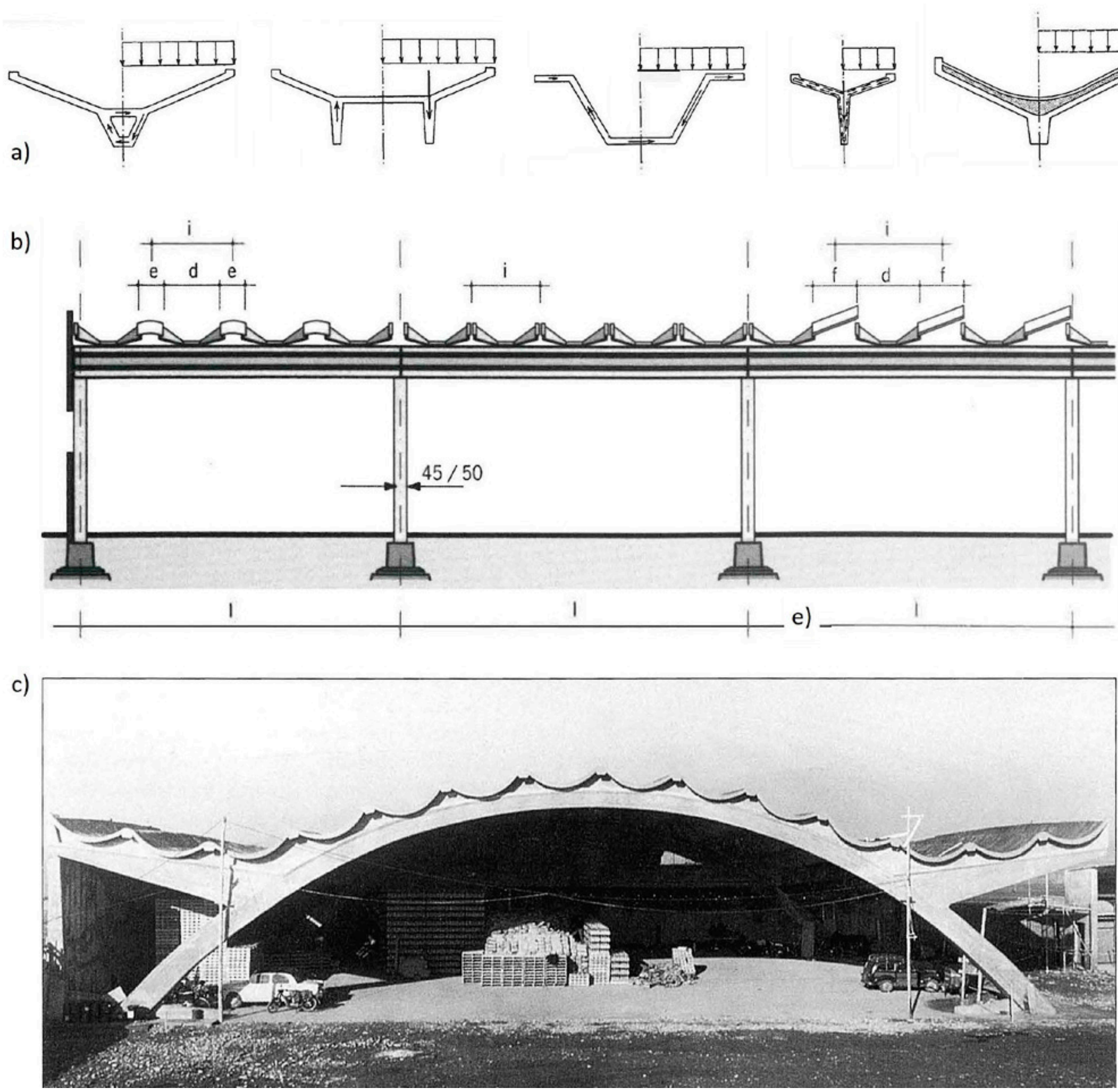

Fig. 9. *(a) Wing types and diagram of overall flexural behaviour and torsional actions on wings; (b) diagram of different wing layouts (spaced, juxtaposed or alternating); (c) historical image of roofing made with microsheds. Source: [23].*

using structural polycarbonates, with ratios of blind surfaces to translucent surfaces ranging from approximately 20% to 50%. This change has led to obvious benefits in terms of foundation loading as well. The dimensions of the skylights help compensate for dimensional tolerances in design, production, and assembly. Microshed types now also allow for the energy upgrading of existing industrial buildings by incorporating solar absorbers on the soffit of the elevated wing, which typically has its blind side facing south or southeast [20].

Winged slabs and microsheds utilise the double slope created by prestressing and the variation in the central core to dispose of stormwater laterally, necessitating their coupling with channel beams, preferably of the H-section type. Non-optimal support on inverted I, L, and T beams requires additional on-site work to create impermeable channels. In such cases, the level of industrialisation achieved through total factory precast – often including insulation and waterproofing agents within the forming cast – is partially reduced.

The production of winged slabs has altered the module of rectangular structural meshes. Previously organised with double-sloped or straight beams on the long side (12-30 m) and floor components on the short side

(8-12 m), these systems are now designed with H, I, L, or T beams on the short side (10-12 m) and slabs on the long side (15-25 m).

3. THE WALL PANELS

As is well known, the wall panels realise the internal-external boundary and take on different values regarding the formal connotation of the project, their physical-technical performances, and their static performances, including their self-supporting in the absence of deformations and/or cracks, their capacity to transfer actions to the structure, and their safety against detachment in the case of special events such as impacts and earthquakes [21].

In contrast to housing, where load-bearing partition systems are developed, the wall panel has the exclusive function of enclosing the frames in industrial construction. The wall panel subsystem, despite its obvious intersections with the structural subsystem, therefore, constitutes a field in itself that responds to completely autonomous performance, aesthetic, and functional criteria [22].

The development of the wall panels in the period under examination presents three phases: the first includes the 1950s and 1960s, the second is typical of the 1970s and partially of the 1980s, and the third crosses the century to the present day. The three phases represent the progressive development of material and production technologies, adaptation to standard updates, especially in the energy field, and changes in the formal sensibility of designers [8]. Industrial wall panels are geometrically two-dimensional rectangular slabs whose primary material is reinforced concrete; regarding the longest side, they can be positioned horizontally or vertically.

In the first phase, brickwork still prevails for lightening and providing a minimum of thermal insulation, which is incorporated in the casting. The production phase takes place on horizontal formwork, whereby the process comprises the following steps: reinforcement and casting of the first 0.02 m concrete layer; positioning of the bricks; reinforcement of the internal stiffening ribs and the second layer; completion of the casting with the 0.02 m layer for total thicknesses of 0.14-0.20 m and lengths of 4 to 8 m (Fig. 10a) [8].

Vertical formwork, also in series, produces load-bearing solid slabs. The presence of ribs considerably reduces the insulating capacity of the panel, favouring the typical phenomena of thermal bridges. Hollow brick panels are preferably of the horizontal type and, concerning the columns, can be positioned in front or inserted in the span. In this case, the pillar takes on T or H sections. Since a maximum of two panels of module 1.20 or 2.40 m can be installed, the possible infill heights are 2.40, 3.60, and 4.80 m. The finishing up of the edge beams is generally achieved through glazing. The vertical hollow brick panels (with a short supporting side of 1.20 m and thickness of 0.18 m) reach 8.50 m. For greater heights (up to a maximum of 10 m), a solid concrete panel with a reduced thickness of 0.13 m and two reinforced side ribs of 0.20 m thickness is used. The finishing of the hollow brick panels is limited to the eventual clay floor covering for the external surfaces. In the vertical ribbed panels, the clay is positioned between the ribs, which always remain in exposed concrete. For this type of panel in the 1960s, production technology allowed the first experiments with specially washed grits in white or coloured marble; the internal finish is always in plastered mortar.

In the second phase, the hollow brick panel solution is progressively abandoned for concrete slabs lightened with polystyrene layers of low specific weight (12-15 Kg/m^3). The internal ribs, for panels of standard widths of 2.00, 2.40, and 2.50 m, fill the external perimeter and divide the length at the lifting inserts and in any case so that the distance between the ribs does not exceed 40 times the thickness of the polystyrene (Fig. 10b). It is indifferent whether they are used horizontally or vertically, but even more evident for the through-ribs is the criticality of these components with respect to the thermal performance of the envelope. Ribbed panels allow significant heights since, where necessary, prestressing is applied to the ribs. Regarding external finishes, there is a certain general regression as clients, for reasons of economy, tend to prefer the grey exposed concrete panel, thus slowing down research into different production technologies [23].

The third phase, which began at the end of the 1980s and continues to the present day, sees at least three guidelines for the development of components: the improvement of thermal performance, research into formal characterisation and the approach for free geometries to be combined with other materials [24]. In the mid-1990s, C.E.N., (*Comitato Europeo di Normazione* - European Committee for Standardisation) within the Technical Committee *Precast concrete products*, activated Task Group 8 Wall elements, dedicated to this category of precast products, which will produce the European reference standard for Italian product quality regulations. In this context, it is definitively established that the "lightened" panel with low-density polystyrene layers and through-ribs (which, for environmental reasons, has replaced polystyrene) does not have the thermal performance that sandwich-type multilayer panels with thermal break and aerated panels can guarantee. In industrial construction, where load-bearing walls are not used, a specific product is employed: the lightened sandwich panel. This design incorporates lightweight layers into the internal concrete section while maintaining the thermal break, which would otherwise serve a load-bearing function (Fig. 10c) [23]. The complex stratigraphic articulation of the panels is also enabled by the considerable development in recent years in the production of metal inserts intended for the various connections. The increasing height of the panels also imposes greater attention on the minimum thicknesses of the slabs, 0.06 m for the outer protective ones and 0.08 m to 0.30 m for the inner load-bearing ones. The insulation thickness, min 25 kg/m^3, generally does not exceed 0.20 m to avoid excessive torsional effects between the concrete slabs.

Surface finishes, which define the material appearance of the panel, exploit the possibility of colouring the conglomerate with oxides, introducing surface layers of marble grits of various kinds, shaping the concrete with matrices, and applying different materials. Also significant here is the contribution made by developing production technologies for processing castings before and after their solidification. In summary, processing on panels, whose exposed face can be the one in contact with the formwork or the one above the casting surface, can be divided into:

- formwork finishes without further processing after the formwork: pigmentation of concrete, preparation of formwork bottom of matrices to give relief patterns to the face, "fresh" treatments with mechanical intervention on the non-solidified mix (scratching) [25];
- off-site formwork finishes, that is, performed after the formwork has been broken down with specific equipment: washing with a waterjet, sandblasting and matriline work with a jet of varying power of metal microspheres, sanding with a "polished" effect obtained by passages of diamond wheels, acid etching bath, chemical treatments with the application of a liquid film that alters the visible surface at will, and silk-screen printing obtained with numerically controlled machines that etch the conglomerate, reproducing any image. The different work processes can also be combined on the same panel [19].

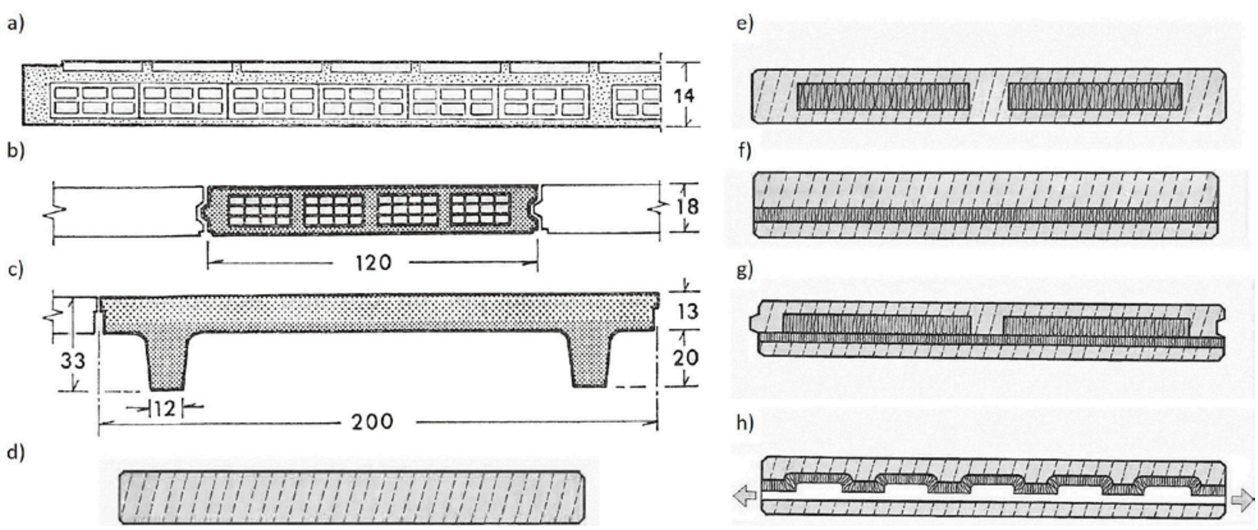

Fig. 10. *The wall panels: (a) horizontal hollow clay block panel; (b) vertical hollow clay block panel; (c) ribbed panel; (d) monolithic panel; (e) lightened panel; (f) sandwich panel; (g) complex panels with lightening of the load-bearing slab and (h) presence of air gaps. Sources: a-c: [8]; d-h: [23].*

4. CONCLUSIONS

The industrial construction sector has served as a testing ground for precast techniques. Following World War II, there was a gradual shift from metallic solutions to those employing prestressed reinforced concrete. This experimentation was driven by the proliferation of large industrial entities capable of introducing new technical solutions to the market.

Initially, the industry used hollow blocks to create elements supporting large spans, eventually progressing to complex vaults made of brick and thin concrete. This process allowed of most construction work to be precast, with only finishing touches required on-site. From the 1980s onwards, improvements in materials and infrastructure led to the development of fully precast constructions, eliminating the need for on-site work. This shift was particularly notable in developing structural components such as foundations, columns, beams and roofing elements, as well as the introduction of new products like winged slabs and micro shreds.

Alongside the evolution of structural systems, it was essential to outline the evolutionary path of wall systems, which transitioned from massive brick-based solutions to lightweight elements consisting solely of concrete and insulating material. This transition addressed the demands for versatility and the high thermal performance characteristics required in contemporary buildings.

The discussion presented in this article is situated within the context of the gradual rediscovery and new evolutionary impetus for prefabrication in industrial construction in recent years. The overview of construction systems provided here contributes to the ongoing debate in two ways. On the one hand, the knowledge of precast techniques has been fundamental in restoration projects aimed at preserving the historical and technical significance of built artefacts. On the other hand, the increased digitisation of the design and construction process has enabled the realisation of highly complex structures using the precast systems developed between the post-war period and the end of the 20th century, adapting them to the new technical and aesthetic requirements characteristic of 21st-century architecture and construction. These aspects demonstrate the resilience and adaptability of precast concrete elements in the face of evolving architectural demands, highlighting their pivotal role in shaping the future of sustainable and efficient building practices.

Authors contribution

The research presented in this contribution is the result of a collaborative effort. The individual contributions of the authors are as follows: Conceptualisation and supervision, E.D.; Investigation, E.D., S.P, and C.V.; Writing-original draft preparation, review, and editing, S.P. and C.V.

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THE ITALIAN SOCIO-HISTORICAL FRAMEWORK OF PRECAST CONSTRUCTION IN THE SECOND HALF OF THE 20TH CENTURY

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Abstract

The events that have given nearly exclusive prominence to concrete precasting techniques since the second half of the 20th century (at least in Italy) in the production of industrial buildings offer a chance to create an engaging overview of the industrialization of the construction sector. This overview cannot be separated from brief recollections of previous decades as well as a glance at contemporary developments. Unlike the housing sector, industrial precasting does not suffer from the obstructionism of complacent builders towards traditional technologies, the distrust demonstrated by many architects toward the ideologization and politicization of principles, or, ultimately, the confinement to a low-cost, low-quality building market. The survey begins in the 1920s when a strongly rational approach to building design and production processes emerged and mainly focuses on the post-World War II period, when industrial construction encouraged experimentation and developed avant-garde techniques, achieving significant results across various fields of application.

Keywords

Italian precast construction, Industrial buildings, 20th-century overview.

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1. INTRODUCTION

Reading and understanding the events that gave concrete precasting techniques almost exclusive prominence in the second half of the 20th century (at least in Italy) in the production of industrial buildings cannot be separated from a brief reminder of what happened in the earlier decades [1, 2]. Particularly interesting is what, starting in the 1920s, determined the affirmation of a strongly rational approach in building design and production processes; an approach that generated a substantial renewal of procedures and techniques towards a transfer to the civil sphere of the principles of industrial operation, typical above all the mechanical one (Fig. 1).

The legacies of the First World War are the acceleration of industrial development processes with regard to production capacity and technological refinement, the almost definitive transformation of society from an agricultural to an industrial one, and the introduction into the labour market of large numbers of workers made up of demobilized soldiers and the unemployed due to the sudden fall in demand in the industrial sphere.

On the socio-political level, there is a strong downsizing of the liberal bourgeoisie, while the echoes of the October Revolution foster growing awareness in the popular masses towards their rights to work, wages and

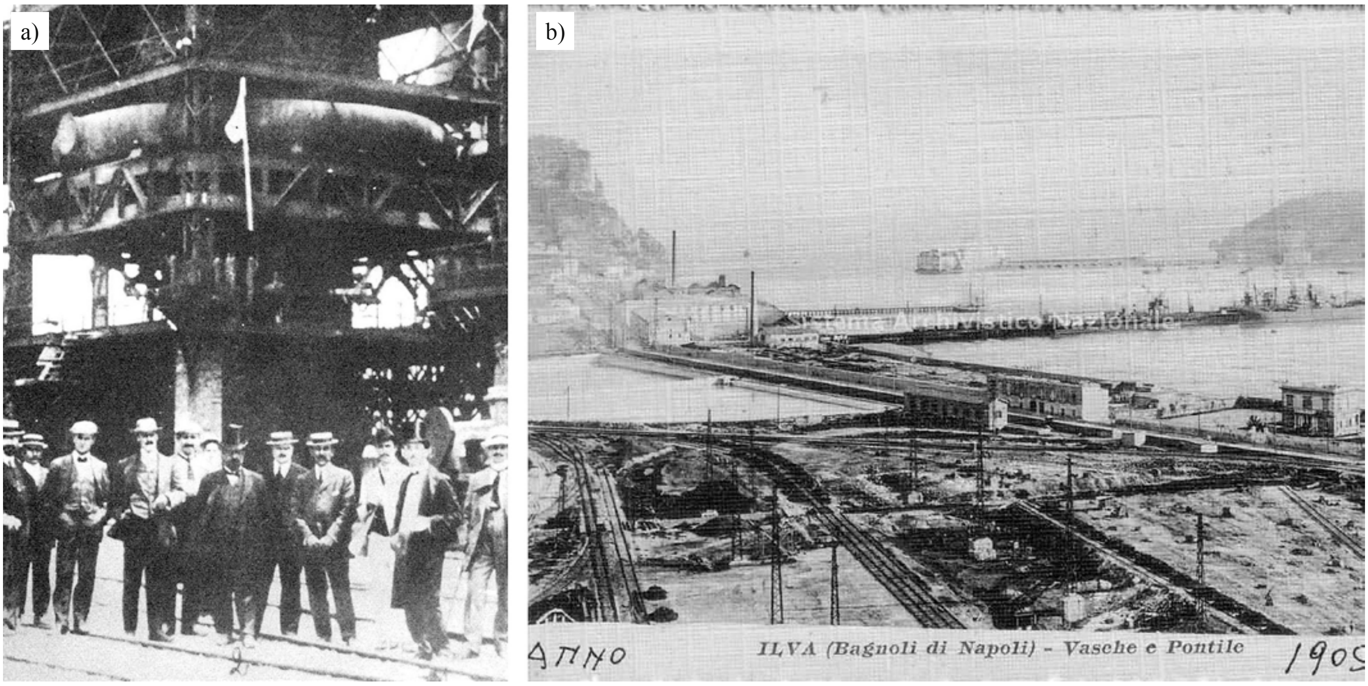

Fig. 1. *The renewal of procedures and techniques towards a transfer to the civil sphere of the principles of industrial operation, typical above all the mechanical one: (a) inauguration of Ilva at Bagnoli in 1910. Source: Rocco Lurago, CC BY-SA 3.0, https://commons.wikimedia.org/w/index.php?curid=20187415; (b) postcard of the Ilva Plant in Bagnoli in 1905. Source: unknown author, Istituto Centrale per gli Archivi, CC BY-SA 3.0, https://commons.wikimedia.org/w/index.php?curid=66858669.*

housing. In this framework, the extension of suffrage to an ever-greater number of citizens and the increasingly invasive presence of public intervention, which changes the profiles of employers, are important.

In the construction sector, the socio-economic events of this period are to be considered for the massive urban concentration, resulting in significant socio-urban problems. They demand eminently quantitative responses of new urban visions, new parameters for residential design, and new techniques and technologies capable of satisfying the demand for new buildings in a short time.

On a philosophical level, the common reasoning of intellectuals investigates a vision of technology that, after the tragedy of war, can no longer be that of unlimited power because it must set itself the goal of improving the living conditions of individuals.

In this context, the need to build many new dwellings appears to be central rather than new technical requirements to which large companies devote themselves. The need for buildings with large spans, which mainly concerns infrastructure works, is an example of these new requirements. At the turn of the 19th and 20th centuries, however, infrastructure was able to satisfy needs without significant innovations.

The collapse of the positivist-bourgeois "values" that had led to the war event is followed by a strong desire to break with the consolidated schemes; the result is the budding of new ways of thinking and seeing, true processes of clarification driven by new interests in scientific thought and logic: critical researches oriented towards drawing the balance between technical, economic and social needs and formal demands.

On the pre-war pro-rationalist experiences of Perret, Behrens, Loos, Gropius and Meyer, a renewed rational thought was grafted, a sort of neo-humanism that rediscovered the human subject and distanced itself from a technique as an end and a means, in which order and rationality proved not to exclude disorder per se.

All over Europe, the new social order was complicated by the substantial blockage of activities due to the war events; in this context, building responded with great public interventions characterized by formal simplification, unification of building types, compaction of housing blocks, and encounter between art and industry. These are years in which reinforced concrete becomes the reference construction technique for popular buildings and is no longer a subject for patents and specializations of firms.

Fig. 2. *The Frankfurt precast concrete panel system by Ernst May.*

In Italy, the process of massive urbanization would only be completed with the internal migrations of the 1950s; previously, it experienced quantitatively less relevant phenomena in housing, little affected by the war events, while the interventions aimed at modernizing the road and railway networks grew. Nevertheless, in a political framework that is certainly not favourable, *Istituti Case Popolari* and *Cooperative* (Italian public entity that promotes, builds, and manages social housing) play an important propulsive role in social and economic housing. Reinforced concrete asserts itself due to the competitiveness of its short construction times and its structural performance. Furthermore, the regime's policy in favour of the agrarian economy, the corporatist system, the crisis of 1929 and, finally, autarchy do not favour an orderly and mature development of the construction industry.

In Germany, the intellectualism of the Weissenhof and the almost obsessive serialities of Hilberseimer give way to the concreteness of the *Siedlung*. Their dimensions activate industrialized approaches to the project and the building site that also take their cue from Martin Wagner's earlier studies on the application of Taylorist theories and the industrial processes of prefabrication that Ernst May applied in the production of load-bearing reinforced concrete panels as early as 1928 (Fig. 2) [3].

In 1930, May himself gives lectures in Moscow and Leningrad, exporting to the Soviet Union those technologies that are ideal for the massive construction of planned cities, assuming political significance.

Iconic in 1930 is the Shell building in Paris, where Lucien Bechmann, returning from a trip to America to design firms and building sites, demonstrates the full metabolization of the criteria of industrialization and precast.

What emerges in the transition from the 1920s to the 1930s is the complete clarification of the two terms: industrialization is a mode that applies to processes, while prefabrication is a construction technique with its own characteristics. Although there is clearly a close reciprocity between the two, the former is not necessarily matched by the latter and vice versa.

The 1930s are compressed between the protracted crisis of 1929 and the socio-political events that prelude the Second World War. The process of industrialization of the building sector proceeds in different directions, also becoming part of the debate on the renewal of architecture. In this context, we must remember the primary role assumed by reinforced concrete, innovations in the field of cement, the development of technical regulations for calculation and standardization, and significant theoretical-practical contributions. In Italy, we recall Colonnetti's studies on states of compaction in the prestressed reinforced concrete field and innovations in site equipment.

Taking inspiration from Maillart's projects, applications in large reinforced concrete structures generate a movement of designers who legitimize the technology of industrialization and prefabrication as the inspirational source of form. In Italy, mention must be made of engineer Nervi and his *Aviorimesse*, designed from 1935 onwards.

The 1940s are inevitably marked by the world war, which, unlike the previous war, carried out large-scale destruction of cities and infrastructure. During the war, interest in the principles of industrialization is pragmatically pursued in the United States, where Konrad Wachsmann founded the General Panel Corporation with Gropius and patented the *Packaged House System* in 1942.

At the end of hostilities in 1945, the building stock throughout Europe is severely compromised. However, at least until 1950, the main theme is the survival of civilian populations wounded by the war, as demonstrated by the Marshall Plan of 1947 and the Berlin Airlift of 1948. A special mention is deserved by the Consortium of Local Authorities Special Programme (CLASP), based on metal components, which provides for the construction of school buildings from 1946 to 1957. Another element to be noted is the new political order resulting from the "East-West" conflict that was to be decisive for the events of the following decades (Fig. 3).

Fig. 3. *CLASP Block at Nottinghamshire County Hall during demolition in March 2017. Source: by Sjtaylor75 - Own work, CC BY-SA 4.0, https://commons.wikimedia.org/w/index.php?curid=57329127).*

2. NEW SOCIETY AND NEW NEEDS

The second part of the 1940s, with the birth and consolidation of the republican state, sees an Italy dominated by a formidable anxiety for reconstruction and, at times, exasperated towards oblivion and normality. It begins a path that will lead in the early 1950s to what is recognized as the "economic boom" period, represented by an average annual GDP growth of 6 percent, which will last until the mid-1960s. The state asserts its presence with the creation of more than three hundred controlled entities.

Between 1951 and 1961, the process of intense urbanization is consolidated, linked to the massive phenomenon of abandonment of the countryside, where income does not exceed subsistence level, and migration from the South to the industrialized North [4, 5].

In this context of socio-economic events, the construction industry takes on a leading role, addressing the housing crisis, rebuilding and expanding infrastructure, and constructing operational service buildings for all the booming industrial sectors. In contrast to the first conflict, where the war fronts were limited to precise geographical areas, World War II diffusely affected almost all urban areas, with extensive damage to the building stock due to the massive deployment of air forces.

In this period, it is interesting to divide the different types of initiatives in the construction sector:

- Private housing, dominated by private initiatives, registered a real speculative market, also favoured by easy access to bank credit, based on the differential between the low cost of agricultural land and the rapid increase in housing value.
- Public housing, on the other hand, is embodied in the Italian *Piano INA-Casa* (Fig. 4) in force between 1949 and 1963 (the so-called *Case Fanfani*) and in the programs of the Italian *Istituti Autonomi Case Popolari* (IACP). These institutions have been active since the beginning of the 20th century, with specific competences until 1977, when they were decentralized to the single Italian Regions.
- Infrastructural construction, which can also be referred to as service construction, is managed by large public contracting authorities, which become the primary examples of expenditure for the private sectors of component production and shipbuilding.
- Industrial construction is practically the exclusive domain of the private sector, representing both demand and supply in terms of the entire production chain (Fig. 5).

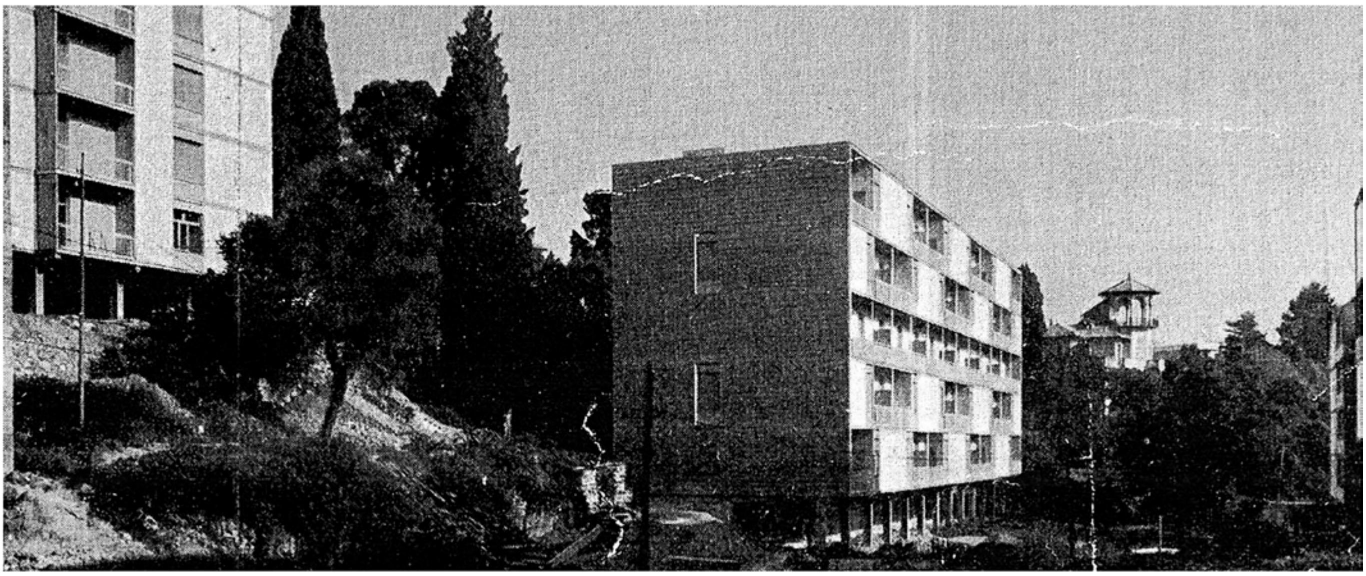

Fig. 4. *Neighbourhood* INA-Casa*, "villa" Bernabò Brea: photo of the building a few years after construction 1954. Source: https://censimentoarchitetturecontemporanee.cultura.gov.it/scheda-opera?id=662.*

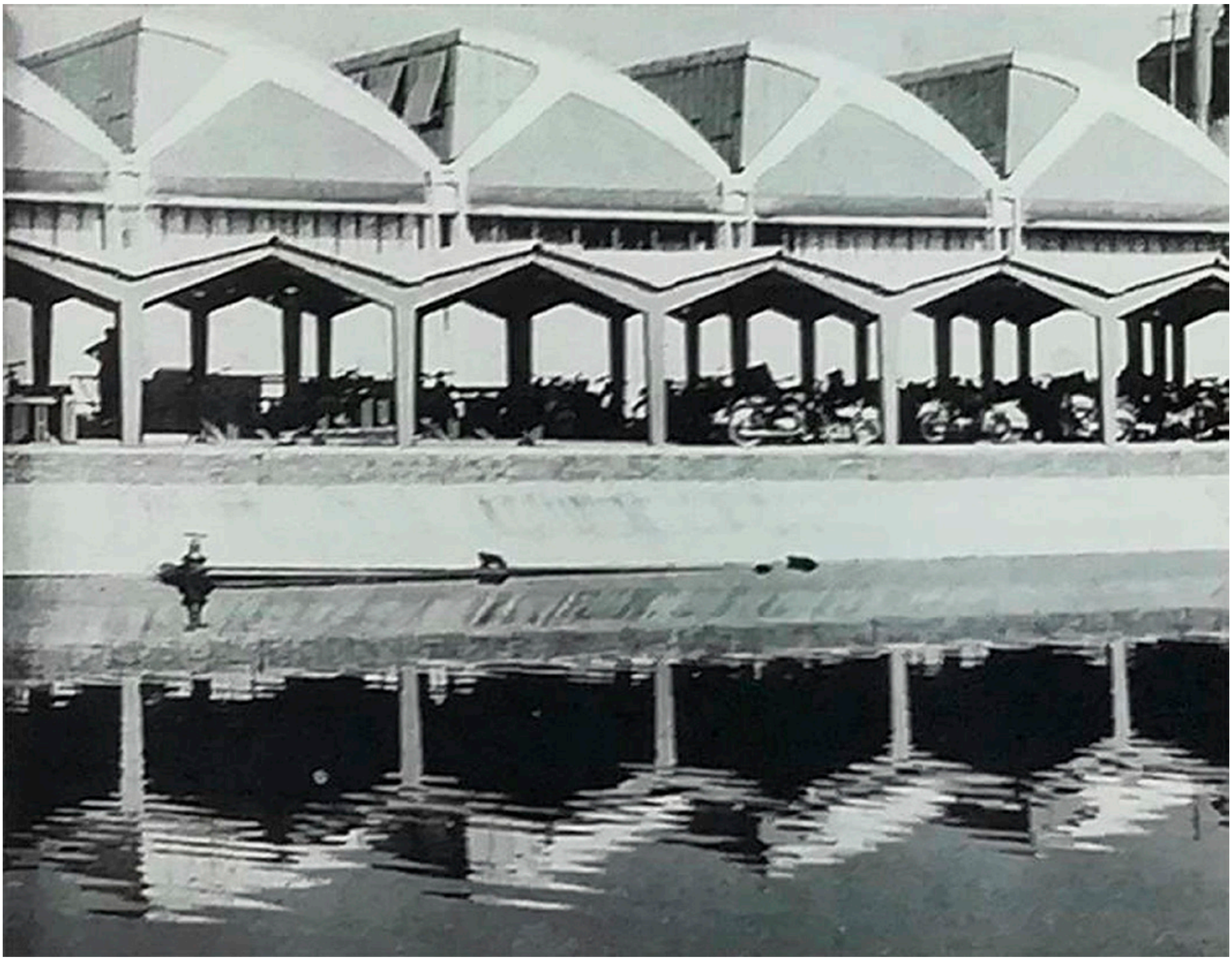

Fig. 5. *Olivetti factory, carpentry-St. Bernard district: the west front of the carpentry. Source: https://censimentoarchitetturecontemporanee.cultura.gov.it/scheda-opera?id=2342.*

3. TECHNIQUES AND TECHNOLOGIES

In the post-war reconstruction phase, the reference technique for all uses is the reinforced concrete, mostly for housing, in the form of the multi-level structure with hollow brick slabs and open-plan.

Starting from pre-war experiences, companies equipped themselves with advanced construction machinery; structural designers became familiar with calculations thanks also to the spread of manuals and the first computational supports; and the architectural project found in the malleability of the overall form, in the dialectic of infill and cladding materials, and the freedom of plan, the tools to articulate an anxious language to give aesthetic pretension to the dominant type of apartment building. There was no interest in the issues of seismic safety and energy behaviour of buildings, which, due to external events, would only appear in the 1970s.

To talk about the other building categories, infrastructure and industrial construction, it is necessary to refer to prestressed reinforced concrete (PRC) technology, which, theoretically, was developed in the 1940s. This is demonstrated by the publications of Levi, Mattiazzo and Cestelli Guidi [6] in 1940 and, especially, in 1947, the publication of the first edition of the text *Cemento Armato Precompresso* by Cestelli Guidi, which opens with the definition of the compulsion state given in 1921 by Colonnetti. In 1948, the ANICAP (*Associazione Nazionale Italiana Cemento Armato Precompresso* - Italian Association for Prestressed Reinforced Concrete) was founded in Italy with the aim of spreading the new technology.

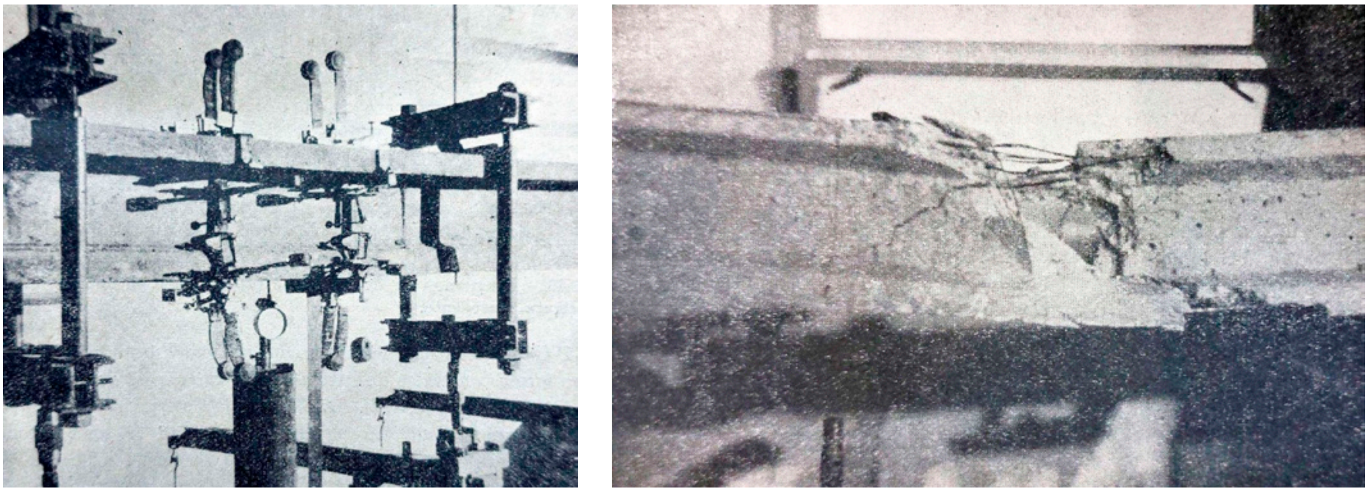

Fig. 6. *Example of experiment on ptototype prestressed beams. Source: Cestelli Guidi C (1947). Il Conglomerato precompresso: teoria, esperienze, applicazioni. Edizioni della Bussola, Roma.*

From 1943 to 1954, interesting experiments were carried out on prototype prestressed beams to test the effects of slow deformations on structural efficiency [4, 7] (Fig. 6).

What links prestressed concrete technology to infrastructure and industrial structures is the use of large spans. Conventionally, the optimal field of application of prestressing covers spans from 8-10 m, which is quite unusual for residential construction, which, as is well known, develops over ideal spans of 4-6 m. Prestressing technology, on the other hand, approaches prefabrication techniques, finding applications in "industrialized" construction for new "social districts" designed outside "historic" perimeters [8].

Precasting for housing has a tormented development which, on a political-economic level, saw the new industrial sector, in 1956, the *Associazione Nazionale Produttori Manufatti in Cemento* (Assobeton since the 1980s) is set up, clash with that of the so-called "traditional" construction companies, which managed almost all private building sites. The first companies producing precast components are incorporated into the ancient activity of a few brickmakers, who are already practising embryonic forms of industrial organization in their factories. The contrast between the two worlds is evident if one observes the different approach between the IACP programmes, aimed at maximizing the volume built with massive use of precasting in a minimum time, and the *Piano INA-Casa*, which Fanfani had conceived with the parallel aim of maximizing employment, thus favouring the use of traditional low-productivity techniques.

After the first interventions carried out successfully by the IACP between 1960 and 1964, using the in-line type with transversal or longitudinal load-bearing panel systems and floor slabs, the process came to a stop mainly due to the lack of continuity in the job orders that put the companies in difficulty, causing their closure in many cases. However, in 1964, the AIP (*Associazione Italiana per la Prefabbricazione* - Italian Association for Prefabrication) was founded with the aim of keeping alive a technical knowledge that was nevertheless acquired. The impossibility of proceeding with the industrial criteria, subordinated to the series production, brings traditional companies back to the housing market share, which at most accept to engage for a short period with the industrialization systems of castings in the "banche-table" and "tunnel" variants, imported from France. The designers, fearful of losing control of the project, quickly start to criticize the extreme rigidity of the modular design, which translated into the invasive presence of load-bearing partitions and the objective poverty of the formal solutions [5].

It is no coincidence, given the pre-war precedents, that so-called "heavy" precasting finds widespread application in France, where the policy of the Grands ensembles began in the 1950s and where the CSTB (*Centre Scientifique et Technique du Batiment*) and the CERIB (*Centre d'Études et de Recherches de l'Industrie du Béton*) have been operating since 1947 and 1967, and in the countries of the Communist bloc, where construction models, often of French derivation, are imposed by the regimes.

Reservations about architectural and technological quality, combined with the ideal approach of precasting to the economies of the other side of the Alps, mean that precasting, except in negligible cases, has no place in private residential construction. In 1969, the MLLPP (Ministry of Public Works) issues Ministerial Circular No. 6090 on the calculation, execution and testing of precast large-panel buildings. The document is late in coming but manages to capture the return of precasting in the transition to the 1970s when the strong increase in labour costs challenges traditional techniques. The industry is trying to overcome the criticism of designers by introducing framework systems and relatively versatile three-dimensional systems.

The Law No. 64 of 1974 and the Ministerial Decree of 3 March 1975, with prescriptions for seismic zones, profoundly affect construction techniques with regard, for example, to chaining, while Law No. 373 of 1976, an indirect consequence of the Kippur War of 1973, imposes attention to the thermal insulation of buildings. Law No. 313 of 1976 regulates the operation of industrial vehicles and is of particular importance for the dimensional adjustment of precast building shapes.

In 1974, the need for an advanced technical-scientific approach leads to the founding of the CTE (College of Construction Industrialisation Technicians), which brings together materials and construction manufacturers, academics and industry professionals. A significant contribution in this period is made by Peppino De Lettera, founder of the ITEC editor, dedicated to the sector which, among other things, publishes the magazine *La Prefabbricazione* (The Precasting) alongside the other "historical" magazine, *Prefabricare Edilizia in Evoluzione* (Precast Construction in Evolution).

After a few years in which precasting, broken down into small operations, still showed a certain vitality, not without greater attention to the solution of construction details, it can be said that at the end of the 1980s, the season of residential precasting came to an end, as its convenience compared to traditional solutions in this area also diminished [9, 10].

Completely different from residential is the use of precast construction for industry, which, as we have said, makes great spans the paradigm that eliminates at the root the comparison with traditional cast-in-place systems. Even in this sphere, which must be extended to the so-called operational buildings and infrastructural works, the Italian tradition makes reinforced concrete the unique protagonist, deriving mainly from the availability of raw materials (Fig. 7).

Fig. 7. *Example of precast construction for industry of the 1960s-1970s. Source: https://censimentoarchitetturecontemporanee.cultura.gov.it/scheda-opera?id=2275.*

4. CONCLUSIONS

In Italy, as we have seen, industrial prefabs are a deep-rooted and concrete reality that has played a central role in the country's industrial development since the years of post-war reconstruction. Unlike the housing sector, it has suffered neither from the obstructionism operated by complacent builders towards traditional technologies nor from the diffidence manifested by a large part of architects towards an ideologization and politicization of principles that should have remained predominantly in the instrumental sphere, nor, finally, from confinement to a low-cost, low-quality building market.

During the period examined, even if at times functional choices have mortified technological and formal research, industrial construction has promoted experimentation and developed avant-garde techniques, achieving significant results in various fields of application, not least, more recently, those of quality management systems, products and sustainability.

From here on, it is necessary to delve into the purely technical aspects that have given rise to another "story", that of the technological evolution of precast reinforced concrete construction elements; they are the main protagonists of three post-war requirements in industrial construction, high spans, controllable costs and times, but this is another story.

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AFTERWORD: MATTER OF FACT AND OPEN ISSUES ON THE INDUSTRIALISED BUILDINGS HERITAGE

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Abstract

Within the postwar building stock, prefabricated buildings represent a significant subset in both terms of the quantity and the urgency of its safeguard, which is increasingly needed by their ongoing and extended deterioration phenomena. According to "The Twentieth-Century Historic Thematic Framework", published in 2021 by Getty Conservation Institute, the heritage of prefabricated buildings is outlined in Theme 2, "Accelerated scientific and technological development", enclosing the product of the large-scale pervasive effects of the technological progress of the 20th century. Nevertheless, at the time of this writing, the post-war industrialised buildings are still generally neglected and rarely protected: supported by the generalised public negative image of the prefabricated buildings – which have aged poorly – demolitions and the canceling of memories are broadly the case worldwide. In this text, some matters of fact and open issues functional to the reframing of industrialised buildings within the 20th-century architectural and technological heritage are outlined and discussed.

Keywords

Preservation, Prefabricated buildings, Postwar, Construction history, Digital catalogue.

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1. INTRODUCTION

Within the postwar building stock, prefabricated buildings represent a significant subset in both terms of the quantity and the urgency of its safeguard, which is increasingly needed by their ongoing and extended deterioration phenomena. In Europe, about 93 million housing units were built in the countries of the European Union between 1945 and 1979; an average of 67% were built using prefabrication techniques, but the percentages rise to 92-93% in most industrialised nations like France, West Germany, and Scandinavian countries, and 97-98 % in the former Eastern Europe [1]. At a global level, these figures grow quickly: in the former Soviet Union's countries, 1,689.8 million m^2, that is 161.7 million dwellings, were built between 1956 and 1982, out of which 95% was made by using prefabricated techniques [2]; in China from 1949 to 1999 the government built 35.2 billion m^2 resorting to imported techniques from USSR and other socialist countries [3]. However, this process was neither an isolated case nor was it exclusive to Eastern countries or the Soviet Bloc. In fact, on a truly global scale, concrete panel systems made countless journeys from Asia (Mongolia, Vietnam, Nepal, China, Japan, Taiwan, and North Korea), to Africa (Morocco, Egypt, Zaire, Gabon, and Zanzibar); to the Middle East (Iraq, Kuwait, Syria, and Bahrain), to America (the US, Cuba, Colombia, Venezuela, and Chile), including Australia, to name just a few.

According to “The Twentieth-Century Historic Thematic Framework”, published in 2021 by Getty Conservation Institute, the heritage of prefabricated buildings is outlined in Theme 2, “Accelerated scientific and technological development”, enclosing the product of the large-scale pervasive effects of the technological progress of the 20th century. In particular, the document outlines that «the increasingly widespread use of new types of building materials and prefabrication in construction transformed the built environment», representing, thus, a specific subtheme of 20th-century cultural heritage [4].

Nevertheless, prefabricated buildings, apparently lacking unique or exceptional architectural value due to their mass production, are frequently neglected and rarely protected [5]: demolitions and canceling of memories are broadly adopted to face the poor or outdated condition of the buildings, supported by the generalised public negative image of the prefabricated building. Indeed, if the industrialised buildings have aged poorly is induced by the insufficient experience of the adopted new types of materials and the limited span of the expected life, considered in the original design process, it is mostly the product of the lack of care, in the broad sense of a lack of in-depth knowledge, even about the materiality of those buildings. In this sense, the Construction History studies propose a challenging shift based on the use of material culture approaches to disclose the intangible values of the prefabricated buildings related to the «tremendous ramification of the building world» as the socio-economic and technological backgrounds, supporting awareness of the prefabricated building contribution to the heritage of the 20th century and construction [6-9].

This text outlines some matters of fact and open issues functional to the reframing of industrialised buildings within the 20th-century architectural and technological heritage. In Section 2, the prefabricated building as a “cultural object” is presented and discussed, referring to current research and cultural initiatives carried out by the international scientific community. Section 3 discusses some “traditional” topics from the 1980s debate about the preservation of 20th-century architecture, adapting them to the inherent characteristics of industrialised buildings. Section 4 focuses on the opportunity to develop a specific cataloging approach to document and protect industrialised buildings. In Section 5, some notes on the Italian case are drafted as a remarkable example of the locally based declination of internationally affirmed construction systems, technologies, and design approaches. Conclusions and further perspectives are reported in Section 6.

2. THE PREFABRICATED BUILDING AS A “CULTURAL OBJECT”

The history of the global distribution of industrialisation and prefabrication in buildings has remained at the margins of contemporary scientific debates for a long time. In the last decade, academic research and cultural initiatives have increasingly addressed the topic of post-war industrialised construction despite the difficulties posed by the multilingual nature of the research in the integration of German, French, and Italian studies, which are simultaneously overlooked by English-language research, thus obstructing the construction of a comprehensive historical framework.

The historical studies focused at first on the fascinating story of the delivery home: the “Home Delivery: Fabricating the Modern Dwelling” exhibition at MoMA in 2008, which displayed the process of architectural design and production, connecting past examples with contemporary ones (Fig. 1). By spanning 180 years of history, the projects were presented through a multimedia approach (film, architectural models, original drawings and blueprints, fragments, photographs, patents, games, sales materials and propaganda, toys, and partial reconstructions), underlining «how the prefabricated house has been and continues to be, not only a reflection on the house as a replicable object of design but also a critical agent in the discourse of sustainability, architectural invention, and new material and formal research» [10].

Afterwards, the exhibition “Architecture in Uniform. Designing and Building for the Second World War”, held at the Canadian Center of Architecture in 2011, highlighted the relationship between prefabrication and Wartimes. The research based on archival and field research

Fig. 1. *Research initiatives. Left: "Home Delivery". Source: © MoMA 2008. Middle: "Flying panels". Source: © Dom Publishers 2019. Right: "Between conventional and experimental" covers. Source: © Leuven Press 2024.*

explored the different ways in which architects and engineers worked during the Second World War to improve the building technology supporting the war effort of different countries [11].

The exhibition "Flying Panels – How Concrete Panels Changed the World", held in 2019-20 at the ArkDes in Stockholm, proposed a holistic approach through models, posters, paintings, films, toys, and cartoons – exploring how concrete panels influenced culture for the developing of new settlement and society (Fig. 1). Special attention was paid to the internationality of the prefabrication both as a technical tool and cultural issue: «the exhibition tells the story of a time when flying concrete panels became a symbol of the future, both in politics and in art, and embodied the dream of a better world, from the second half of the twentieth century to the present day» [12].

In 2021, the congress "Between Conventional and Experimental. Mass Housing and Prefabrication in Modernist Architecture" organised by the Israeli and German section of the Docomomo pointed the attention to mass housing, referring to the stories of the builders and designers, or single geographic contexts. In 2024, the outcomes of the conference were collected in the homonymous book (Fig. 1), which reframed «how mass housing and prefabrication shaped global modernist architecture, offering a comprehensive exploration of how both conventional and experimental prototypes and series gave rise to an architecture for all and responded to crises, nation-building, and housing shortages within the context of transnational and regional research» [13].

The scientific literature also shows an increasing interest in discussing industrialised buildings in the context of heritage studies, focusing on the "heritage of the ordinary" demand for a rethink of the classic concepts and practices that inform architectural heritage conservation. In this sense, the 2020 book by Graft and Delemontey *Histoire et sauvegarde de l'architecture industrialisée et préfabriquée au XX^e siècle* was published aiming at recapturing the diversity and complexity of the century's construction systems, focusing on emblematic industrialised and prefabricated systems, opening at the problems of architectural conservation of those buildings [14].

Within this latter preservation approach, noteworthy are the ongoing research project addresses industrialised buildings in the German context, such as the topic related to "System halls as historical Monuments" within SSPP 2255 "Kulturerbe Konstruction" [15], the musealisation of the apartment within the WBS 70-system building in Berlin (Fig. 2) within the DDR museum [16], or the future exhibition "Prefabricated Building East / West" to be inaugurated in autumn 2025 at the Dresden Stadt Museum [17]. The preservation of Soviet

Fig. 2. *Technical brochure of the WBS-70 system and the musealised apartment in a WBS-70 prefabricated building in Berlin (former East Germany). Source: © Museumswohnung WBS 70.*

precast reinforced concrete buildings, opening the issue about preserving "buildings that are utterly generic", has been discussed by Kuba Snopek in the book *Belyayevo Forever: Preserving the Generic* [18]. Eventually, experimental preservation approaches of prefabricated buildings related to the topic of reuse and upcycling have recently been developed by the European project "Re-Create" [19] and the Italian one "Upcycling Architecture in Italy" [20].

3. OPEN ISSUES ABOUT PRESERVATION

The building stock of the postwar decades has been the subject of a broad discussion about historical preservation. In the evolving definition of architectural heritage conservation, changing from "individual" to "holistic" and from "holistic" to "sustainable", the actual "living preservation" approach focuses on a balance between architectural heritage and contemporary needs, grounding on the shift including intangible attributes in the conservation process [21]. In this research framework, for the specific subset of industrialised buildings, some of the topics that emerged in the 1980s debate about the preservation of 20th-century architecture can be broadened and further discussed. In the 1980s, the non-ideological matrix of architectural studies based on material culture played a crucial role in establishing 20th-century architecture within the historical heritage, allowing for overcoming and reconciling the inherent conceptions of transitoriness and functionalism with the conservation approach [22]. However, these inherent concepts must be stretched to be applied to industrialised buildings.

First, the preservation of industrialised buildings demands a further rethinking of the concept of "durability" associated with protection and safeguarding. In postwar industrialised architecture, the design process of classic Modernity is absorbed and stressed: if the question of durability has already been discussed and modified within the debate about the historical preservation of modern architecture, the concept of disposal and transitory in construction that featured prefabricated buildings deserves further consideration to embody this specific design syntax in the preservation approaches.

Second, the process demands the adaptation of the definition of "uniqueness", which is classically associated with the monument. Indeed, in postwar industrialised architecture, the mass production of the relation between the original and the copy is stressed and exploded. Is the uniqueness of the technical innovation in the state-of-the-art or the architectural design of the single construction system to be protected? Is instead the "replica" of the same construction system within the technological and productive adaptation to local contexts (Figs. 3-4) linked to the inner values of knowledge transfers?

At the same time, even the role of the "authorship", classically associated with the artistic value of the building, must be redefined. Indeed, in post-war industrialised architecture, the relationship between the author and the building is mediated by the industrial production process. How is the architectural design of the single building related to other authors' inventions? Moreover, in this specific case, how can the compresence of multi-authors be treated within the safeguard of the single building? Is instead the authorship of the single construction element,

Fig. 3. *Global distribution of 98 trajectories of prefabricated systems, mapping by T. Carbonell Guillón and J. Hernández published in the book "Flyng Panels", Dom Publisher, 2019. Source: © J. Hernández and P.I. Alonso.*

Fig. 4. *The "global" construction systems in the 1960s: prefabricated buildings with large panels. Left: Prague. Source: © Národní Technické Muzeum. Right: Milan. Source: © Aler Archive, Milan.*

in terms of technological invention or design model, to be protected? Furthermore, expanding the topic, how can the authorship be traced in the international declination of the most affirmed construction systems?

To give a practical example, for the notable case of the "Camus" system, which was worldwide diffuses, how can be retraced, within the safeguard action, the significant contribution of the national dealers, producers, and design involved in the application of the system? In fact, beyond the conventional authorial role of the architect, there is another group of less acclaimed agents comprising politicians such as Khrushchev in the USSR and George Romney in the US, together with industrialists and entrepreneurs such as Raymond Camus in France, Allan Skarne in Sweden, and Nares Craig in the UK. The group also includes lesser-known engineers such as Hiroshi Yoshida in Japan, Milo Shemie, William F. Dawson, and Zenon Zielisnki in Canada, and Josh. F. Munch-Petersen in Denmark; and architects such as Hugo D'Acosta and Edmundo Azze in Cuba, Wilfried Stallknecht, Hubert Scholz, Konrad Püschel, and the DAH group (Deutsche Arbeitsgruppe Hamhung) in the GDR, Mart Port in Estonia, the Pécs Group in Hungary, and Vitaly Pavlovich Lagutenko in the Soviet Union.

There are also more celebrated architects, such as Marcel Lods, who designed ensembles with the Camus system in Fontainebleau; James Stirling, who designed Saint Andrews' Dormitory in Scotland; or César Tacchini, who founded the IGÉCO factory in Switzerland. Tacchini, himself a combination of architect, engineer, and entrepreneur, reveals how working with panel systems went beyond disciplinary and professional boundaries and played a role in the gradual, collective transformation of systems globally.

The questions are manifold and call for the multiplication of studies that rigorously focus on the reconstruction of the design and building process rather than the product of the building itself, retracing the network of productive, economic, and social actors concurring on the "collective" ideation and construction of the industrialised building. Exploiting the affinity between the concept of "monument" and that of "document", it is the act of documenting the entire process of ideation, production, and construction that supports the construction of the collective identity of the industrialised building.

4. TOWARDS A GLOBAL CATALOG OF INDUSTRIALISED BUILDINGS

In this research framework, a significant strategy for the preservation of industrial buildings is traced by the historical-relational path [23], exploiting, on the one hand, the consideration of the industrial building within its territorial and landscape context; from the other, the consideration of the industrial building within its historical-relational network with heteronomies such as the cultural or technological histories.

The application of the historical-relational approach urgently demands the public dissemination of the base knowledge of industrialised buildings at a global scale, based on the established "cataloging approach" already adopted for Modern architecture [24] and in the field of industrial archaeology [25].

In this sense, the catalog can support the construction of a historical series based on the definition of paradigmatic exempla, considered as the prototypes of the application of a specific artistic or technological innovation, that devolves in a process persistent in time, providing, thus, a remapping of the significant local developments and modification of the internationally affirmed construction systems.

In particular, the catalog can produce an in-depth knowledge framework regarding the construction process, technical innovation in the state-of-art, manufacturing process, and technological design approaches embodied immaterial values of the prefabricated buildings that require their protection, even if they are not fully detectable in the materiality of the built work.

International action should be undertaken to produce an effective catalog rooted in a shared classification of available sources and the development of specific tools to display and represent the results. In the following, some considerations about the documental sources and the digital tools significant to the study and the cataloging of industrialised buildings are synthetically outlined.

4.1. SOURCES

The post-war buildings feature as documentary double, which returns significant traces of the project, construction, and modification of the buildings over time. The act of building produced a massive number of documents, which represent, at the same time, a resource and an obstacle for the historical and technical knowledge of the building: if, on the one hand, the papers' capillarity allows us to reach remarkably accurate information about the design and building processes, providing valuable evidence to retrace the building in its cultural and technological network; on the other hand, their mass, their capillarity and, at the same time, heterogeneity requires systematization and iterative verification to achieve some valuable knowledge, including unavoidable irresolution, about the materiality of the buildings [26]. For the specific case of industrialised buildings, the act of building features the proliferation of the documents, including, in a broader sense, specific categories related to multi-actors' involvement within the industrial building process.

The classic collections produced by the traditional building process – drawings, technical reports, diaries,

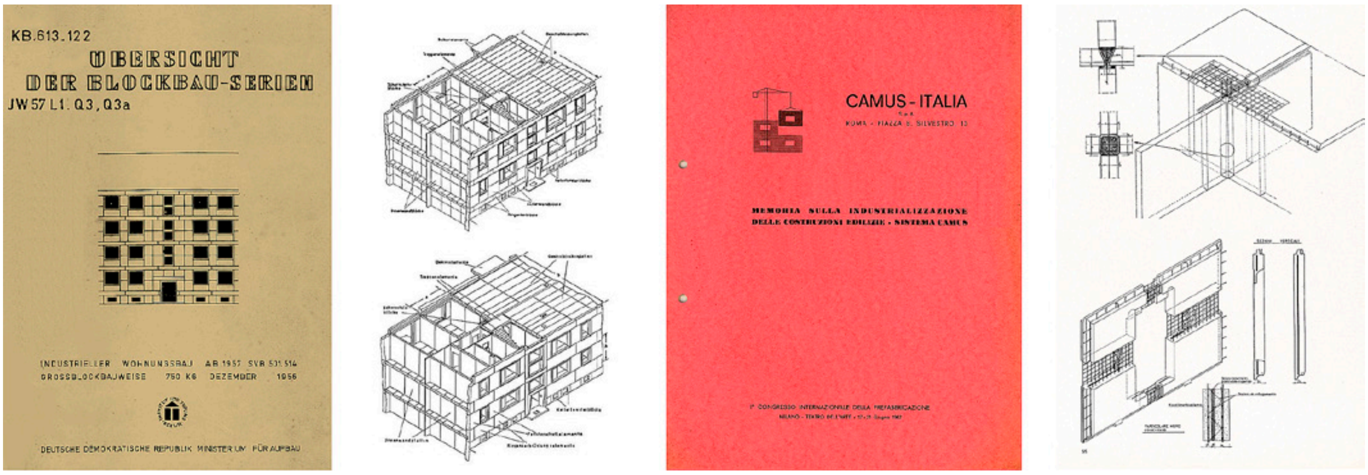

Fig. 5. *Left: commercial documents of East-Germany series. Source: © Berliner Zentralarchiv. Right: Italian-Frech Camus system. Source © Aler, Milano.*

and photographs of construction sites – are, in this case, widened by the special documentary series produced by the styling and marketing process of the industrialised construction systems (Fig. 5).

In this sense, a unique documental collection is represented by the industrial patents protecting prefabricated systems (Fig. 6): similarly to the pattern of the stages of reinforced concrete development in the years 1900-1950, throughout the massive industrialisation undergone by building since the late 1940s, industrial patents afforded the means to make technical innovations commercially available; thanks to patents, in fact, performances (essential when dealing with industrial products) could be codified. At the same time, the intellectual property of products could be protected to allow them to be used in a wide range of markets. On the one hand, patent-based production was essentially getting the trade of inventions underway; on the other, the exchange of technical know-how – triggered by the availability of patents – led to resorting to "international" building patterns, extended further by a gradual resort to common-acknowledged technical norms. In this sense, the invention timeline reveals (besides an interesting chart of the paths of know-how) various local interpretations prompted by the natural need to suit them to the features of the countries they "journeyed through", as regards production-patterns and technology and – more generally – the cultural and technological background of projects. Most of the time, industrial patents were accompanied by commercial brochures of the prefabricated systems, elaborated

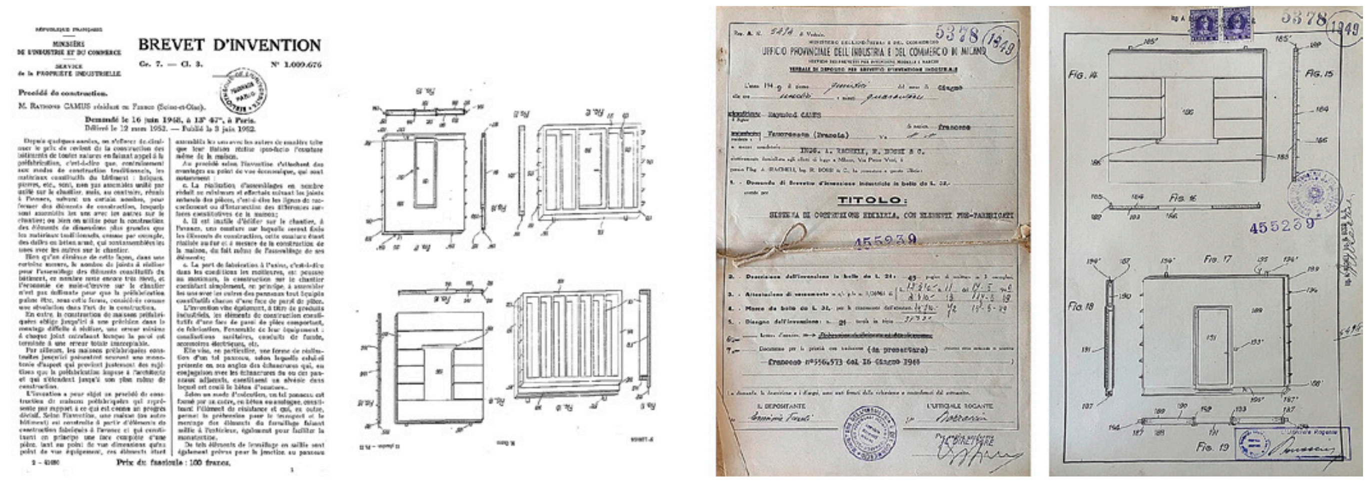

Fig. 6. *Left: industrial patent of the Camus system in France. Source: © Espacenet INPI. Right: industrial patent of the Camus system in Italy. Source: © Archivio Centrale dello Stato, Fondo Ufficio Italiano Brevetti e Marchi.*

by the leading producers and, thus, by the national dealer. These documents, embedding valuable photographic evidence on the production and assembly process and by a repertoire of standard projects, bear witness to the original design of the most affirmed construction systems and, thus, to their worldwide commercial transfer and technical modifications.

Since the late 1960s, the special documentary series that characterize the industrial building process have been enriched by pioneering "digital" documents generated by the pioneering application of computers to support the design and control of the production process. The analysis and conservation of this latest series of sources, produced by the first attempts of the "*Sfida elettronica*" (Electorinc Challenge) [27] phases, remains an open issue, which requires the development of dedicated studies.

4.2. TOOLS

Three-dimensional and informative modeling tools have assumed a key role in the knowledge, protection, and valorization of the historical built heritage. Based on the historical material affinity between the industrialisation of buildings and the pioneering application of computer-based approaches, the construction of a catalog oriented to disseminating base knowledge framework and protecting industrialised buildings represents an ideal field of application.

On the one hand, by exploiting the modularity and the "component-based" construction that characterizes prefabricated systems, it is possible to obtain a detailed three-dimensional and informative restitution of a wide range of technological systems, fully exploiting the native functions of the current applications for parametric object-based modeling [28]; on the other hand, the structuring of databases linked to the three-dimensional geometric representation allows to transform the model into an effective "digital archive" to be used within public dissemination and pedagogical approaches.

The digital model can be exploited in a deep affinity with the philological approach [29], established in archaeology, serving respectively as a tool of investigation, systematization, and representation of the data provided by the documental sources: during the collection of documents, the model supports the classification and organization of the documentary series; in the analysis phase, it is, therefore, used as a reconstructive tool to support the cross-referencing and iterative verification of the data contained in the different series of documents and, thus, display the results as interactive visual representation and organised set of informative data (Fig. 7).

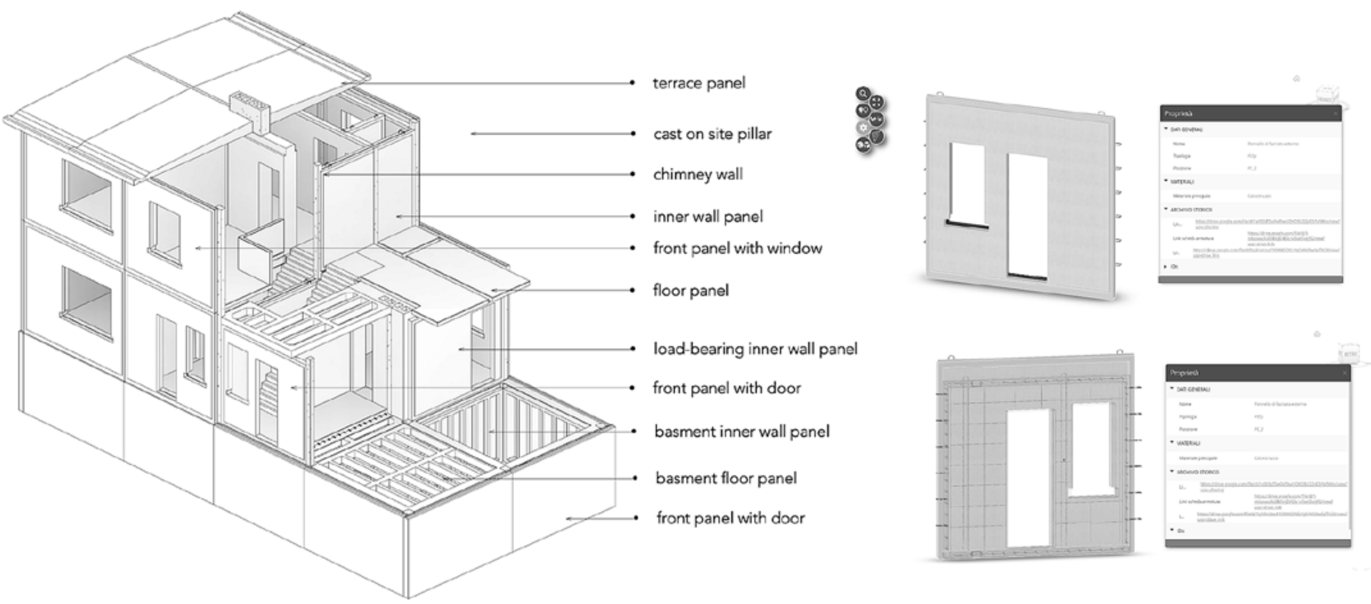

Fig. 7. *Left: philological digital models of the Camus system: the type building based on the1949-Italian industrial patent. Right: sample of the interactive viewer. Source: © [29].*

5. BETWEEN GLOBAL AND LOCAL: NOTES ON THE CASE OF ITALY

According to the proposed open issue about the definition and the safeguard of the specific heritage of industrialised buildings, the Italian case deserves some special notes. On the one hand, Italy features a law framework that presents significant issues concerning safeguarding modern architecture; on the other hand, Italy represents a significant case of the declination of internationally affirmed construction systems to specific technological-productive and cultural local frameworks.

Regarding the first aspect, the law constraint for the safeguard of the 20th-century architectural heritage avoided any graduality. For a vast heritage in terms of quantity and quality, such as that of 20th-century industrial buildings, that go far beyond the architecture of affirmed architects, the question arises of the fate of anonymous buildings [30, 31]. As mentioned above, the actual law framework grounds on the minimum life span, which extended to 70 years, represent the base condition for activating safeguard actions, opening a significant legislative gap for the younger architectures. In the case of anonymous or multi-author buildings, such as the case of industrialised architectures, the gap is amplified by the impossibility of recurring to the so-called "authorship right", usually called to protect specific architectural design [32].

Regarding the second aspect, in Italy, the singularity of the socio-technological and economic backgrounds that feature post-war Italy, the development of industrialised constructions followed a tortuous path. Starting from dense experimentation that arose in the urgency of Reconstruction, passing through a forced pause in the 1950s, with some noteworthy exceptions, the process restarts in the 1960s, looking at the foreign models. The progressive adaptation of foreign models in the backward economic and productive framework of the country allows for the establishment of a very special industrialisation in construction that never detached the building site. Quoting the worries expressed by Giulio Carlo Argan – in the noteworthy essay *Modulo-misura e modulo-oggetto* [33] – about the inevitable detachment of the design from the construction site, that featured most of the international dimension of Post-war building industrialisation with the subsequent break between ideation and the execution, are peacefully solved within the singularity of the Italian path (Fig. 8).

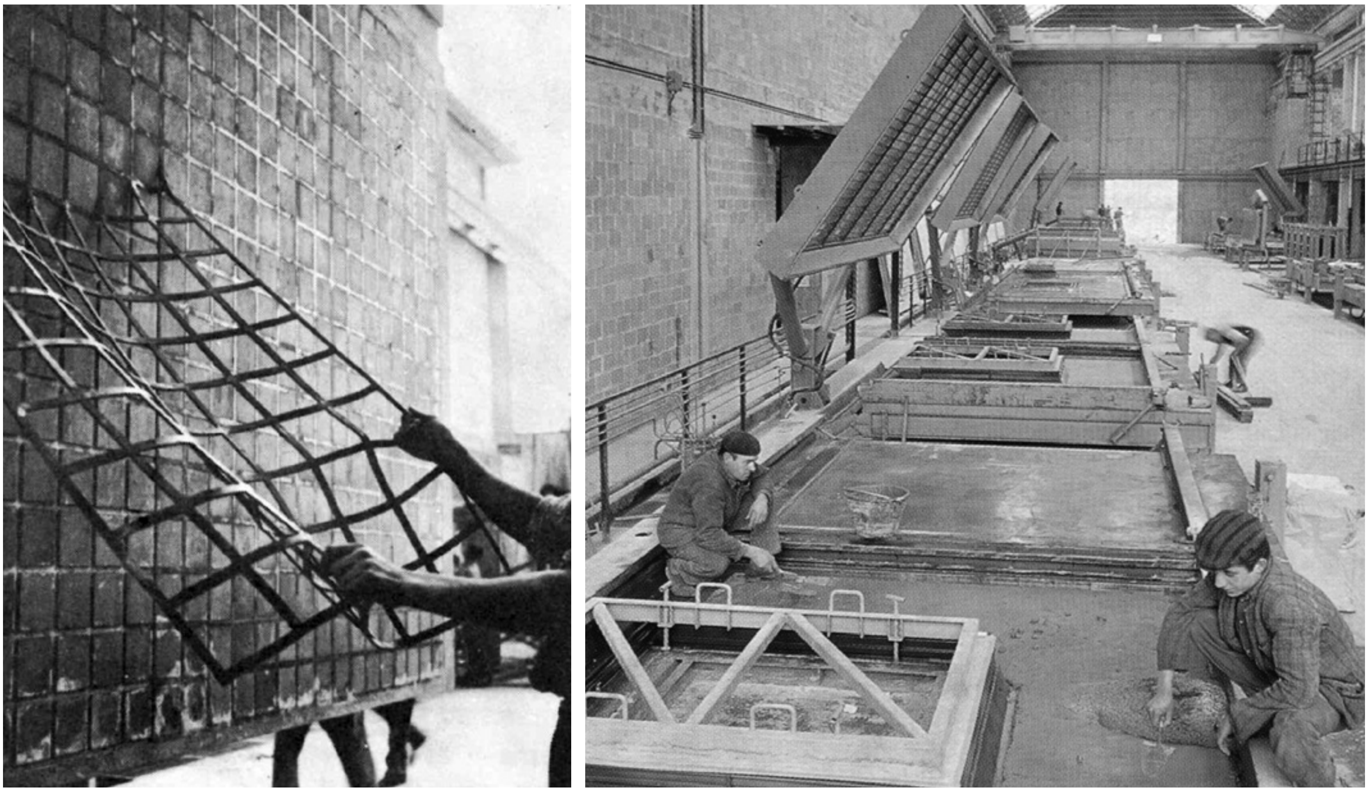

Fig. 8. *Tailored industrial manufacturing of the MBM-Balency prefabricated panels based on Balency French patent with new design features made by Vico Magistretti. Source: © AITEC, 1966.*

The construction site – relocated in the factory – remained the "cultural gym" where the traditional construction elements are progressively renamed in industrial products, approaching the boundaries of the industrial design [34]. According to this specific technological and cultural *milieu*, safeguarding actions should deal with the reconstruction of the specific microhistory of the single building and, thus, reframing it in the international history of building industrialisation.

6. CONCLUSION: RESEARCH TO BE DONE

At the time of this writing, the post-war industrialised buildings are still generally neglected and rarely protected: supported by the generalised public negative image of prefabricated buildings – which have aged poorly – demolitions and the canceling of memories are broadly the case worldwide. As a matter of fact, significant historical studies and safeguard actions have been conducted, producing a significant base of knowledge that is increasingly useful for reframing industrialised buildings within the 20th-century architectural and technological heritage. Nevertheless, a lot is still to be done to outline possible scenarios for their safeguard and preservation.

We can outline two urgent paths. The first is the improvement of the Construction History studies in support of the "historical-relational approach" to safeguarding and preservation. In this sense, the material histories of the building processes of the industrialised building – extended to the actions of the manifold actors and disciplinary fields involved – provide documentary evidence on the relational network between the industrial building itself and its socio-economic and technological backgrounds.

The second is the importance of developing a global catalog of industrialised buildings based on the historical series and the identification of paradigmatic examples at the scale of the construction systems. This catalog could provide, on the one hand, documentary evidence of the relationships between a given system and all its associated social and technological histories. On the other hand, it could provide documentary grounding to see and explore the systems' transnational movements, transformations, and adaptations in further inquiring into the "mode of existence" of a still overlooked kind of collective design processes that, for over a century now, have worked both at the levels of the typologies and the level of the technologies.

Authors contribution

The authors are listed in alphabetical order. They contributed equally to conceptualisation and writing.

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