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

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Cover illustration: MBM factory in Trezzano sul Naviglio (Milan), Italy.

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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

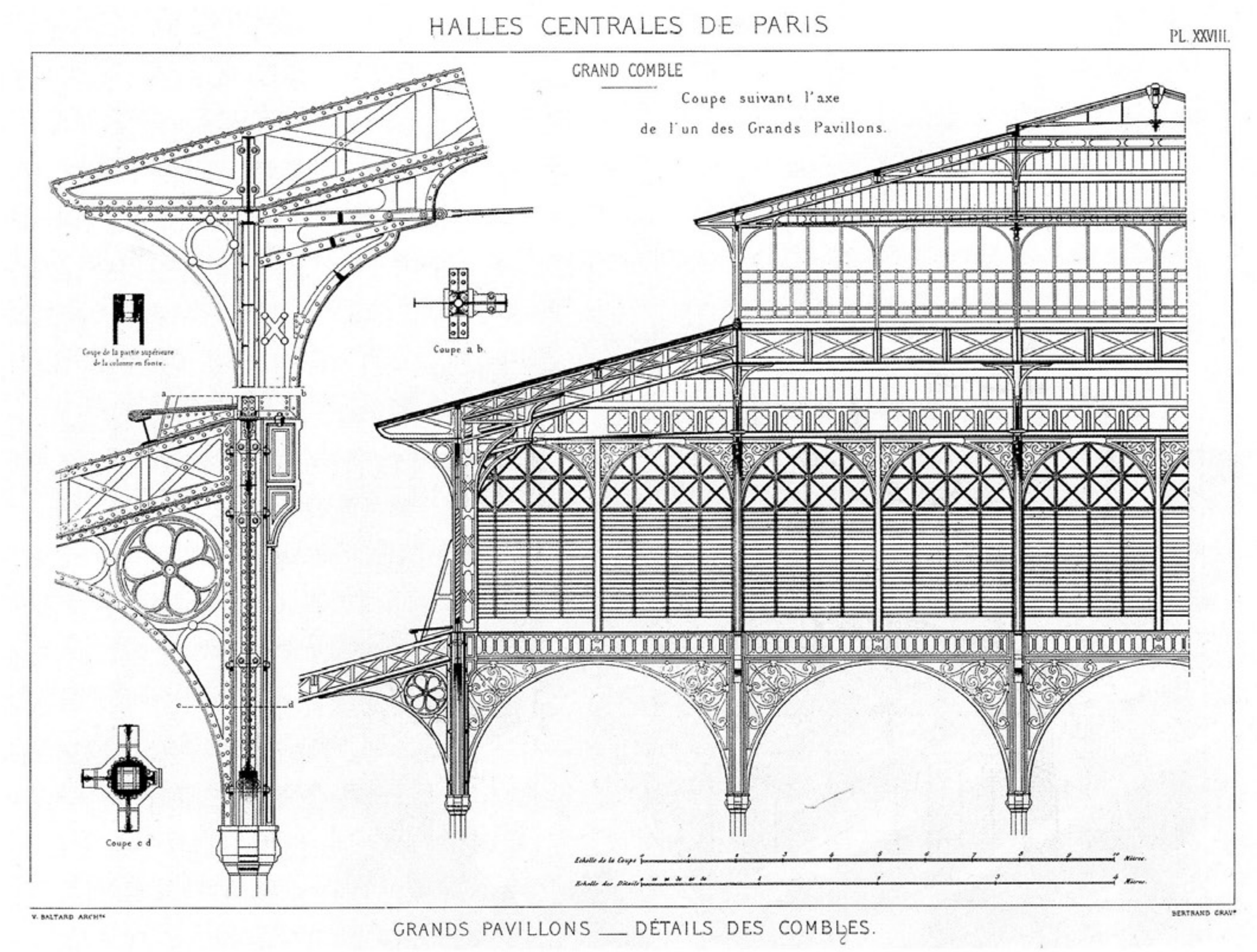

Fig. 1. *Top: boards designed by Baltard and Callet for* Les Halles *in Paris. Bottom:* Crystal Palace.

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 pre-planned 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,

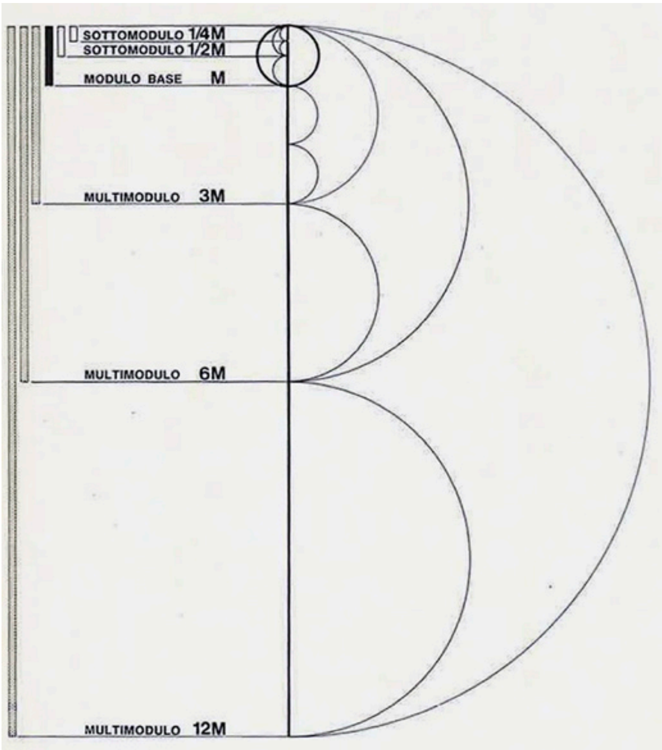

Fig. 2. *Modular Coordination Length System. Source: [9].*

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

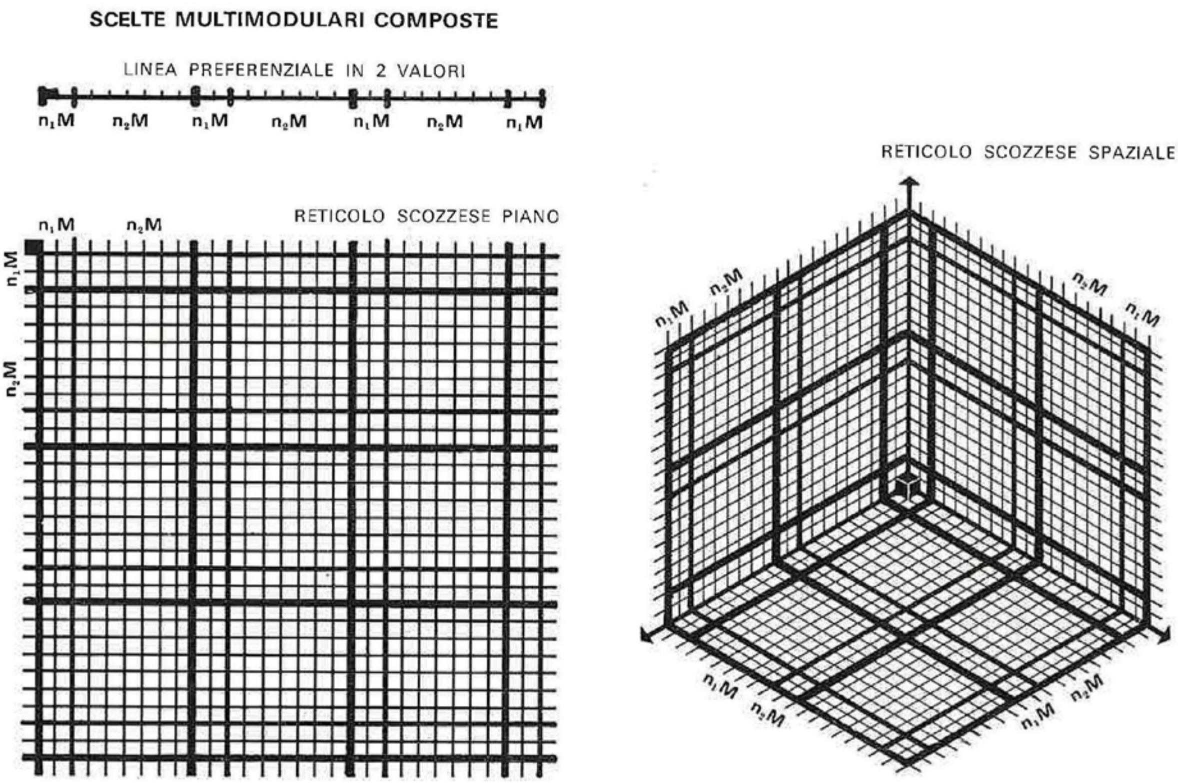

Fig. 3. *Scheme of composite multi-modular choices «Compound multi-modular choices can result in the combination of several fixed grids, thus the Scottish grid applied in the design of the building organism, or the reference line or variable grids, applying the system known as the "number pair" (combination 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)

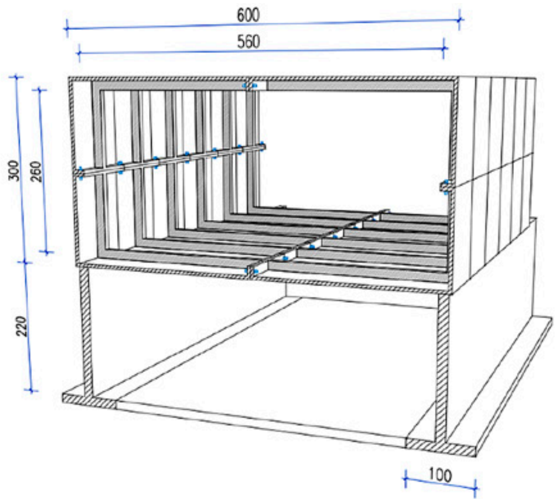

Fig. 4. *Left: prefabricated elements realised according to architect D'Olivo's design in the first attempt at the prefabricated tubular house in 1960. Source: © E.M.E. Ursella Srl, 2024. Right: three-dimensional reconstruction of the architect D'Olivo for the study and experimentation of the first prefabricated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

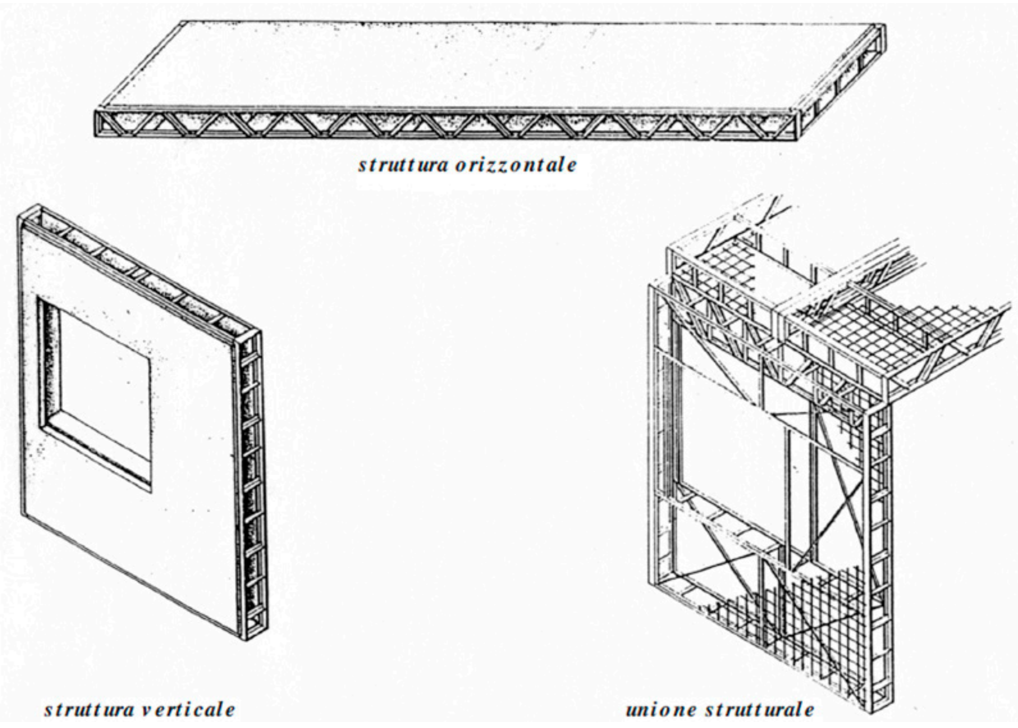

Fig. 7. *The "Semi-Block": axonometry of the vertical and horizontal element as well as the structural union. Source: © E.M.E. Ursella Srl, 2024.*

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-

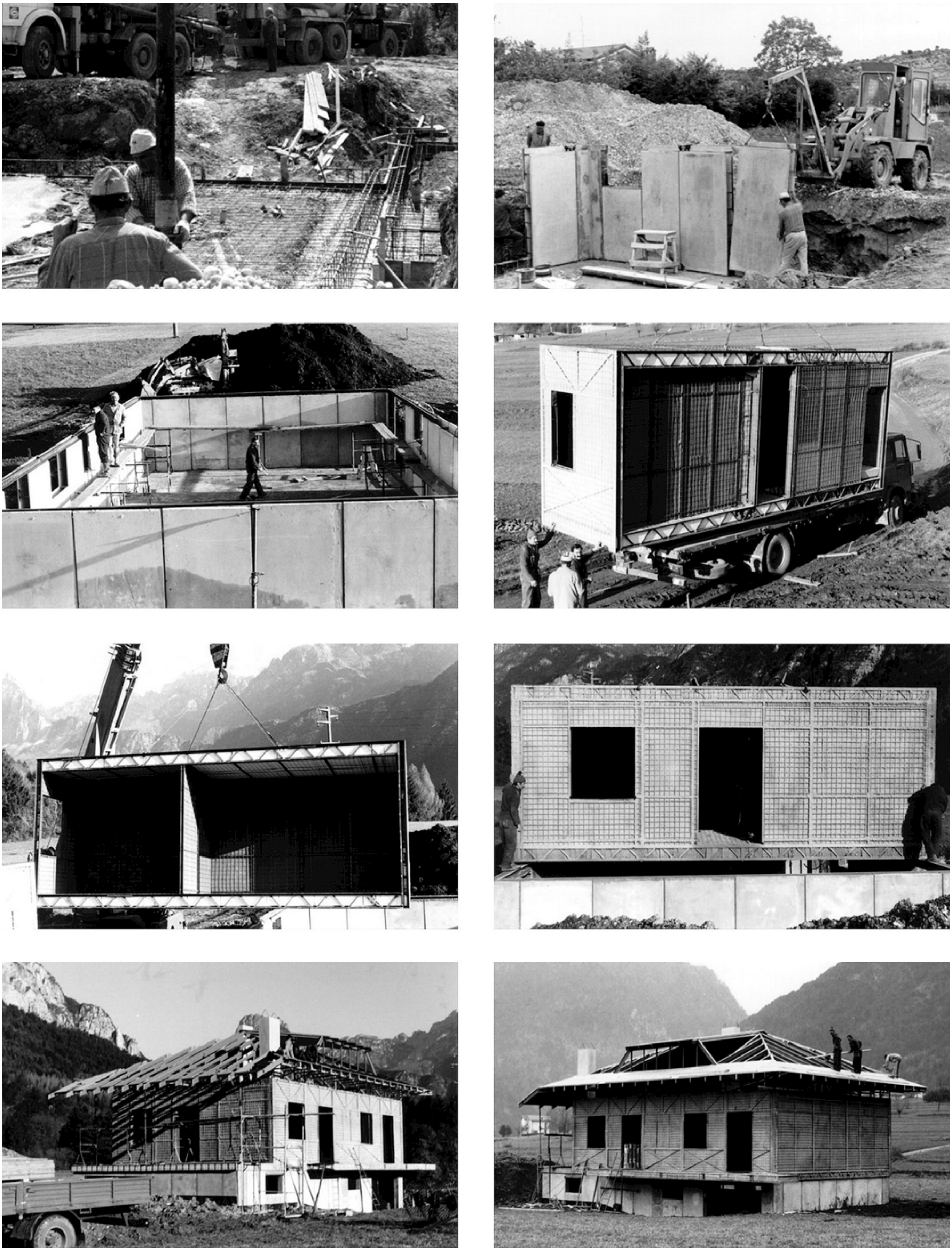

Fig. 8. *From the top, the assembly of a house with "Block-Volume" produced in the factory and plastered on site in the first years after the 1976 earthquake. Source: © E.M.E. Ursella Srl, 2024.*

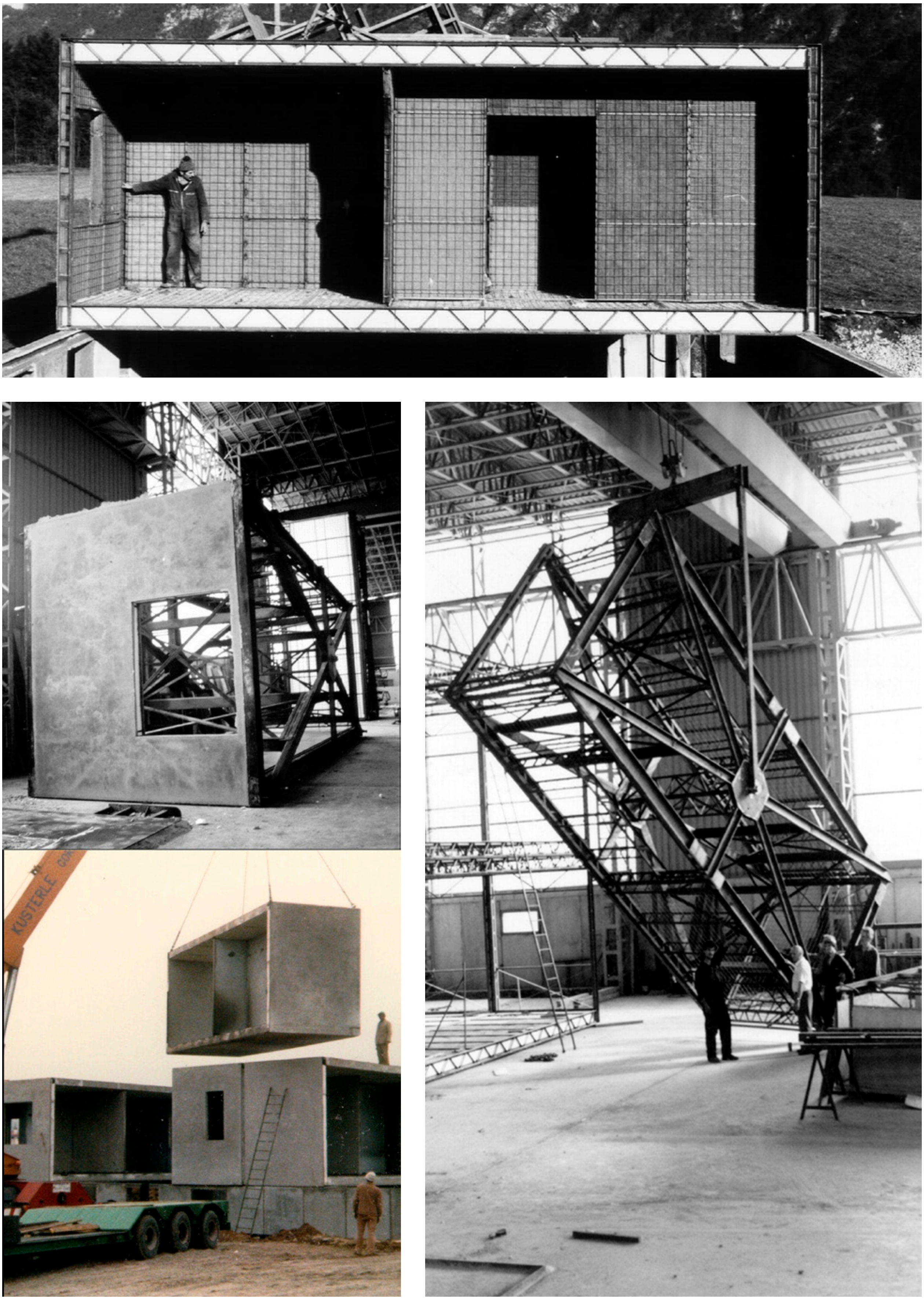

Fig. 9. *Top: "Block-Volume" laid on formwork panels forming the basement floor. Bottom left: production and assembly of a "Block-Volume" element forming part of the villas plastered in the factory in the post-1985 period. Bottom right: tipping of the "Block-Volume" using an overhead crane (the solution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