THE BAY AS STRUCTURAL DESIGN DEVICE. THE PARADIGMS OF THE REINFORCED CONCRETE PROTOTYPES FOR FACTORY IN ITALY (1950-1975)

Introduction

The idea of the bay as architectural device takes shapes in the XIX century as a fundamental topic of architectural composition. As Jacques Lucan (Lucan 2017) said, the Viollet-le-Duc and Choisy's theory recognizes the construction as a new paradigm of the composition. From this perspective, the idea of the bay has a crucial role: it is no longer simply that of the space between architectural elements, but it stems from the dimensional and grammatical relationship between the members that determine a structural span. In this sense, it is no coincidence that the idea of the bay consolidates with the development of French architectural treatises on the issue of the construction. These treatises of construction used the term "bay" as a segment of the design that summarizes the whole building, because it implies the possibility of these parts of the building to be repeated in a sequence. In this sense, the bay is an open system of construction that, like the Choisy axonometric views (Choisy, 1899), goes from the bottom to upwards, reflecting the sequence of the steps in the construction process that starts from the foundations and finishes with the roof. Indeed, the bay consents to establish a set of rules, that, as in the cathedrals drawings, the builder can transfer from a construction to another. From this point of view, the design of the bay departs from the synchronous control, by the designer, of the structural elements, schematically identifiable by two kind of relationships: the support/coverage/foundations system and the distance apart one and other of them that tests the unit structural system validity. This idea to conceive the architecture lies with the Modern idea of repetition, prefabrication and assembly.

As highlighted by Jacques Gubler (Gubler 1985), the design process that leads to the definition of the bay, passes through a "reasoning by recurrence" , recognizing the bay itself as a device potentially repeatable, a structural unit of the architectonic organism. The process of construction industrialization that concerns to the Modernism revived the notion of the bay as a feature of architectural design, taking on the idea of "reasoning by recurrence" as a *conditio sine qua non* for the definition of the built Form. According to this process, the risk on the concept of the bay was its degeneration in a purely structural fact, applied in a mechanical and slavish way. On this aspect, Luigi Moretti (Moretti, 1951/52) asserted the difference between formal and informal architecture: "*an architectural work is both a reality and a representation, if, naturally, it exists a will of representation, that is to say an expressive will. The lack of this will determines the absence of architecture and the building has only structural and technical features; in this way the building is subject to the ageing of the technic and not to the immutability and immortality of the Form*." However, how the bay, a system so rigorous can produce an idea of architectural expressiveness? Indeed the risk on the concept of the bay is its degeneration in a purely structural artefact, an informal building. Hence, the probable answer to the question brings to light the dual nature of the idea of bay, metaphorically traceable in the history of architecture.

The first one deals with the possibility, implicit in the bay, to identify the strong link of the assembly of structural elements and a clear overview of their construction methods; the second one recognises the value of the bay in the sequence that comes out from the hierarchical aggregation of the parts, the "expressive concatenation" , according to Moretti's definition. In this first case, the expressiveness of the architectural building depends on the syntactic paradigm of the structural elements' grammar and by their topological and hierarchical definitions. Consider, for example, the project of the Arnolfo di Cambio's two projects for the ciborium of San Paolo fuori le Mura and Santa Cecilia, described by Arnaldo Bruschi (Bruschi 1998) : "*in both cases, the ciborium was conceived in a three-dimensional way, as a canopy or an ideal square bay; that is to say as the elemental spatial module of the European Romanic-Gothic tradition. […] The layout of the adopted solution […], is a syntagm, a comprehensive system of elements, none of which is independent from the others, or, on the contrary, it transforms substantially the whole of the building. Even if one were to make the arch greater, keeping unchanged the layout, it should increase also the lateral frames, the overhead gable, and then the supports. Arnolfo tends to identify an architectural*

drawing coherent with the construction needs, but first of all, valid in itself, autonomous and invariable respect to the physical dimensions". The case of the Arnolfo di Cambio's ciborium is the ideal metaphor of the synthetic power of the bay to prefigure the built form. The part, constituted by the device bear-pillar-foundation, represents the whole of the building and it is a guarantee of an architectural expressiveness. The second nature of the bay, as stated above, focuses on its inclination to become a sequence of spaces. Around this notion, Luigi Moretti constructed the logic structure of his essay "*Strutture e sequenze di spazi*"(Moretti 1952/53). Indeed, the Roman architect the author wrote: "*The survey should cover the spatial unit formed by inner volumes, which compose a layout and a concatenation; they establish, with the changing of their perspective and in relationship to the paths and the necessary and possible time for their vision, a sequence, in the current meaning of the term. I would clarify the different modalities of the sequences of these volumes, coordinated in units, and then the structure of their composition, that is to say type and reason; I would understand the differences between the volumes and the chain of spaces that they form*." The added value of the bay resides in its *dispositio*, not in its autonomous unit. This value is recognizable only when the bay makes up with the others bays, giving rise to a structural pattern, as Moretti says. In order to understand this nature of the bay Moretti made some stone models of famous buildings in which the bay adopts this role. He carved out the void of the empty space of the structure frame, so we can see in his models a sort of negative of the architectural space. So, Moretti focuses on the concatenation of the bays because he sustains that the expressive value is recognizable only when the bay makes up with the others bays, giving rise to a structural pattern. To this end, the main topic in the design of the bay is the void space cut from the structure within the building; the perceptive tension created by an organic system works only in the physical experience of its inner character.

Indeed, the topic of the expressiveness of the bay further radicalizes the relationship between architectural expressiveness and structure looking at the places of production, because of the production processes that imposed to the architect the dimension of standardisation, repetition and economy of means. This approach reduced the distance between architectural form and informal building.

The bay as structural device in Italian reinforced concrete prototypes for the factory

The particular category of reinforced concrete prototypes, built in Italy between 1950 and 1975, embedded a proof of this different design approach. These prototypes regarded a specific type of factory, the single-storey reiterated bay. In those years, the development of prototypes was affected by the adoption of prefabricated structural elements; this phenomenon introduces the problem of spatial modulation in which "the prefabricated system puts into action the bold industrial chain of production and assembly and becomes an architectural work as a prototype of forms expressive figuration"(Pizzetti, 1956). This operative presupposition influences the design process, forcing the designer to identify precisely the structural elements (beams, pillars, deck boards), associable to the tectonic assembly system that guarantees the expressiveness of the concrete shape. The Italian experience shows how the tendency to standardisation and cataloguing of structural elements does not correspond to the disappear of an authorial design, but that on the contrary, it is possible preserve a traditional approach on the design of reinforced concrete component, through a direct encounter with architect, engineer and producers.

It is possible distinguish two-construction categories for the single-storey factories: the first one regards structures based on linear structural elements; the second one regards structures based on form working elements. In the first case the design of structural pattern focuses on the cross section analysis of the elements, forming the framework. Such structures are governed by the principle of tectonic assembly in which each element has a dual nature: it has an autonomous shape that reflects the role of the elements in the discharge of forces; both, at the same time it has a discontinuity that refers to the connection with the others structural elements. In the second case, each element is a frame of a structural continuum, undistinguishable as part of a whole. From a strictly structural point of view, the difference between these two categories is clear: the structures based on linear elements correspond to bending forces, so they are

“inactive structures”; the structure based on form working elements deviate the bending forces, taking advantage from the formwork resistance, so they are “active structures” (Candela,2013).

The bay as a device in the structures based on linear elements for the factory

In the current state of the research, I investigated the first category of single-storey factory: the structures based on linear elements. According to the two paradigmatic interpretations of the bay, that consider the bay as syntagm and the bay as a sequence, it is possible to identify the specific character and the value of six experimental prototypes: (in the figure 1 from the left to the right) the Kodak factory in Marcianise (1971-1975, designed by Aldo Favini and Gianluigi Ghò); the Perugina factory in Perugia(1962, designed by Aldo Favini and Carlo Rusconi Clerici); The Necchi factory in Pavia, (designed by Marco Zanuso); the Olivetti factory in Merlo, (designed by Marco Zanuso); The Olivetti factory in Marcianise; (designed by Antonio Migliasso, Eduardo Vittoria and Marco Zanuso); the Cedis factory in Palermo (designed by Marco Zanuso).

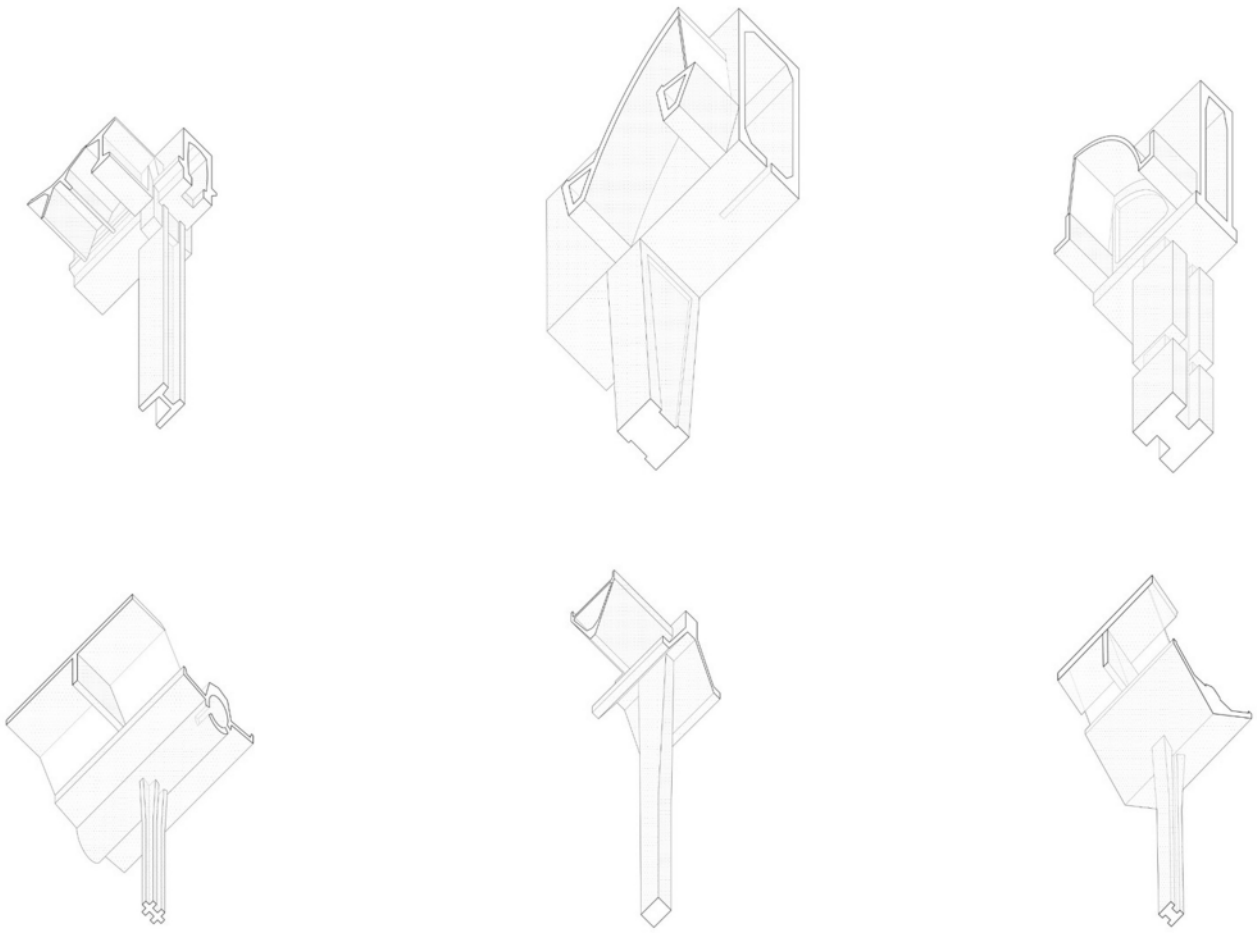

Fig.1 Axonometric view of the pillar-beam-deck device of the case studies, V.Quadrato, 2018

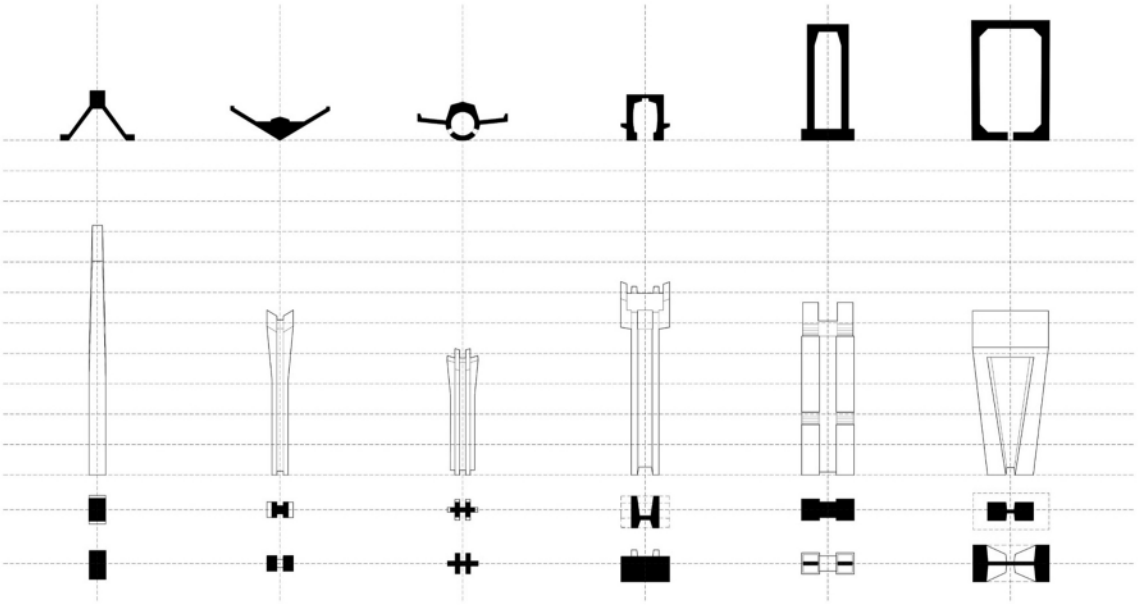

Fig.2 Taxonomy of the pillars and the beams of the case studies, V. Quadrato, 2018

The figure 1 shows the axonometric view of the structural elements of these six factories. We can observe that in all of these cases the structural hierarchy of the bay consists of the relationship between the pillar, the beam and the deck, which relates these building to the classical construction tradition of the trilithic system and the trabeate Form. The definition of these three elements is the founding moment of the design of the factory, because it influences the process of prefabrication that leads to the completeness of the single prototype. The form finding of these elements also influences and are influenced in a metaphoric system of "questions and answers" by the need to provide to the building of the maximum structural span (which in these cases ranged between the 12m and 21m), to simplify the arrangement of the production chain. Another important aspect that influenced this process of Form finding is visible in the taxonomy of the elements (fig.2) and lies with the principle of the material-saving (between fifties and seventies the cost of the concrete has a relevant impact on the general cost of the building) or exploiting the structural resistance section of the elements, eliminating the superfluous. The third aspect cuts to the need to absorb in the thickness of the structural elements the enormous technological system of the industrial building program. Hence, we can observe on the one hand that the pillars tend to enlarge at the top and to restrict downward, outlining a structural joint; on the other hand, the beams tend to present a hollow form in the sectional view that consents to bring inside the cooling water system and the ventilation system.

The figurative results of these practical need are substantial: the structure acquires a significant thickness, its elements provide for an internal void that in some cases hides, in other cases reveals the impressive mass of the technological systems, converting an aesthetic problem in an expressive opportunity for the design process. The figure 3 isolates the structural units of the six case studies, showing the single bays as a ciborium: they appear as autonomous parts of buildings, whose form has guaranteed by the relationship between each elements of the spatial unit. These sorts of ciborium are the focus of the design process of this type of factory, lying with the classical idea of *syntagma*, a combination of elements that forms an autonomous unit of the space. We can observe also the structural hierarchy of the elements: the beam

with hollow section prevails dimensionally on the other frames, embodying the element that determines the longitudinal direction of the space and the structural weave. The deck becomes the giver element of the natural light, carving out the interior space with a continuous or discontinuous system.

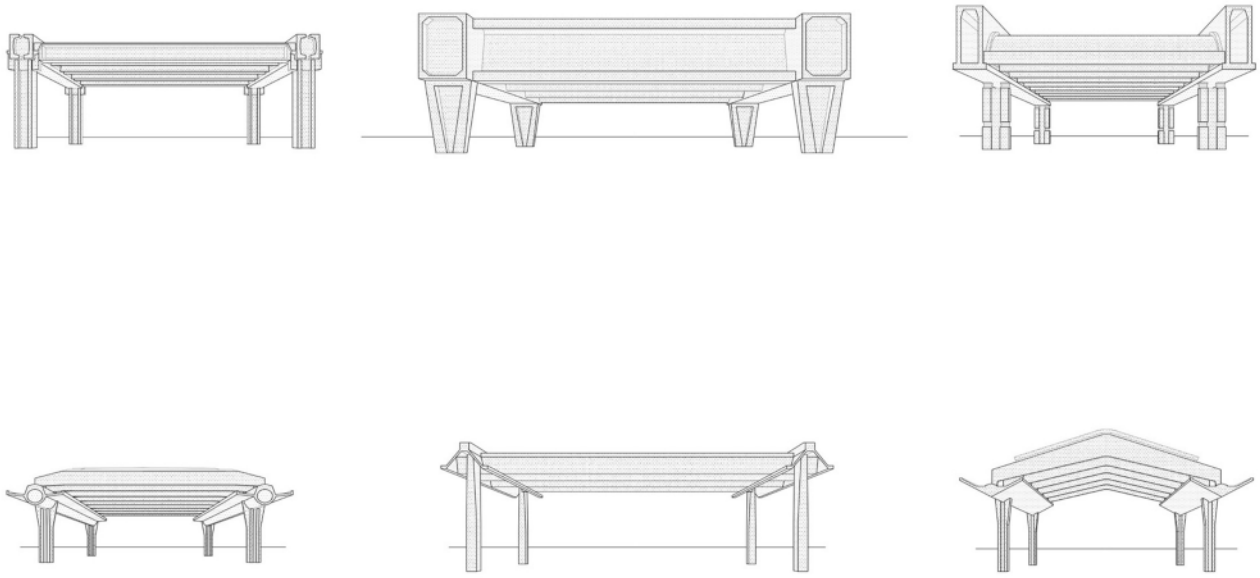

Fig.3 Perspective central view of the structural units of the case studies, V. Quadrato, 2018

The figure 4 highlights on the second key to the interpretation of these case studies, proposed in the previous paragraph, focusing on the idea of the bay as sequence and “expressive concatenation” , as Moretti said. Hence, if on the one hand the bay has an autonomous expressiveness provided by the minimum relationship between the structural elements, on the other hand the bay acquires a deeper meaning through the composition and the disposition of the single units.

A spatial module consisting of the structural span defines the architectural organism, but the direction of the beam with a hollow section determines the structural pattern that lead to understand the character of the interior space. The disposition of the single units sets the bay as a “gallery” that gives to the space a strong orientation and tension, according to a longitudinal direction. This feature is valid for all the case studies, but every project articulates the composition of the bay according to three kind of architectural disposition and hierarchy: the first one is paratactic, or the spatial module is simply one next the other; the second one identifies a center of the composition, an internal court or a volume that organizes the sequence of the structural unit; the third one identifies a principal axis that distributes transversally the sequence of the bays. Once the affected disposition has been determined, the designers proceed to plastic operation to rotation, subtraction or addiction of the bay, according to the functional program of the building.

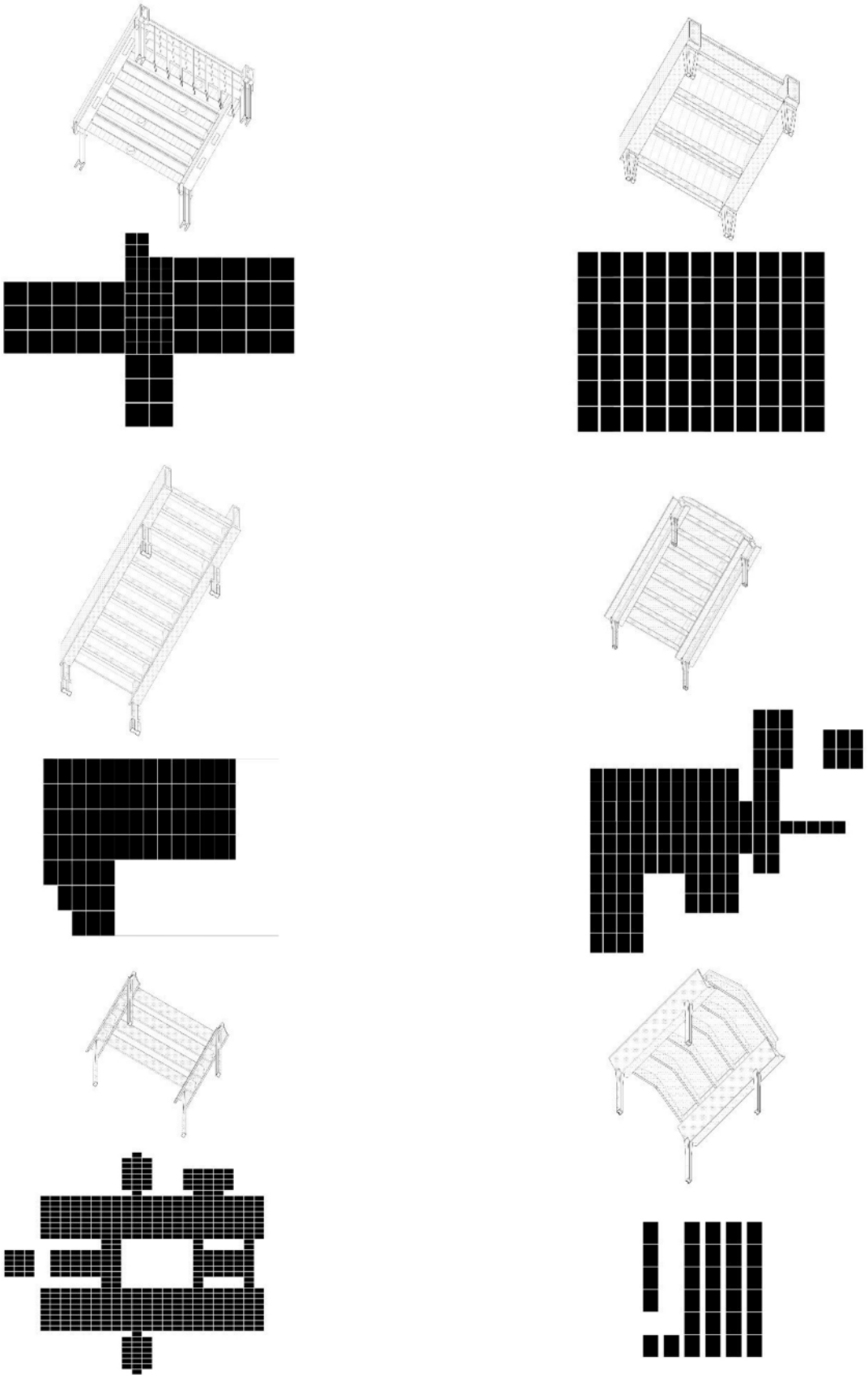

Fig.4 Ideograms on the disposition of the structural units, V. Quadrato, 2018

The bay as the starting point for reusing the factory. Three design strategies for the conversion of the former soap factory in Fasano

The international urban design workshop on the reusing of the disused workspaces, held at Polytechnic of Bari in February 2018, gives to my research group the opportunity to understand how this research can be useful to develop strategies of transformation compatible with the character of the single-storey factories. The former soap factory in Fasano has been chosen as the pilot project area and specific proposals drawn up with the students of the master's degree in architecture at Polytechnic of Bari. The soap factory, the oldest of the still in operation companies, is part of chemical Apulian industries. The factory was built in 1927 and housed the first soap production in Apulia thanks to the great access to olive oil in this area, which it is essential to the manufacturing of the soap. The complex belongs to L'Abbate's family which conducted this business over three generations. The layout of the complex, that exceeds the 4'000 mq, consists of a great fence, 2,50 meters high, constituted by a tufa wall. In the middle of this fenced area there is the real soap factory, which has a structure based on three reiterated bays, as three great longitudinal blocks repeated in a sequence; each bay has 10 meters of structural span, covered by a truss-system. The internal structural arrangement is declared on the façade by a series of three gables. The style of the facade imitates, in certain respects, the examples of basilicas building, according to the habit of the first years of 20th century in Italy for the design of factory: a special attention to the architectonic envelope, in which the designer tries to treat the façade as a monumental architecture, in order to ensure an aesthetic ennoblement to the utilitarian structure. On the inside, the three bays consist of four walls discretized with arcades; this solution consented to create, visually, a whole open space. The coverage of each bay has made by a truss system constituted by a reinforced concrete ceiling, with 10 centimetres of thickness, which is anchored to the truss through steel beams. Each nave was dedicated to a specific production line: soap, detergents and disinfectants. The nave on the left housed the first stage of production and three tanks carved into the soil, in which the soap was mixed.

Thus, if the bay were the most significant character of the space, how would it be possible transform the factory in order to preserve this aspect? We proposed with the students three strategies, adopting the presence of the bay as the starting point for the design of the reusing project. Each strategy welcomed other common choices such as keeping the visual permeability of the interior space, (thus so preserving the direction of the space as a gallery, determined by the direction of the bay), preserving the architectonic envelop of the wall that testifies a specific style of the 20th century factory, eliminating the existing roof, currently in a less than perfect state of conservation. Therefore, all the proposals considered the form of a new roof, as the key to transform the soap factory in a co-working space.

The first project was called "the bay and the inhabited roof" (fig.5) and it started from the possibility to imagine a great coverage system that housed on the inside a series of suspended rooms, consenting to cross freely the space at the ground floor. The timber frame was the structural device that we have chosen in order to create a sort of "beam's weft" which cross transversely to the arcades that define the three bays of the factory. Thus, the roof becomes a sort of typological overlap that takes advantage from the lower arcades as support system; while the new higher floor constitutes a whole unit; the lower floor maintains the logic of a tripartite subdivision of the space. The inside layout provides for the localisation of the stairs and services across the existing walls, creating a double-walled system.

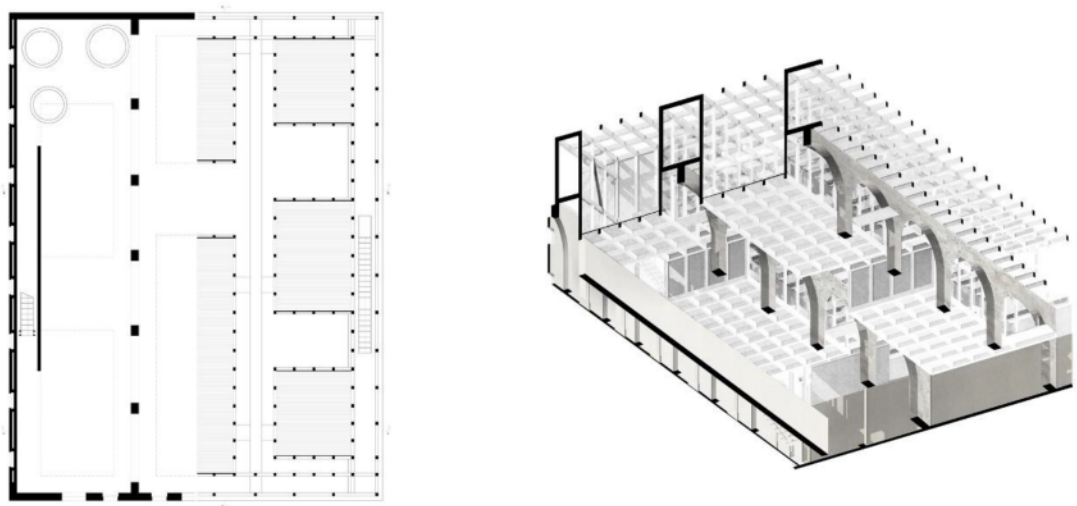

Fig.5 The bay and the inhabited roof, students: Maddalena Colonna, Antonia Valeria Di Lauro, Remo Pavone, Aldo Pisanello, Tutors: Michele Montemurro, Antonio Nitti, Vito Quadrato, Francesco Protomastro, Nicola Selvaggio, 2018

The second project was called “the bay and the sequence of rooms”, (fig.6)working on the idea that the form of the roof can mark a unit of the space, such as a room. The structural choice provides for a series of reinforced concrete pyramid-shaped shell, placed as a “suspended enfilade” which defines through the coverage system a part of the bay with different facilities, creating in the longitudinal sectional view a sort of compression and decompression of the space. The structural span of these shells accords to the ten meters of the bay, and the coverage system becomes the giver of the vertical light. A flexible system of curtains hanged to the shells permits to combines the rooms respect to the change of needs.

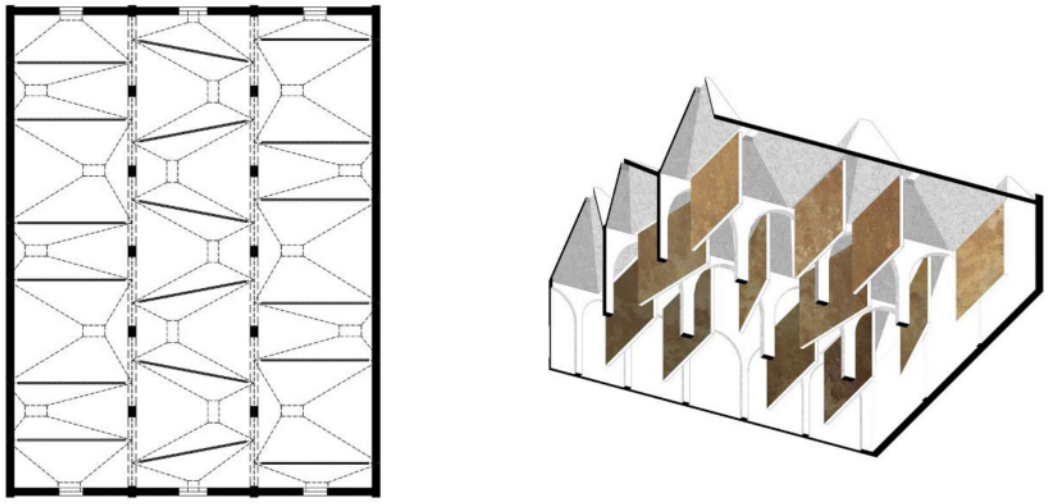

Fig.6 The bay and the sequence of room, Students: Floriana Cavallo, Domenico Cristofalo, Nicoletta Derosa, Roberta Gaetani, Giovanna Moccia. Tutors: Michele Montemurro, Antonio Nitti, Vito Quadrato, Francesco Protomastro, Nicola Selvaggio, 2018

The third project was called “the bay and the beams”, (fig.7) working on the idea of four great continuously supported beams, that maximises the longitudinal sense of the space, like the Marco Zanuso’s Cedis factory. These beams are V-shaped and relies upon the arcades as a system that responds to the lighting need and the water drainage. A series of platform, with the longer side in parallel with the sense of the bay have been hanged to the beams, C-shaped in the cross sectional view. The system of connection between the lower and the upper floor was placed between the platforms and the arcades, allowing to link the platforms each other through some crossing passages.

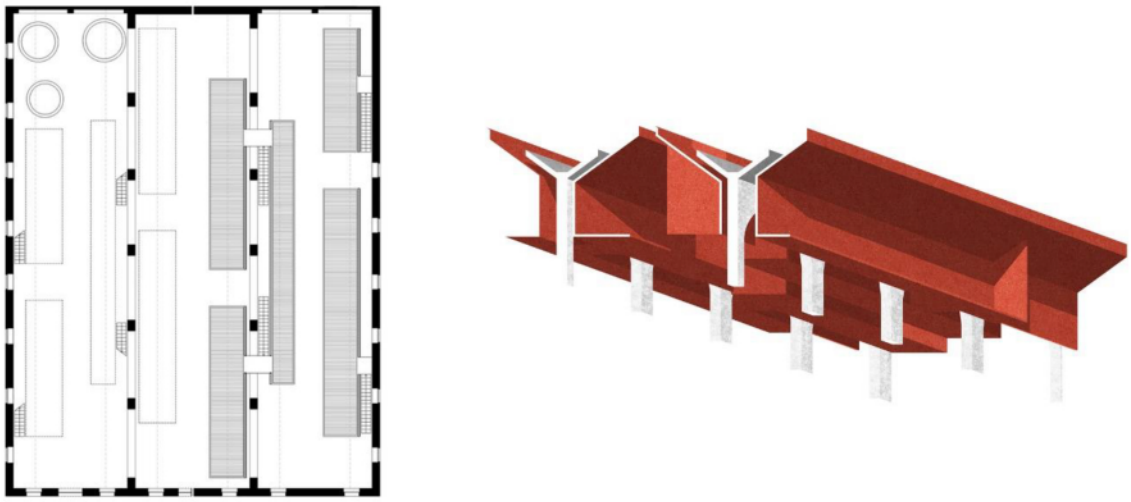

Fig.7 The bay and the beams, Students: Maria Giovanna Gassi, Walter Lollino, Nicolò Montuori, Giancarlo Sgaramella Tutors: Michele Montemurro, Antonio Nitti, Vito Quadrato, Francesco Protomastro, Nicola Selvaggio, 2018

The critic and theoretical research on the reinforced concrete prototypes for the factory shows how the structural design can make a meaningful architectural space. The understanding of the relationship between the structure and the space seems to be a focal point especially for the single-storey factories, in which the construction guarantees the expressiveness of the building, thus so the aspect that permit us to include some industrial examples as a part of historical heritage and permit to understand the design strategies for an adaptive reuse, respectful of the character of the space.

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